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Embodied labors during the state formation of Egypt and Nubia (ca. 4800–1750 BCE): Elucidating transformations in behavioral patterns with entheseal changes

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Abstract
Throughout Egypt and Nubia's state formation periods (4400–1750 BCE), broad transformations impacted Nile Valley communities, which experienced agricultural consolidation, sedentarization, and more complex social organization. The current study examines the various patterns and levels of physical activity in the skeletal remains of 259 predynastic and early dynastic individuals from Nubia (Northern Dongola Reach) and Egypt (el-Badari, Naqada, el-Ballas, and Hu). Using entheseal changes in the upper and lower limbs and non-parametric tests, we have observed changes in behavior patterns between the fifth and second millennia BCE in the Nile Valley. These transformations include an increased impact on the evolution of physical activity and possibly specialized occupations in the Old Kingdom. In this regard, we discovered differences in activity based on the type of burial and the tasks performed by females compared with males. Furthermore, we found additional evidence to support the hypothesis that the Nubian state of Kerma was based on a highly mobile pastoral way of life.

KEYWORDS
musculoskeletal markers, Nile Valley, Nubian Kerma, physical activity, predynastic Egypt

1 | INTRODUCTION

1.1 | Theoretical background

The process of state formation has been an issue that has generated intense debate in Archaeology since it has led to questions about the emergence of social inequalities, power politics, or the patriarchy (Flannery, 1999). However, in the context of Egyptian and Nubian state formation, the narratives have focused on the elites' rise. In contrast, these discourses have blurred social majorities (Stevenson, 2016). That is why bioarchaeological studies can significantly contribute to understanding the realities experienced by most Egyptian and Nubian populations during these processes.

One of the most critical osteoarchaeological methods that address the daily life of past communities has been the study of musculoskeletal stress markers (MSM) or entheseal changes (EC), which refer to the modifications produced at the attachment points of muscles, ligaments, and tendons (Hawkey & Merbs, 1995).

However, the limitations of this type of bone modification must be considered, mainly related to the multifactorial etiology of the EC (Villotte et al., 2010). Several investigations have addressed some of the sources of bias in the interpretation of these changes, such as degenerative processes associated with age (Villotte et al., 2021), sexual dimorphism (Weiss et al., 2012), the fibrous or fibrocartilaginous nature of each enthesis (Santana-Cabrera et al., 2015), or the role of metabolic factors in the development of the EC (Bakirci et al., 2020).

Nevertheless, we could more safely use EC to examine physical activity patterns in ancient populations thanks to recent research development. The evidence supporting this hypothesis involved experimental work based on 3D morphometric methods, indicating that entheses can be used as activity markers (Karakostis et al., 2019; Schrader, 2019).

In the case of the Nile Valley, some specific osteoarchaeological studies have applied EC in the framework of state formation in Egypt (Cross Denton, 2005; Refai, 2019; Zabecki, 2009) and Nubia (Martin, 2015; Schrader, 2012, 2015, 2019). However, very little bioarchaeological research addresses the influence of the formation of the Nilotic states from a diachronic perspective (Stock et al., 2011; Zakrzewski, 2003).

1.2 | Archaeological and historical background

The precedents of the first complex societies of the Nile Valley come from the cultures of the Late Neolithic, of which the Badarian culture (ca. 4800–4200 BCE) has been characterized as the first element of Predynastic Egypt (Midant-Reynes, 2000), where we begin to observe a more structured society in the elaborated grave goods (Vorster, 2016).

At the end of the Badarian Neolithic, the cultural communities of Naqada IA–IIB (ca. 3800–3450 BCE) also begin to develop in this Upper Egypt region. In these groups, we observe the first substantial evidence of cereal agriculture, sedentarization, and social inequalities, but exchanges are only produced within the community (Stevenson, 2016).

However, a transformation in the previous social-economic relations was observed from Naqada IIC–D (ca. 3450–3325 BCE). As a result, the centralized production of ceramic elements will expand throughout the Nile Valley and reach the Levant within the trade for luxury goods (Hendrickx & Eyckerman, 2012).

The dynamics during the protodynastic period of Naqada III (ca. 3325–3085 BCE) have been overshadowed by the elites' political-military history, which were buried in specific spaces such as the Cemetery T of Naqada (Figure 1). However, we observe a simplification of the funerary profile in the rest of the tombs (Stevenson, 2016).

Towards the Early Dynastic (ca. 3085–2867 BCE), the social dissymmetry, and the appropriation of bodies from the lower hierarchies are becoming more evident (Zabecki, 2009). However, the processes of state development during the Old Kingdom (ca. 2700–2150 BCE) were needed to achieve greater assimilation of the ideology of the elites into the bulk of society (Bussmann, 2014).

Throughout this time, the foundations of what was known as the Kingdom of Kush were also forged in Upper Nubia. Over the next five centuries of the Early Kerma period (2500–2150 BCE), a centralized state with the sprawling capital of Kerma emerged (Schrader & Smith, 2021). However, there was a particular socioeconomic differentiation with exterior settlements that had grown thanks to the

FIGURE 1 Examples of burials included in this study, of a mature adult male in Northern Dongola Reach Cemetery P37 (a: ortophoto of the reproduction of burial G4(8) located in the British Museum, following the ethical standards for human remains exposed by Daniel Antoine, 2014), and of a young adult male in Naqada Cemetery T (b: tomb T 16, drawing by Digital Egypt for Universities, adapted from plan in Petrie et al., 1896: pl. LXXXII) [Colour figure can be viewed at wileyonlinelibrary.com]

new flow of paleochannels, where there were probably remnants of previous pastoralist models (Welsby, 2001).

At the turn of the millennium, Kush began a period of consolidation known as Middle Kerma (2050–1750 BCE). The growth of cities and fortifications, along with the new specialized productions of prestige objects seen in workshops and burial tumuli of elites, may impact the labor of these new urban communities (Martin, 2015). Furthermore, inequalities were also evident in the rest of the tombs of most of the population (Figure 1), which practically continue to maintain the same funerary signs as in previous chronologies (Schrader & Smith, 2021).

1.3 | Research goals

In this study, we have analyzed the entheseal changes between different social and chronological groups and thus evaluate the transformations in the patterns of physical and behavioral activity of diverse populations from the Nile Valley between the fifth and second millennia BCE, addressing questions regarding (a) the diachronic evolution, (b) territorial and cultural variability, and (c) engendered labors.

2 | MATERIAL AND METHODS

2.1 | Sample

The sample comprised 634 bone remains from three skeletal collections: the Badari Collection and the Naqada Collection at the Duckworth Laboratory of the University of Cambridge and the Northern Dongola Reach Project Collection of the Department of Egypt and Sudan at the British Museum. The remains belonged to a minimum of 259 individuals, recovered from 11 different cemeteries.

On the other hand, the conservation status of the bones and the minimal number of individuals was calculated from a fragmentation ratio (FR) (Lambacher et al., 2016). From this, it has been observed that they were relatively well preserved, especially the patella (FR: 4.55%) and the talus (FR: 6.29%), although other remains, such as the fibula (FR: 39.09%) and calcaneus (FR: 40.54%), were in worse condition. In this way, the excellent state of conservation has made it possible to analyze all the muscular attachments of each bone, which could prevent a particular type of enthesis from being overrepresented (e.g., fibrous ones).

2.1.1 | Chronological span and geographical distribution

The skeletal remains included here encompass seven periods between the fifth and the second millennia BCE that form part of the state formation contexts in the Nile Valley (Table 1). For Egypt, we have selected individuals from the Badarian Neolithic (ca. 4800–4200 BCE), from Naqada IA–IIB (ca. 4000–3600 BCE), from Naqada IIC–D (ca. 3600–3350 BCE), from Naqada III and Early Dynastic (ca. 3350–2700 BCE), and the Old Kingdom (ca. 2700–2150 BCE); and for Nubia, we have also included individuals from the Early Kerma (ca. 2500–2150 BCE) and Middle Kerma (ca. 2150–1750 BCE) periods. The chronological ranges have been established from the schemes of Hendrickx (2006) and Vorster (2016) for Egypt and of Gratien (1978) for the Kerma culture.

The chronological association of the skeletal remains has been made by dating the material culture. The sequences have been provided by the investigations of Brunton and Caton-Thompson (1928) and the excavations of the SARS concession in Northern Dongola Reach (Welsby, 2001), as well as the works of Petrie and Mace (1901), Baumgartel (1970), del Río Álvarez (2015), and Stevenson (2020).

The 259 individuals come from 11 cemeteries distributed between Upper Egypt and Upper Nubia (Table 2). Figure 2 shows the distribution of the sites along the Nile Valley: el-Badari, various sites in Diospolis Parva/Hu (cemeteries B, H, W, and Y), el-Ballas, three cemeteries from Naqada region (the Great Cemetery, the elite Cemetery T, and the Cemetery B), and the cemeteries O16 and P37 in Northern Dongola Reach.

The mortuary context of each necropolis was relatively homogeneous in terms of sociocultural ascription since the grave goods revealed that most individuals are part of the same social group (Petrie & Mace, 1901; Welsby, 2001). In this way, the existence of cemeteries of elite social groups (e.g., Cemetery T of Naqada) could be differentiated from others belonging to poorer communities (e.g., Cemetery H of Hu).

TABLE 1 Chronological and age distribution of the sample

Age group	Badarian Neolithic	Naqada IA–IIB	Naqada IIC–D	Naqada III–Early Dynastic	Old Kingdom	Early Kerma	Middle Kerma	Total (age groups)
Juvenile	2	1	5	4	3	2	2	16
Adult	5	11	1	2	7	10	4	40
Mature	1	7	9	1	2	4	2	26
Senile	2	0	0	0	0	1	1	4
Undetermined	0	63	52	30	28	0	0	173
Total	**10**	**82**	**67**	**37**	**39**	**17**	**7**	**259**

TABLE 2 Geographical and sex distribution of the sample

Archaeological sites	Acronym	Female	Male	Undetermined	Total
Great Cemetery of Naqada	GCN	48	39	32	119
Cemetery T of Naqada	CTN	9	14	4	27
Cemetery B of Naqada	CBN	0	3	1	4
Cemetery of el-Ballas	CEB	10	11	5	26
Cemetery B of Hu	CBH	17	9	7	33
Cemetery H of Hu	CHH	1	2	0	3
Cemetery W of Hu	CWH	3	2	0	5
Cemetery Y of Hu	CYH	2	2	4	8
Cemetery of el-Badari	CB	5	5	0	10
Cemetery O16 of Northern Dongola Reach	O16	10	7	0	17
Cemetery P37 of Northern Dongola Reach	P37	5	2	0	7
Total		**110**	**96**	**53**	**259**

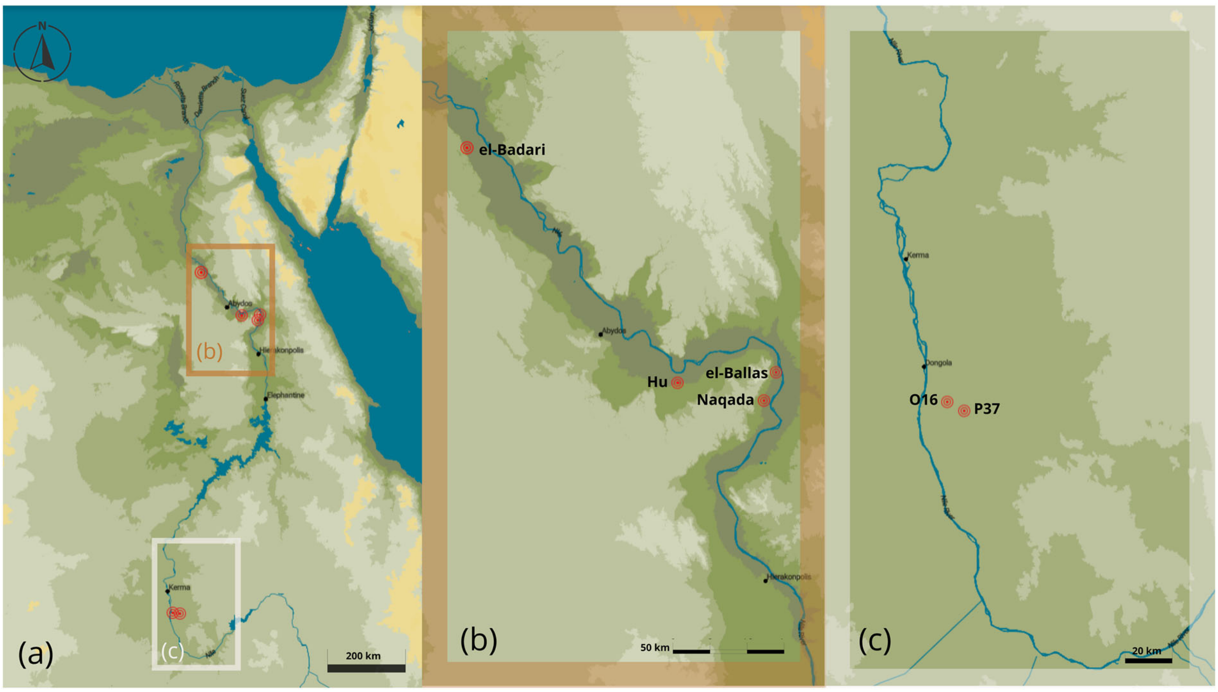

FIGURE 2 Map with the geographical distribution of the collections included in the sample along the Nile Valley (a), with a close-up of the four selected areas in Upper Egypt between el-Badari and Naqada (b), and another close-up up from the region of Northern Dongola Reach in Upper Nubia (c) (source: Scribble Maps and Google Maps) [Colour figure can be viewed at wileyonlinelibrary.com]

2.1.2 | Sex estimation

The sample comprised 110 females, 96 males, and 53 individuals of undetermined sex (Table 2).

For bone remains organized by individuals (57.68% of the sample), sex was estimated using the standard methods for associated crania and pelvis (Buikstra & Ubelaker, 1994: pp. 16–19; Klales, 2016). These remains corresponded to el-Badari (Upper Egypt) sites and cemeteries P37 and O16 of Northern Dongola Reach (Upper Nubia).

For remains that were organized by bone type (42.1%), the estimation of sex had to be carried out by combining the discriminant functions of the Old Kingdom Egyptian population (Marlow & Kozieradzka-Ogunmakin, 2016) with previous osteological information available in the Duckworth Laboratory. These remains corresponded to the cemeteries of Naqada, Hu, and el-Ballas (Upper Egypt).

The previously mentioned categories were due to the conditions of excavation and storage of human remains between the end of the 19th century and the end of the 20th. In this way, the excavations of the team of W.F. Petrie did not collect all the remains, and they were organized in boxes by type of bone. Therefore, although many remains had been labeled with their corresponding grave, it was not always possible to associate the bones in our sample with skulls and pelvises, limiting the estimation of sex from their characteristics.

2.1.3 | Age-at-death

Age-at-death was calculated for individualized collections based on morphological changes in the ilium, pubic symphysis, and fusion of the ectocranial suture (Brooks & Suchey, 1990). For the comingled Naqada collection, we combined the changes in the epiphyseal ring from the body of the sacrum (Albert & Maples, 1995) and the fusion of the epiphyses in long bones (Schaefer et al., 2009). Age-estimated individuals were grouped into four age categories following the classification in Krenzer (2006): juveniles (14–20 years), young adults (21–40 years), mature adults (41–60 years), and senile adults (+61 years).

The age-estimated sample consisted of 16 juveniles (7 female, 7 male, and 1 undetermined), 40 young adults (23 female, 13 male, and 4 undetermined), 26 mature adults (12 female, 9 male, 5 mature), and 4 senile adults (2 female, 2 male). The limitation of this sample was due to the previously exposed conditions of excavation and storage of those collections in which the remains were classified by type of bone. In this case, as we did not have morphometric methods to specify the adult age groups of the Nilotic populations, we have only been able to include an age-estimated sample of 86 individuals.

2.2 | Methods

2.2.1 | Entheseal changes (EC)

Changes of robusticity in the morphology of fibrous and fibrocartilaginous musculoskeletal attachments were analyzed in the upper and lower limbs, including (33 entheses; Table 3). Both types of entheses have relatively different anatomical characteristics and bone responses. However, the fibrocartilaginous ones have been the most used since they are easier to detect, and higher correlations with physical activity are found (Henderson et al., 2013). In the case of fibrous entheses, even though there has been less clinical literature, we decided to include them since they have been used jointly in previous studies in which their correlation with activity has been demonstrated using the same methodology (Carballo-Pérez et al., 2021; Santana-Cabrera et al., 2015).

We have included 20 entheses from the upper limb, selected according to the Coimbra method and previous works (Henderson et al., 2017; Santana-Cabrera et al., 2015; Villotte et al., 2010). Each enthesis from the upper limb was scored into 5 degrees of robustness (Figure 3) following the method compiled in the visual and descriptive atlas by Santana-Cabrera et al. (2013, 2015) and considering other validated methods (Galtés & Malgosa, 2007; Hawkey & Merbs, 1995; Henderson et al., 2013; Mariotti et al., 2007; Robb, 1998).

On the other hand, we have included 13 entheses from the lower limb, following the proposals of other studies (Acosta et al., 2017; Al-Oumaoui et al., 2004; Djukic et al., 2018; Jiménez-Brobeil et al., 2011; Lieverse et al., 2013; Mariotti et al., 2007; Niinimäki & Baiges Sotos, 2013; Weiss, 2004). In this case, we applied the scoring method used by the authors in previous studies (Carballo-Pérez et al., 2021; Schrader, 2015).

In addition, we performed an interobserver error analysis on the included EC variables, applied by both authors from data collected separately on a standard sample of 96 long bones from the Northern Dongola Reach collection. Using the Cohen-Kappa test, an average coefficient of 0.32 was obtained, with values ranging between 0.48 and 0.08 and a low positive significance ($p < 0.14$). According to previous health studies, this data could be within an acceptable margin (Cerdà & Villarroel, 2008), although more recent research indicated that the lowest reliable margin is 0.48 (McHugh, 2012). These limitations have been extremely common in traditional entheseal scoring systems (Davis et al., 2013; Wilczak et al., 2017), although there have been more recent virtual methods for three-dimensional morphology quantification, whose repeatability has been much higher (Karakostis et al., 2018). Fortunately, the analysis of the entheseal changes in this study has been carried out exclusively by a single author (JCP), which would eliminate the problems related to the interobserver error.

2.2.2 | Non-parametric tests

The main objective of the statistical analysis has been to compare groups whose data distribution is unknown. Hence, non-parametric techniques are the most appropriate methodology (Auerbach, 2018), as demonstrated in previous studies (Cardoso & Henderson, 2013; Refai, 2019). First, Mann–Whitney U test has been used to verify the heterogeneity between the groups by sex and laterality. Since part of the sample was organized by bone type (42.1%), we had to maintain the analysis using each bone remain as the primary analysis element. Since the cases were not paired by laterality, the Wilcoxon statistical test could not be applied, but the Mann–Whitney test, as previously applied with similar collections (Carballo-Pérez et al., 2021). Second, the Kruskal–Wallis H test has also been used to examine differences in age groups, archaeological areas, and chronological phases.

Although it has not been the most appropriate method for ordinal data, in this study, we have followed the analytical procedures of previous research (e.g., Carballo-Pérez et al., 2021; Santana-Cabrera et al., 2015; Villotte et al., 2010) and have used the average values to summarize the results data.

Finally, the coefficients of bilateral asymmetry [(Xr − Xl)/100] and sexual dimorphism with MDI parameter [(Xm − Xf)/100] were used to visualize better the differences in robustness between groups of sex and laterality.

TABLE 3 Entheses analyzed on the upper and lower limb (acronym and type)

Bone	Abbreviation	Enthesis	Type of enthesis[a]
Clavicle	CLDT	Deltoid	FC
	CLCS	*Ligamentum costoclavicularis*	FC
Humerus	HUMSB	*Subscapularis*	FC
	HUMTm	*Teres minor*	FC
	HUMPM	*Pectoralis major*	F
	HUMDT	Deltoid	F
	HUMCR	*Coracobrachialis*	F
	HUMFC	Flexor (common)	FC
Ulna	ULANC	*Anconeus*	FC
	ULBR	*Brachialis*	FC
	ULSP	*Supinator*	No information
	ULAPL	*Abductor pollicis longus*	F
	ULEI	*Extensor indicis*	F
	ULFDP	*Flexor digitorum profundus*	F
Radius	RAAPL	*Abductor pollicis longus*	F
	RABB	*Biceps brachii*	FC
	RAFPL	*Flexor pollicis longus*	F
	RABRO	*Brachioradialis*	F
	RAPT	*Pronator teres*	F
	RAPQ	*Pronator quadratus*	No information
Femur	FEGMa	*Gluteus maximus*	F
	FEVM	*Vastus medialis*	F
	FEGMe	*Gluteus medius*	FC
	FEGMi	*Gluteus minimus*	FC
	FEAM	*Adductor magnus*	F
	FEGCN	*Gastrocnemius*	FC
Tibia	TITIA	*Tibialis anterior*	F
	TISO	*Soleus*	FC
	TIFDL	*Flexor digitorum longus*	F
	TICRA	*Ligamentum cruciatum anterior*	FC
Fibula	FIBF	*Biceps femoris*	FC
	FIPE	*Peroneus*	F
	FIIM	Interosseous membrane	FC

[a]F: Fibrous. FC: Fibrocartilaginous.

3 | RESULTS

3.1 | Diachronic differences

None of the ECs showed statistically significant differences between chronological phases (Figure 4). For Egypt, we observed a decrease in the entheseal scores between the Badarian ($\bar{x} = 1.78$) and Naqada IIC–D ($\bar{x} = 1.57$) in the upper limb, followed by an increase toward the Old Kingdom ($\bar{x} = 1.80$). On the other hand, in the lower extremities of the whole Egyptian sample, we also have seen a slight decrease between the Naqada I–IIB ($\bar{x} = 1.79$) and the Naqada IIC–D samples ($\bar{x} = 1.76$). Towards Naqada III–Early Dynastic, we noted another concentration in higher scores ($\bar{x} = 1.95$), followed by a substantial decrease in the Old Kingdom sample (1.66). Regarding the Nubian samples, there seems to be a slight increase between the Early Kerma and Middle Kerma remains, in both the upper ($\bar{x} = 1.59$–1.63) and lower limb ($\bar{x} = 1.91$–1.95).

3.2 | Intersite comparison

Of the 33 entheses analyzed, only four (12.15%) showed statistically significant differences when performing the Kruskal–Wallis test between sites: m. *vastus medialis* on the tibia ($p = 0.01$), the tibiofibular interosseous membrane ($p = 0.03$), the m. *anconeus* in ($p = 0.04$), and the m. deltoid at the clavicle ($p = 0.05$).

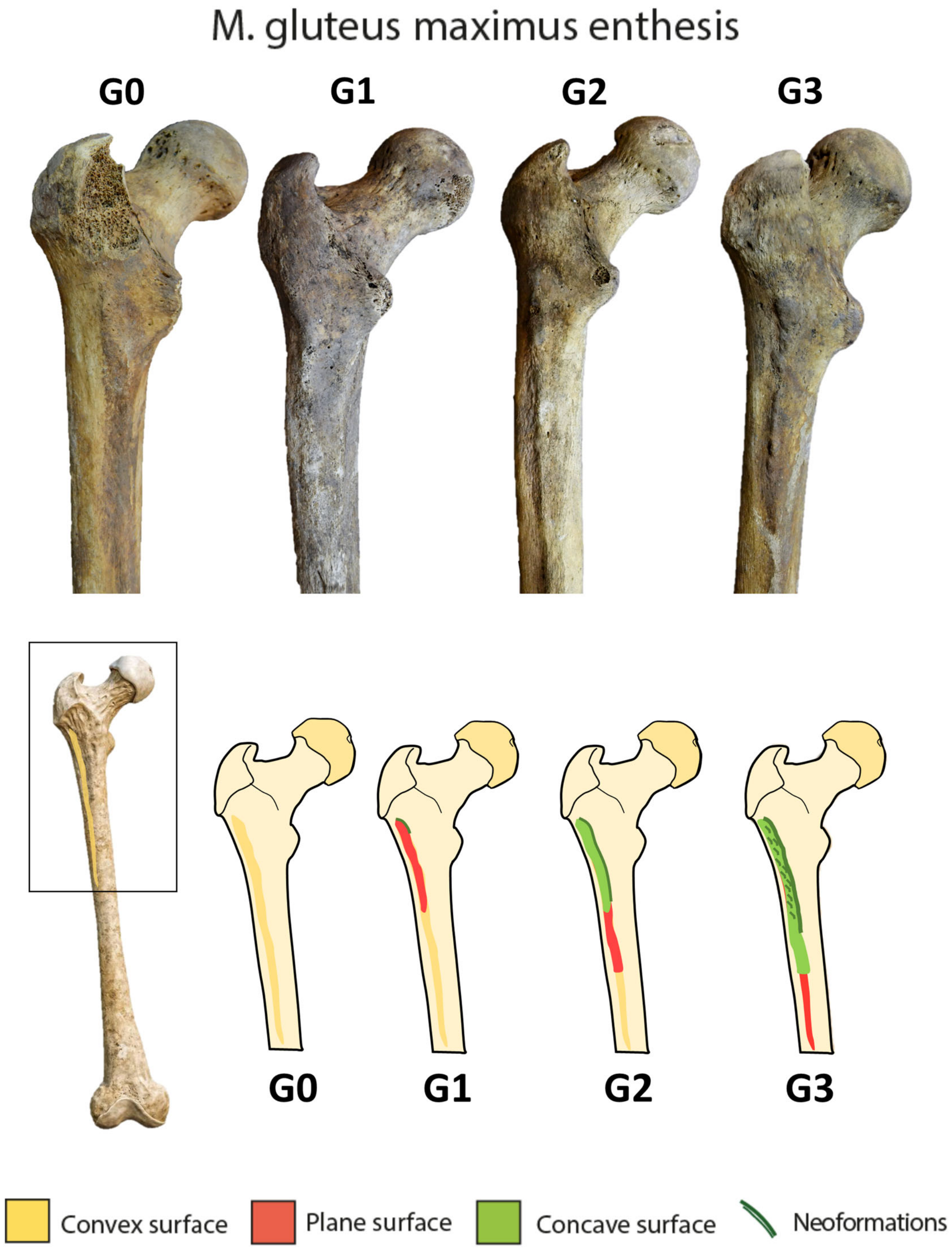

FIGURE 3 Example of the different grades of robustness in the m. gluteus maximus enthesis in femora: G0, absent robustness; G1, slight expression; G2, intermediate expression; G3, severe/extreme expression. No pathological expression (G4) has been observed during our study in this specific case. [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 5 (upper) shows an average value of 1.84 among all sites from Upper Egypt, while in Upper Nubia, it was 1.61. The highest values were observed within the Hu area cluster in the CHH and CYH samples ($\bar{x} = 2.00$) and the lowest in CWH ($\bar{x} = 1.20$). The CBH sample would be in an intermediate-low range ($\bar{x} = 1.52$), following the scale of the maximum and minimum values for the complete sample. In the Naqada area cluster, it is observed that the highest values were concentrated in the CBN sample ($\bar{x} = 2.00$) and the lowest in CTN ($\bar{x} = 1.61$). Those of the GCN sample were slightly higher than the latter ($\bar{x} = 1.67$).

Figure 5 (lower) shows the geographical distribution of the average values from the lower limb in each deposit. In Upper Egypt, an average value of 1.60 was observed, while in Upper Nubia, it was 1.93. The lowest levels in the entire Nile Valley would be

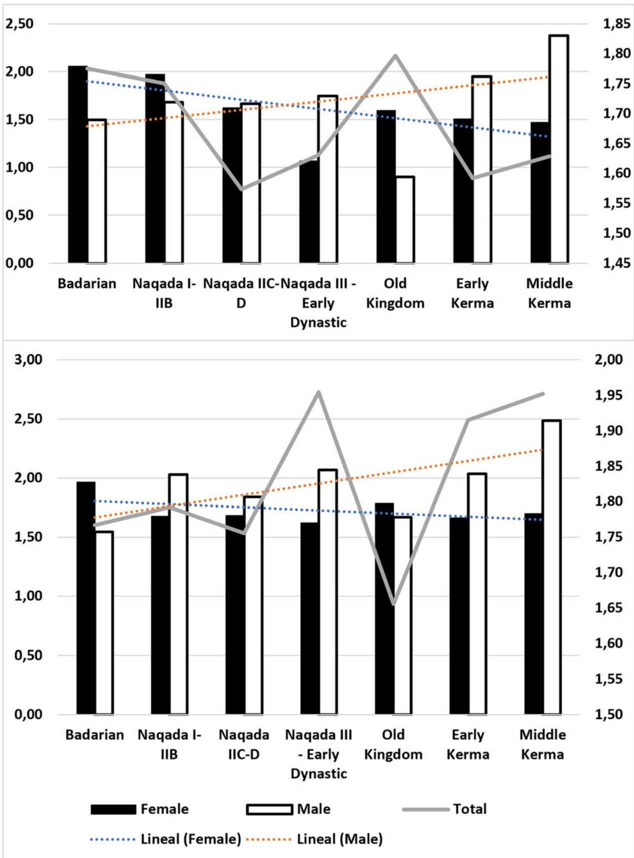

FIGURE 4 Compared results of entheseal changes averages in the upper limb (up) and in the lower limb (down) between chronological groups, sorted by sex and including its lineal tendency [Colour figure can be viewed at wileyonlinelibrary.com]

concentrated in the CEB sample ($\bar{x} = 1.54$). In the Hu area cluster, there was once again a great variety of values: The highest ones were between the CHH ($\bar{x} = 2.00$) and CZH (1.92) samples, while the lowest is in CBH ($\bar{x} = 1.60$). In the Naqada area cluster, although we did not have enough data for CBN, we noted that the sample values for CTN ($\bar{x} = 2.00$) were slightly higher than for GCN ($\bar{x} = 1.81$). Finally, for the Northern Dongola Reach area cluster, we could see that the averages for both the upper and lower extremities of the O16 sample ($\bar{x} = 1.91$) were lower than in P37 ($\bar{x} = 1.95$).

3.3 | Sexual dimorphism

According to the Mann–Whitney test (Table 4), only three muscle insertions (9.09%) provided significant differences between male and female groups in the 33 entheses analyzed, precisely the m. *deltoid* in clavicles ($p = 0.01$), the m. *supinator* in the ulnae ($p = 0.01$), and the m. *peroneus* in fibulae ($p = 0.05$). It should be noted that the m. *flexor pollicis longus* ($p = 0.07$), m. *brachioradialis* ($p = 0.07$), and m. *abductor pollicis longus* in the radius ($p = 0.09$) showed high differences, although not statistically significant. We observe that 45.45% of the entheses were more robust among female individuals, while 54.55% of the remaining attachments had higher entheseal remodeling among males. However, if we compare the averages of both groups, we see that the levels of robustness were slightly higher among female individuals ($\bar{x} = 1.77$) than among males ($\bar{x} = 1.76$). The sexual dimorphism coefficient (%MDI) corroborated these data, showing a lower average among female individuals ($\bar{x} = -0.0001$). In this sense, we have noted the sexual dimorphism in the entheses of the clavicle ($\bar{x} = 0.003$), fibula ($\bar{x} = 0.003$), femur ($\bar{x} = 0.002$), and tibia ($\bar{x} = 0.001$), which were higher among male individuals. At the same time, those of the ulna ($\bar{x} = -0.004$), radius ($\bar{x} = -0.001$), and humerus ($\bar{x} = -0.001$) were higher in the female group. All in all, it must be considered that the differences were quite low, although, in the discussion, we have explained the importance of these data.

When comparing the differences by sex in each chronological phase in Figure 4, we observed a general decrease in the entheseal robustness of the female individuals and linear growth of the robustness indices among male individuals. In addition, in the Badarian group, there was a coefficient of sexual dimorphism (%MDI) of female tendency in the upper limbs (UL: $\bar{x} = -0.006$) and lower limbs (LL: $\bar{x} = -0.004$), towards Naqada III–Early Dynastic, we found frequencies of male tendency (UL: $\bar{x} = 0.007$/LL: $\bar{x} = 0.004$), although in the Old Kingdom, there was again greater robustness among female individuals (UL: $\bar{x} = -0.007$/LL: $\bar{x} = -0.001$). There was a general increase in male frequencies for the Nubian samples between Early Kerma (UL: $\bar{x} = 0.004$/LL: $\bar{x} = 0.009$) and Middle Kerma (UL: $\bar{x} = 0.004$/LL: $\bar{x} = 0.008$).

Figure 6 shows the sexual dimorphism coefficients (%MDI) at each site where we collected enough cases. The CEB, CWH, and CB sites showed robustness frequencies with a tendency towards the female group in the upper and lower limbs. On the other hand, the CTN, O16, and P37 samples had higher frequencies in the male groups for both anatomical regions. Regarding the GCN and CBH sites, we observed that the entheses of the upper limb present higher levels of robustness in the female groups. In contrast, the impact of the lower extremities was concentrated in the male groups. It should be noted that the highest sexual dimorphism coefficients were distributed in the upper limbs of individuals from CTN ($\bar{x} = 0.011$) and P37 ($\bar{x} = 0.009$).

3.4 | Age-at-death groups

According to the Kruskal–Wallis test, 52.94% of the 17 included entheses showed statistically significant differences between the age groups (Table 5). The muscle attachments with the highest significant differences were the m. *deltoid* ($p = 0.01$) and the m. *coracobrachialis* ($p = 0.01$) in the humerus and the interosseous membrane in the fibula ($p = 0.01$). It should also be noted that the m. *pectoralis major* of the humerus ($p = 0.02$), the m. *adductor magnus* ($p = 0.02$), and the m. *gastrocnemius* of the femur ($p = 0.02$), as well as the m. *flexor digitorum longus* ($p = 0.02$) were also significantly different among age groups.

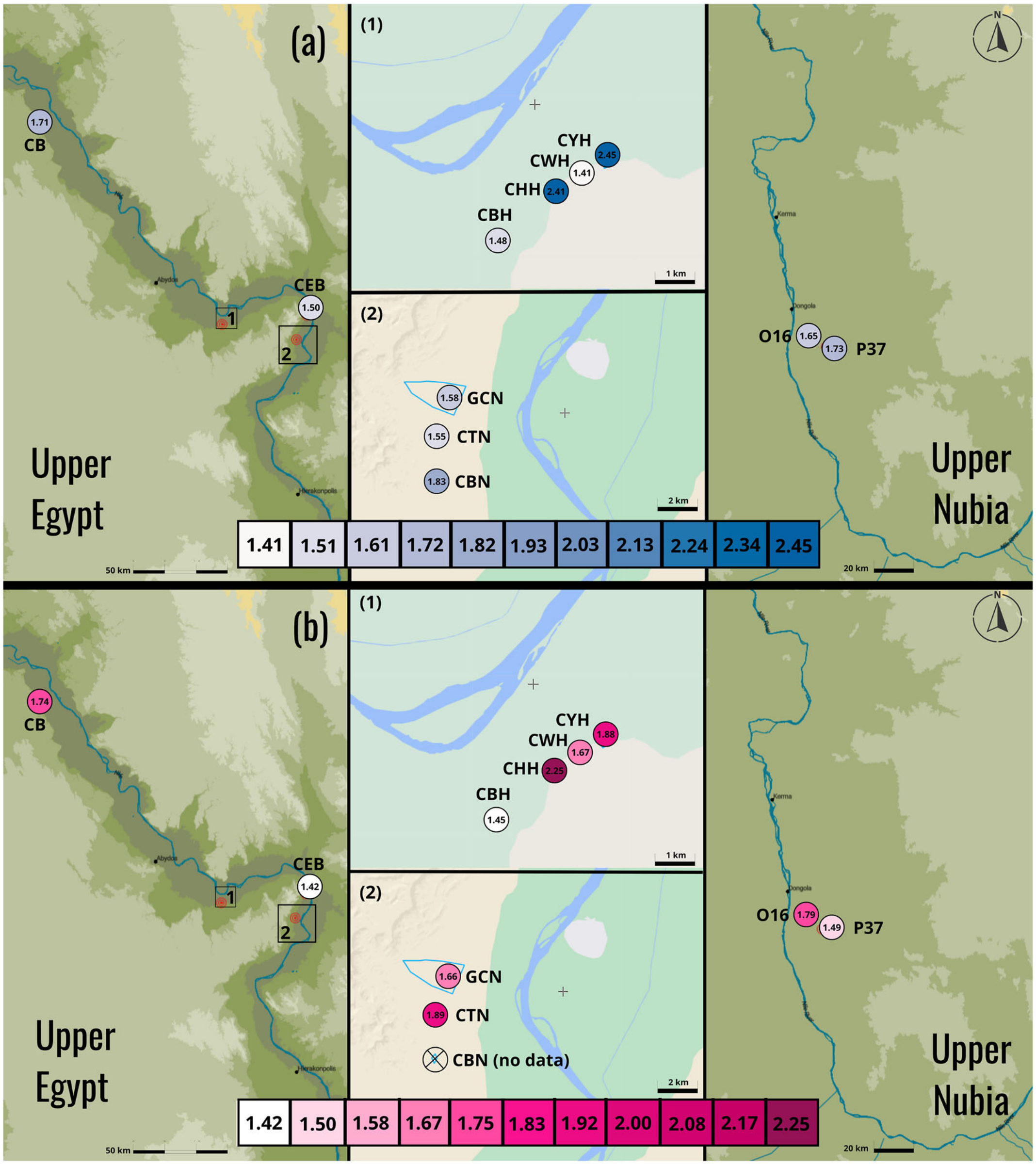

FIGURE 5 Map with the geographical distribution of the average of the upper limb (a) and lower limb (b) in each of the sites, with a close-up to show the four selected cemeteries in the Hu area (1), and another close-up to show the three sites in Naqada (2). The averages have been represented with a blue and pink monochrome scale established from the minimum and maximum average values (source: Scribble Maps and Google Maps). [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 7 shows an irregular growth between the juvenile ($\bar{x} = 1.03$), adult ($\bar{x} = 1.98$), mature ($\bar{x} = 1.81$), and senile ($\bar{x} = 2.04$) age groups. In the comparison by sex, we contemplated that within the adult age category, there were slightly higher averages in the female group (2.02). In contrast, in the mature age category, the male group accumulates a more elevated concentration of high grades ($\bar{x} = 2.09$).

3.5 | Bilateral asymmetry

Table 6 shows the frequencies of the 33 entheses classified by laterality. According to the Mann–Whitney test, no muscle attachments had significant differences when comparing the right and left sides. We have verified that 60.61% of the entheseal changes accumulated slightly higher frequencies in the insertions on the left side, leaving 39.39% of the rest on the right side. However, when comparing the total averages, we observed that those of the left laterality ($\bar{x} = 1.77$) have slightly lower degrees than those of the right ($\bar{x} = 1.78$). The directional asymmetry parameter (%DA) confirmed these data, which shows a slight tendency towards the right side (0.0001). The average parameters of the clavicle ($\bar{x} = 0.002$), humerus ($\bar{x} = 0.001$), tibia ($\bar{x} = 0.0001$), and fibula ($\bar{x} = 0.002$) attachments showed a directional asymmetry to the right. At the same time, those of the ulna

TABLE 4 Results of EC for the Nile Valley sample and *p* values for significant differences among sex-estimated cases (Mann–Whitney test)

	Female			Male			Total				Mann–Whitney test	
	n	Mean	*S*	*n*	Mean	*S*	*n*	Mean	*S*	MDI%	*Z*	*p*
CLDT	22	1.73	0.83	13	2.54	0.78	35	2.03	0.89	0.008	−2.77	**0.01**
CLCS	19	2.11	1.24	12	1.92	0.90	31	2.03	1.11	−0.002	−0.06	n.s.
HUMSB	33	1.85	1.44	30	1.50	1.36	71	1.73	1.38	−0.003	−0.96	n.s.
HUMTm	24	1.88	0.74	25	1.72	0.84	57	1.74	0.81	−0.002	−0.52	n.s.
HUMPM	48	2.04	0.90	40	2.28	0.99	100	2.14	0.95	0.002	−0.90	n.s.
HUMDT	54	2.06	1.16	42	1.88	1.11	108	1.94	1.11	−0.002	−0.61	n.s.
HUMCR	53	1.30	1.08	42	1.55	0.97	109	1.41	0.99	0.002	−1.25	n.s.
HUMFC	53	1.23	1.05	41	1.05	0.80	107	1.16	0.93	−0.002	−0.68	n.s.
ULANC	29	1.76	1.02	18	2.17	0.79	47	1.91	0.95	0.004	−1.48	n.s.
ULBR	29	2.45	1.18	17	2.00	1.22	46	2.28	1.20	−0.004	−1.24	n.s.
ULSP	29	2.66	1.08	17	1.71	1.21	46	2.30	1.21	−0.009	−2.64	**0.01**
ULAPL	31	2.19	0.79	16	1.81	0.75	47	2.06	0.79	−0.004	−1.58	n.s.
ULEI	26	2.08	0.84	14	1.57	1.28	40	1.90	1.03	−0.005	−1.46	n.s.
ULFDP	32	1.69	0.64	16	1.44	0.81	48	1.60	0.71	−0.002	−0.95	n.s.
RAAPL	32	1.91	0.93	20	1.50	0.83	52	1.75	0.90	−0.004	−1.71	0.09
RABB	27	2.11	1.22	20	2.30	1.17	47	2.19	1.19	0.002	−0.53	n.s.
RAFPL	30	1.77	1.17	20	1.20	0.89	50	1.54	1.09	−0.006	−1.79	0.07
RABRO	17	1.24	0.83	15	0.73	0.59	32	1.00	0.76	−0.005	−1.80	0.07
RAPT	24	1.29	1.12	18	1.67	1.24	42	1.45	1.17	0.004	−1.02	n.s.
RAPQ	21	0.71	0.56	16	0.81	0.66	37	0.76	0.60	0.001	−0.42	n.s.
FEGMa	53	2.47	1.01	36	2.67	0.86	103	2.50	0.97	0.002	−1.02	n.s.
FEVM	59	1.81	0.99	42	2.00	1.19	116	1.81	1.09	0.002	−0.83	n.s.
FEGMe	39	1.95	1.12	35	2.09	0.98	87	2.03	1.04	0.001	−0.74	n.s.
FEGMi	42	1.86	1.07	35	2.17	1.01	91	1.97	1.03	0.003	−1.30	n.s.
FEAM	57	1.93	1.02	42	2.26	1.29	115	2.09	1.14	0.003	−1.25	n.s.
FEGCN	45	1.89	1.19	32	1.75	1.24	88	1.82	1.18	−0.001	−0.49	n.s.
TITIA	52	1.83	0.88	46	1.54	0.91	120	1.74	0.90	−0.003	−1.84	0.07
TISO	45	1.84	1.07	41	2.02	1.27	107	1.89	1.15	0.002	−0.72	n.s.
TIFDL	47	1.36	1.03	41	1.66	1.24	109	1.50	1.11	0.003	−1.02	n.s.
TICRA	35	0.94	0.87	33	1.12	1.11	82	1.04	0.95	0.002	−0.41	n.s.
FIBF	19	1.11	0.94	26	1.46	1.07	50	1.32	0.98	0.004	−1.16	n.s.
FIPE	51	1.76	0.95	51	2.16	1.03	114	1.95	1.00	0.004	−1.94	**0.05**
FIIM	46	1.76	0.97	48	1.94	0.95	104	1.88	0.98	0.002	−1.02	n.s.

Abbreviations: MDI%, sexual dimorphism coefficient; *n*, number of cases; n.s., no significant (value); *S*, standard deviation.

($\bar{x} = -0.0001$), the radius ($\bar{x} = -0.001$), and femur ($\bar{x} = -0.001$) tended to left laterality.

Figure 8.1 compares the directional asymmetry parameters of each type of bone according to sex. The highest female values accumulated in the right laterality for the insertions of the clavicle ($\bar{x} = 0.003$) and the fibula ($\bar{x} = 0.003$). In contrast, those of the left laterality were concentrated in the attachments of the radius ($\bar{x} = -0.003$) and the femur ($\bar{x} = -0.002$). On the other hand, the male parameters with more substantial directional asymmetry were found in the ulnae of right laterality ($\bar{x} = 0.002$) and the left femoral insertions ($\bar{x} = -0.002$). In this sense, it should be noted that the average values of asymmetry in the upper limbs were moderately higher in the male group (0.000972) than in the female group ($\bar{x} = -0.000116$).

Figure 8.2 compares the directional asymmetry values in the upper and lower extremities for each chronological phase. Again, we have observed a linear trend of increased parameters towards the right side in the upper and lower extremities. Thus, in the case of Egypt, it went from a relatively low level of asymmetry towards the left laterality in the Badarian ($\bar{x} = -0.00016$) to a moderately high average of right tendency in the Old Kingdom ($\bar{x} = 0.00413$). This increase is also observed in Nubia between the Early Kerma ($\bar{x} = 0.00211$) and Middle Kerma ($\bar{x} = 0.00416$) phases.

4 | DISCUSSION

4.1 | Diachronic perspectives on physical activity during the state formation

When entheseal changes data were examined diachronically, some subtle yet exciting, patterns emerged. Although no statistically significant differences were found, the mean value data (Figure 4) did suggest temporal variability. The upper body showed a decrease in entheseal changes during the Naqada IIC–D period, followed by a dramatic increase during the Old Kingdom. We posit that the decline in physical activity from Naqada I–IIB to Naqada IIC–D may be associated with increasing specialization and sedentism that also appeared at this time. At Hierakonpolis, we see specific occupational areas dedicated to beer, food, pottery, and lithic production (Stevenson, 2016). Campagno (2019) argued that this would have resulted in occupational specialization, as production demands increased with a growing population and increased trade interconnections. Although,

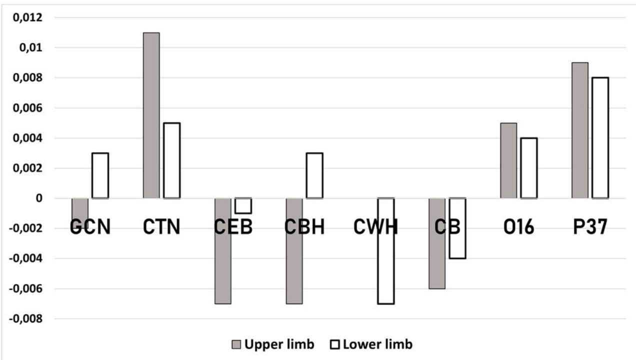

FIGURE 6 Sexual dimorphism in the Nile Valley sample sorted by site. Negative values represent entheseal changes scores higher in females, and positives among males. [Colour figure can be viewed at wileyonlinelibrary.com]

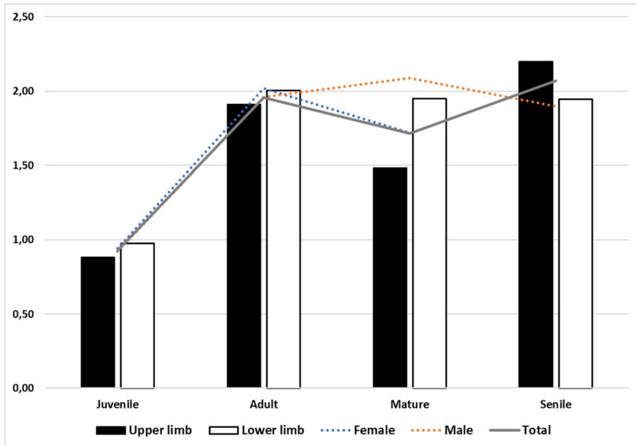

FIGURE 7 Compared results of entheseal changes in the different age groups, sorted by upper and lower limb. The lines represent the average values by sex for each group. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 Results of EC in the Nile Valley sample and *p* values for significant differences among age-estimated cases (Kruskal–Wallis test)

	Juvenile			Adult			Mature			Senile			Kruskal–Wallis test	
	n	M	*S*	*n*	M	*S*	*n*	M	*S*	*n*	M	*S*	H	*p*
HUMTm	3	1.67	0.58	15	1.87	0.99	5	2.00	0.00	2	2.00	0.00	0.46	n.s.
HUMPM	6	1.17	0.41	26	2.35	0.94	11	1.73	1.10	2	2.50	0.71	10.20	**0.02**
HUMDT	7	1.00	0.58	29	2.38	1.08	14	1.43	0.94	2	3.50	0.71	15.79	**0.01**
HUMCR	5	0.00	0.00	26	1.85	1.08	13	0.92	0.95	2	2.00	1.41	13.92	**0.01**
HUMFC	7	0.57	0.53	27	1.11	1.05	12	1.33	1.07	2	1.00	0.00	3.28	n.s.
FEGMa	7	2.14	1.07	26	2.92	0.74	11	2.91	1.22	2	3.00	1.41	3.59	n.s.
FEVM	8	1.63	0.74	28	2.39	1.03	16	2.25	1.00	2	2.50	0.71	4.58	n.s.
FEGMe	6	0.83	0.75	23	2.13	1.06	8	2.50	1.20	2	2.50	0.71	8.72	**0.03**
FEGMi	7	1.29	1.11	22	2.14	0.94	9	2.78	0.97	2	1.50	0.71	7.91	**0.05**
FEAM	7	0.71	1.11	28	2.36	1.16	15	2.40	1.12	2	2.00	1.41	9.86	**0.02**
FEGCN	8	0.88	0.64	20	2.20	1.11	8	1.25	1.04	2	1.50	0.71	9.69	**0.02**
TITIA	9	1.78	0.67	25	1.88	0.83	19	1.89	1.10	[a]	[a]	[a]	0.05	n.s.
TIFDL	8	0.63	0.92	24	1.63	1.17	16	1.94	0.85	[a]	[a]	[a]	7.87	**0.02**
TICRA	8	0.50	0.53	20	0.90	0.79	9	0.78	0.67	[a]	[a]	[a]	1.56	n.s.
FIBF	3	0.67	0.58	17	1.53	1.01	8	0.88	0.64	2	0.50	0.71	5.68	n.s.
FIPE	8	1.38	1.06	31	2.10	0.87	17	2.06	0.90	2	3.50	0.71	6.98	0.07
FIIM	7	0.71	0.76	28	1.89	0.79	12	1.75	1.06	2	0.50	0.71	12.51	**0.01**

Abbreviations: *n*, number of cases; n.s., no significant (value); *S*, standard deviation.
[a]There are not enough valid cases to generate these data.

TABLE 6 Comparison of average values between groups by laterality and *p* values for significant differences (Mann–Whitney test)

	Right			Left			Total				Mann–Whitney test	
	n	Mean	*S*	*n*	Mean	*S*	*n*	Mean	*S*	%DA	*Z*	*p*
CLDT	19	2.21	0.71	16	1.81	1.05	35	2.03	0.89	0.004	−1.09	0.28
CLCS	17	2.00	1.17	14	2.07	1.07	31	2.03	1.11	−0.001	−0.17	0.87
HUMSB	39	2.03	1.31	32	1.38	1.41	71	1.73	1.38	0.007	−2.08	0.04
HUMTm	31	1.81	0.75	26	1.65	0.89	57	1.74	0.81	0.002	−0.73	0.47
HUMPM	53	2.13	1.04	47	2.15	0.86	100	2.14	0.95	0.000	−0.14	0.89
HUMDT	58	1.88	1.08	50	2.02	1.15	108	1.94	1.11	−0.001	−0.69	0.49
HUMCR	56	1.38	1.02	53	1.45	0.97	109	1.41	0.99	−0.001	−0.35	0.73
HUMFC	58	1.29	1.03	49	1.00	0.79	107	1.16	0.93	0.003	−1.37	0.17
ULANC	24	2.00	1.06	24	1.75	0.90	48	1.88	0.98	0.003	−0.88	0.38
ULBR	24	2.21	1.22	23	2.30	1.22	47	2.26	1.21	−0.001	−0.26	0.79
ULSP	24	2.33	1.20	23	2.22	1.24	47	2.28	1.21	0.001	−0.11	0.91
ULAPL	23	2.00	0.80	25	2.08	0.81	48	2.04	0.80	−0.001	−0.35	0.73
ULEI	22	1.82	1.01	19	2.00	1.05	41	1.90	1.02	−0.002	−0.55	0.59
ULFDP	24	1.58	0.72	25	1.64	0.70	49	1.61	0.70	−0.001	−0.33	0.74
RAAPL	28	1.71	0.94	24	1.79	0.88	52	1.75	0.90	−0.001	−0.51	0.61
RABB	25	2.04	1.24	22	2.36	1.14	47	2.19	1.19	−0.003	−0.87	0.39
RAFPL	27	1.52	0.94	23	1.57	1.27	50	1.54	1.09	0.000	−0.20	0.84
RABRO	18	0.83	0.71	14	1.21	0.80	32	1.00	0.76	−0.004	−1.31	0.19
RAPT	21	1.57	1.21	21	1.33	1.15	42	1.45	1.17	0.002	−0.90	0.37
RAPQ	19	0.63	0.68	18	0.89	0.47	37	0.76	0.60	−0.003	−1.49	0.14
FEGMa	54	2.48	0.99	50	2.56	0.97	104	2.52	0.98	−0.001	−0.45	0.66
FEVM	60	1.78	1.08	57	1.86	1.11	117	1.82	1.09	−0.001	−0.45	0.65
FEGMe	47	1.94	1.11	40	2.15	0.95	87	2.03	1.04	−0.002	−1.01	0.31
FEGMi	46	1.85	1.07	45	2.09	0.97	91	1.97	1.03	−0.002	−1.10	0.27
FEAM	60	2.08	1.14	56	2.11	1.14	116	2.09	1.13	0.000	−0.18	0.86
FEGCN	46	1.87	1.28	42	1.76	1.08	88	1.82	1.18	0.001	−0.15	0.88
TITIA	59	1.78	0.81	61	1.70	0.99	120	1.74	0.90	0.001	−0.51	0.61
TISO	52	1.87	1.16	55	1.91	1.16	107	1.89	1.15	0.000	−0.14	0.89
TIFDL	53	1.57	1.17	56	1.45	1.06	109	1.50	1.11	0.001	−0.54	0.59
TICRA	43	0.98	0.86	39	1.10	1.05	82	1.04	0.95	−0.001	−0.35	0.73
FIBF	22	1.41	1.05	28	1.25	0.93	50	1.32	0.98	0.002	−0.53	0.60
FIPE	55	2.09	0.97	59	1.81	1.03	114	1.95	1.00	0.003	−1.68	0.09
FIIM	49	1.94	1.03	55	1.84	0.94	104	1.88	0.98	0.001	−0.49	0.62

Abbreviations: DA%, directional asymmetry coefficient; *n*, number of cases; n.s., no significant (value); *S*, standard deviation.

additionally, the physical demands of said occupational specialization would have been markedly variable, "all these specialized activities, including the provision of raw materials and other inputs such as firewood for kilns and food for workers, suggest the possibility that at least a portion of the inhabitants of Hierakonpolis were attached to economic practices different from agriculture and husbandry" (Campagno, 2019, p. 223). Thus, if there was a growing dependence upon domestication and agriculture during Badarian and Naqada I–IIB, where most of the population contributed to these efforts, followed by occupational specialization during the Naqada IIC–D, it is possible that we actually see a decrease in activity.

The dramatic increase in upper body entheseal changes, concurrent with the notable decrease in lower body entheseal changes, during the Old Kingdom was marked, something that has been observed in previous studies (Refai, 2019; Zabecki, 2009). During the Old Kingdom, socioeconomic inequalities were truly institutionalized, and complete dependence upon domestic agriculture was also intensified, as supported by osteological evidence (Stock et al., 2011; Zakrzewski, 2003). To keep a burgeoning upper class and bureaucracy, the laborers of ancient Egypt would have been responsible for all production, construction, and food provisions. Possible activity-related explanations for an increase in upper body

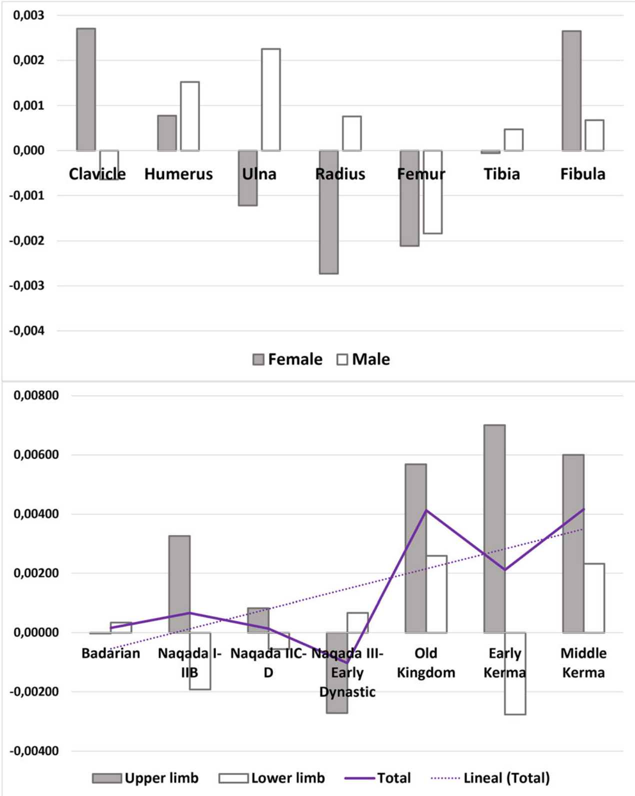

FIGURE 8 Comparison of directional asymmetry parameters between sex groups in each one of the long bones (1) and between upper and lower limb in each chronological phase (2). The grey lines show the total tendency along these phases. Negative values represent that entheseal changes are higher among the left group, and positive values in the right group. [Colour figure can be viewed at wileyonlinelibrary.com]

activity coupled with a decrease in lower body activity include, but are not limited to grinding grain, beer-making, sandal-making, pottery production, hunting, rowing, and guards (Stevenson, 2016).

Kerma's upper body entheses showed less impact and are like those of Naqada IIC–D. However, the lower body entheses had higher remodelation in the entire sample, especially among men. It should be noted that there was an increase between the Early Kerma and Middle Kerma periods, suggesting that agricultural and production activities may have begun to increase at this time (see Welsby, 2001, p. 589). The very high lower body entheses, on the other hand, may be partially explained by a continuation of pastoral practices in Kerma (Martin, 2015; Schrader, 2015). It has been argued that pastoralism was vital in ancient Kerma society (Hafsaas-Tsakos, 2013). The centralized capital city, at the type-site Kerma, and secondary cities (e.g., Saï) were likely very sedentary. Still, a large portion of the population may have herded cattle and caprines regularly, as we see with the Northern Dongola communities. This increased walking over varied terrain, which was sometimes rocky, may have contributed to greater lower body entheseal changes (Henderson et al., 2017).

4.2 | Site-specific variation in entheseal changes among Egyptian and Nubian populations

There appeared to be more significant variation in entheseal changes between sites than in chronological phases. M. *vastus medialis*, the tibiofibular interosseous membrane, m. *anconeus*, and m. deltoid (clavicle) all showed statistically significant variation between sites. The Hu area cluster illustrated quite a lot of variation. For example, Cemeteries H and Y at Hu had markedly high entheseal changes, while Cemeteries B and W at Hu had notably low entheseal changes (Figures 5 and 6). There is archaeological evidence to suggest that both Cemeteries H and Y are associated with lower socioeconomic classes. Cemetery H, dating to Naqada III, consists of simple burial pits with few or no grave goods (e.g., faience beads, wooden figurines; Petrie & Mace, 1901). Cemetery Y, which dates to the Old Kingdom, consists of shallow graves and pit tombs, of which Flinders Petrie accounts, "these must have been the graves of the very poorest of the people, none of them containing more than a pot or two, and a few beads and amulets" (Petrie & Mace, 1901, p. 40). By contrast, Cemetery W, which also dates to the Old Kingdom, has multiple pages devoted to the prestige items found in the graves (e.g., alabaster vases, gold beads, bronze mirrors, coffins, amulets, scarabs; Petrie & Mace, 1901). Graves from Cemetery B contained stone vases, animal skins, wooden models, copper bangles, maces, ivory handles, ivory combs, scarabs, and amulets (Petrie & Mace, 1901). The cemetery cluster at Hu presents an exciting microcosm of the intersectional socioeconomic classes that existed in the state formation process in Egypt and reflected the subsequent variation in an activity that is embodied and tangible in the human skeletal remains.

Other cemeteries that were outliers in this larger dataset of site comparisons include el-Ballas, Naqada, and O16/P37. The Naqada cemeteries, like the Hu complex, illustrated a wide array of entheseal changes scores. However, these cases were not as clearly associated with status. While the upper body scores seem to align, with the highest status segment of the cemetery complex having the lowest entheseal scores (Cemetery T), the lower body presents a different picture. Cemetery T has one of the greatest lower body entheseal changes scores for the entire sample.

On the other hand, the elite cemetery may have contained older individuals (Bard, 1989), and age is often found to be positively associated with entheseal changes (Yonemoto, 2016). The Great Cemetery at Naqada also spans Naqada I–III, whereas Cemetery T is thought to date to Naqada II–III (Bard, 1989). Thus, the diachronic trends we see above might also contribute to this relationship. Lastly, it is also possible that the people buried in Cemetery T were more physically active with the lower limbs, possibly hunting, playing a sport, or engaging in other elite activities (Hendrickx, 2011). The cemetery of el-Ballas, dating from the Predynastic to the Old Kingdom, had the lowest lower body entheseal changes scores. This question may be because the population of el-Ballas was largely sedentary and increasingly dependent upon agricultural resources. The Kerma period cemeteries (O16/P37) had high lower body entheseal scores, which may be associated with pastoral lifeways (discussed above).

4.3 | Gendered labors in the Nile Valley?

As discussed above, we consider gender a social construct that differs from biological sex (Agarwal & Wesp, 2017). As others have argued, occupation and physical activities within a social system are very much gendered rather than sexed. While we acknowledge that we cannot truly address gender, as we will never know how these individuals identified their gender, we can leverage the archaeological record and embodiment theory (Laffranchi et al., 2020).

Several entheseal changes were higher in males, including m. deltoid and m. *peroneus*. These are shoulder and ankle muscles that facilitate arm abduction and plantar flexion. These broad and universal movements may have been integral to construction endeavors, agricultural practices, and walking long distances. Interestingly, several entheseal changes were also higher in females, including m. *supinator*, m. *flexor pollicis longus*, *brachioradialis*, and m. *abductor pollicis longus*. Some have argued that males are more likely to develop entheseal changes because of a biological tendency to develop and maintain more muscle mass (Bakirci et al., 2020). However, other studies have pointed out that men showed more intense activities among Late Predynastic and Old Kingdom people represented in available samples (Martin, 2015; Refai, 2019; Schrader, 2015; Zabecki, 2009). However, in scenarios where females had higher entheseal changes, this can be viewed as a genuine sexual division of labor. This female sample is overcoming the sexual discrepancy precluding males from developing more muscle. In this way, although the differences between groups are pretty low, the impact of hormonal activity must be considered when comparing the results between men and women. In this case, Egyptian women appeared to have been involved in activities relating to forearm supination, rotation, and finger movement. These muscle actions may have been present in archaeologically documented activities such as weaving, handcrafting, pottery production, planting, collecting, and processing agricultural resources (Zabecki, 2009). A 3D entheseal study focusing on extensively documented workers has reported distinctive patterns in the hand entheses of historical long-term seamstresses and tailors, showing muscle chains related to index and thumb interaction in both men and women (Karakostis & Hotz, 2022), which we have also seen in the results of the female group.

In Figure 4, we did see a broad trend of female upper and lower body entheseal changes decreasing in entheseal remodeling over time, while male entheseal changes increase over time. It is possible that the foundations of the Egyptian state were built upon women's labor, with activity being higher in females during the Badarian Neolithic and at the beginning of the state formation processes (Naqada I–II) and decreasing over time (Predynastic and Early Dynastic). There is also proof that the Late Predynastic and Old Kingdom groups had a higher sexual dimorphism (Zakrzewski, 2003). This matter was also evidenced by the site-specific data (Figure 6); el-Ballas, Cemetery B at Hu, Cemetery W at Hu, and el-Badari all indicate that females had more marked entheseal changes than their contemporary male counterparts.

4.4 | Hands on work: Bilateral behaviors?

If we look at Table 6, the differences between left and right values were limited. There were no significant differences, possibly due to the frequency of bilateral movement. In other words, if one hand was not used in activities more than the other, both sides would like to have similar entheseal changes. Limited bilateral asymmetry was also found in an entheseal changes study of the pyramid builders of Giza (Old Kingdom) (Refai, 2019). This pattern is usually quite common in people where agriculture has had a specific weight, since most tasks required the participation of both limbs (Zabecki, 2009). Bilateral practices have been well-documented in archaeological populations (Eshed et al., 2004; Laffranchi et al., 2020; Santana-Cabrera, 2011).

Despite the usefulness of non-parametric tests when evaluating statistical significance from *p*-values, their absence does not mean that there were no differences. Recent discussions of statistical significance recommend avoiding reliance on these values and interpreting the data within a wide range of potential explanations. In this way, factors such as background evidence, study design, data quality, and understanding of underlying mechanisms are often more important than statistical measures such as *p* values (Armhein et al., 2019; Wasserstein et al., 2019).

In this sense, we have observed some subtle differences in our results since females appear to have used their left ulna, radius, and femur more than men (Figure 9), which supports the data presented above (Section 4.3). These data may indicate that females engaged in bilateral movements more frequently, thus making their left side more entheseally robust than their right. Much research has been conducted on the overall right-hand predominance of humans (Al-Oumaoui et al., 2004). The previous pattern indicates that the impact of unilateral tasks was not enough to stand out from the frequency of bimanual activities. On the other hand, men individual are using their right arm more than women, so they were potentially participating in more unilateral, right-handed actions. Activities involving one hand are often more refined and reliant upon finger manipulation. The higher values of bilateral asymmetry in the upper limb among men may be associated with extra-domestic labors or more specific and constant tasks that resulted in asymmetrical manipulative loading. At the same time, females may have been involved in domestic, agricultural, handcraft, and gathering with a more symmetrical manipulative loading (Sládek et al., 2007).

If we look at bilateral asymmetry through time, right-handed predominance becomes more common in the Old Kingdom and Kerma periods. This pattern might be related to the increasing occupational specialization enforced during the Old Kingdom (see above, 4.1). Activities during the Badarian and predynastic Naqada could have been more varied and less intense, leading to equal usage of left and right. However, as the state grew, a need for more intensive labor and production was required, contributing to specialization, and increased movement of select musculoskeletal elements.

4.5 | Limitations of the study

Although we have used a representative sample for the study period, and the applicability of the entheseal changes for the proposed objectives has been demonstrated, we must clarify some limitations. Thus, the potential impact of the lack of age control in other comparisons must be considered, so this factor may have likely biased some of the trends. Although the sample of juvenile and senile individuals was relatively low, growth and degeneration may have contributed to the high grades in some samples. In pre-adult individuals, musculoskeletal tissue production behaves similarly to when changes occur due to physical activity, while in senile individuals, soft tissue calcification increases after 45 years (Santana-Cabrera, 2011). In addition, we must consider that age estimation methods for remains organized by bone type have had a particular limitation when specifying adult age groups, which has reduced the sample of estimated individuals.

In this sense, since the methods for estimating sex and age differed according to the storage characteristics of the remains (e.g., individualized remains vs. remains organized by bone type), we decided to examine the results including exclusively individualized collections. In this case, all patterns observed across the study (both significant and non-significant values) remained as such when focusing on the individualized remains, so the results were valid. However, in the remains organized by type of bone, slight differences in sex and age were observed, which not only revealed the level of reliability of the methods applied but it must also be considered that these collections came from specific sites (Naqada, Hu, and el-Ballas), so there could be an influence of inter-site variability. Therefore, it is recommended to use the results relative to age and sex groups of these sites with some caution.

5 | CONCLUSIONS

We have illustrated through this robust dataset a nexus of socioeconomic status, gender, and activity at multiple archaeological sites during the state formation process in the Nile Valley. This evidence showed that interesting changes in activity occurred throughout state formation, with a dramatic increase in activity and possibly the emergence of specialized occupations during the Old Kingdom. There is proof to support the argument that the Kerma state may have been founded on pastoral lifeways. In some cases, women may have engaged in more intensive activities than men, particularly before the Old Kingdom. These data suggest that women played a crucial role in the development of the Egyptian state and that their labor was integral to the formation of an expansive empire. Clear evidence of the embodiment of socioeconomic status can be found both at Naqada and Hu cemeteries. For the most part, we found here that individuals who were buried in wealthier tombs had lower entheseal changes when compared to individuals who were buried in basic graves. We acknowledge that this relationship between socioeconomic status and activity is much more complicated. However, in this example, we argue that there is clear evidence of embodied inequality.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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