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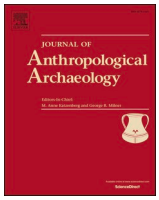

Tumplines, baskets, and heavy burden? Interdisciplinary approach to load carrying in Bronze Age Abu Fatima, Sudan

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ABSTRACT

This paper investigates different body techniques for carrying heavy loads by individuals buried at Abu Fatima, a Nubian Bronze Age cemetery in Sudan. Drawing on iconographic evidence from ancient Egypt and Nubia, as well as African and other ethnographic records, the paper aims to understand gendered patterns behind load-carrying practices and their traces on skeletal remains. A multi-proxy approach was employed, using various skeletal modifications associated with mechanical loading. Examination of entheseal changes, osteoarthritis-related alterations, and degenerative vertebral changes was conducted to investigate the impacts of muscle loading, joint stress, and spinal adaptations. Additionally, unintentional cranial modifications, specifically changes caused by tumpline use, were also considered. The results indicate gender-specific load-carrying techniques among the individuals buried at Abu Fatima. Men displayed evidence of unilateral entheseal changes and humeroscapular osteoarthritis, indicating involvement in activities that necessitated bearing load on one shoulder. Women displayed distinct degenerative changes to the cervical vertebrae indicating frequent musculoskeletal use of the upper neck.

1. Introduction

1.1. Objectives

This study investigates the gendered body techniques of load carrying among the population buried at Abu Fatima, a cemetery in Upper Nubia (modern Sudan), which dates to ca. 2500–1500 BCE (Fig. 1). Abu Fatima is located near the site of Kerma, the capital of the Nubian kingdom known in contemporaneous ancient Egyptian sources as Kush. In order to better understand the gendered patterns behind some of the bioarchaeological findings of this study, ancient visual representations and ethnographic studies were also considered. By integrating skeletal analysis with iconographic and comparative research from ancient Egypt, Nubia, and broader African contexts, this study aims to explore how these techniques reflect and reinforce socially structured gender roles. Specifically, the analysis focuses on the potential use of tumplines, a load-carrying device known from various cross-cultural contexts, and its impact on skeletal modifications observed in the Abu Fatima population.

1.2. Theoretical background

French anthropologist Marcel Mauss (1973: 70) defined body techniques as "the ways in which, from society to society, men know how to use their bodies". His examples included activities such as swimming, digging, marching, walking, positions of hands, and running. He stressed the importance of learning the body techniques through imitation. Mauss (1973: 73) described the social nature of these techniques as *habitus*, a term now mostly associated with French sociologist Pierre Bourdieu who defined it as "structured structures predisposed to serve as structuring structures" (Bourdieu, 1977: 72). Thus, according to both Mauss and Bourdieu, daily activities are the result of learned habits that are socially structured. Furthermore, their enactment and repetition reinforce these social structures.

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Body techniques can have gendered backgrounds. An example is the walk of Maori women whose corporeal aesthetics is encouraged by their mothers (Mauss, 1973: 74). The habitual notions of body techniques were adapted by American feminist and queer philosopher Judith Butler in their theory of performativity of gender. Butler argued that certain stylized and gender-specific bodily acts materialize gendered bodies (Butler, 1993). By doing what is considered appropriate for a certain sex/gender, people materialize bodily differences (for archaeological applications, see Matić, 2024; Perry & Joyce, 2001). The examination of skeletal remains of ancient people provides valuable insights into how specific body techniques are embodied since bones are dynamically formed through activities and experiences (Schrader & Torres-Rouff, 2021; Sofaer, 2006). At the cellular level, remodeling, with osteoclasts breaking down and osteoblasts rebuilding bones, is a gradual process

Fig. 1. Map with the location of Abu Fatima and other archaeological sites mentioned in this investigation (adapted from Schrader and Smith, 2017).

that can transform the skeleton to different degrees (Brickley et al., 2020; Mays, 2010). Entheseal changes are a good example of these processes, as bones adapt to stress and strain, forming ridges, and crests, and experiencing age-related changes (Hawkey & Merbs, 1995; Villotte et al., 2010). These modifications occur in musculoskeletal insertion areas and are influenced by factors such as physical activity, mechanical stress, age, sex, or metabolism (Schrader, 2019).

2. Research questions and Hypothesis

This study explores two primary hypotheses:

Hypothesis 1: If tumpline use was prevalent among women in Abu Fatima, we hypothesize that individuals using tumplines for load carrying would exhibit skeletal modifications in specific areas of the body, particularly the cervical vertebrae, and the occipital and parietal bones of the skull, due to the high mechanical stress exerted on these regions. Additionally, we expect to see changes in the trapezius and other neck muscles involved in stabilizing and supporting the head during load-bearing activities. These modifications should be observable in the skeletal remains, consistent with patterns seen in other cultures where tumplines were used for load carrying.

Hypothesis 2: If there were distinct binary gendered patterns of load carrying, we anticipate differences in skeletal modifications between men and women, particularly in areas associated with specific load-carrying techniques.

These hypotheses are grounded in the cross-cultural ethnographic literature and iconographic evidence, which suggest that such body techniques were integral to the social and gender dynamics of Bronze Age Nubia.

3. Material

3.1. Archaeological context

Abu Fatima, located at the Third Cataract of the Nile River in modern Sudan, is a Bronze Age cemetery attributed to Nubian Kerma culture. It is located approximately 10 km north of Kerma, the capital city of the kingdom of Kush (Fig. 1). During the Second Intermediate Period in Egypt (approximately 1650–1550 BCE), the kingdom of Kush was a rival to ancient Egypt. However, it was eventually conquered by the Egyptians in the early New Kingdom around 1500 BCE (Budka, 2015; Morris, 2018; Spalinger, 2006). The capital in Kerma was a densely populated urban center that featured various facilities such as storage buildings, ritual structures, breweries, bakeries, and defensive walls (Bonnet, 1990; Bonnet & Valbelle, 2014). The presence of a port in Kerma facilitated trade activities, communication among people, and the movement of populations (Bonnet, 1990). Adjacent to the capital, there is a vast 90-hectare royal and commoner cemetery with approximately 40,000 graves. In the Classic Kerma phase, massive mounds, some up to 90 m in diameter, were the resting places of the Kushite rulers, officials, commoners and human sacrifices (Bonnet & Honegger, 2021; Reisner, 1923).

The excavations at the neighboring site Abu Fatima commenced in 2015 under the supervision of Sarah A. Schrader, Stuart T. Smith, and the Sudanese National Corporation for Antiquities and Museums (Schrader & Smith, 2017). The cemetery was continuously used during the Early Kerma (2500–2050 BCE), Middle Kerma (2050–1750 BCE), and Classic Kerma (1750–1500 BCE) phases of the Kerma culture. It covers an area of approximately 500 m^2, however, a significant portion of the site has suffered damage from looting and modern development. Due to its proximity to the capital in Kerma, Abu Fatima likely served as a *peri*-urban area. The community buried at Abu Fatima may have been involved in various activities such as manual labor, agropastoralism (a combination of agriculture and animal husbandry), baking, and brewing. Previous research on Bronze Age cemeteries in Nubia primarily focused on larger sites such as Kerma and Sai, as well as rural areas like the Northern Dongola Reach (Edwards, 2004; Gratien, 1998; Strouhal, 1999; Welsby, 2001). The burial practices observed at Abu Fatima resemble those found in other Nubian sites attributed to Kerma culture, including Sai and Kerma. The graves were small burial pits dug into the ground, with the deceased individuals commonly placed in these pits on a cowhide or a wooden bed in a flexed position (Fig. 2). In contrast to the cemeteries at Sai and Kerma, the burial pits and remnants of tumuli covering them in Abu Fatima were all of a similar size and the range of their grave goods was broadly consistent. The presence of ostrich-feather fans and silver beads, more valuable than gold during this period, indicates that some community members were buried with luxury goods. This probably led to looting in ancient times (Schrader & Smith, 2017).

This study examined the complete excavated sample of adult skeletal remains of 30 individuals (14 female and 16 male) buried in Abu Fatima, selected from a total of approximately 40 individuals excavated to date. Of these 40 individuals, 7 are non-adults, and a few others consist of only small fragments, making them unsuitable for analysis. Notably, almost half of the 30 individuals analyzed were missing their crania, likely due to looting in antiquity. Despite this limitation, the analysis also focused on post-cranial skeletal changes, which provide interesting insights into load-carrying practices through their impact on the vertebral column, including the potential use of tumplines or carrying heavy loads on the head.

Radiocarbon dating and ceramic seriation indicate that 21 of these individuals are from the Early Kerma phase (Units 1–4), 2 could be from Early to Middle Kerma phases (Unit 8), 2 from Middle Kerma phase (Unit 5), 1 individual possibly from Middle to Classic Kerma phases (Unit 6), and 2 individuals from Classic Kerma phase (Unit 7). Temporal comparisons could not be conducted since 70 % of the individuals are from the Old Kerma phase. The number of individuals corresponding to the other phases is insufficient for statistical testing across the four phases of the site. Although the sample is small compared to Kerma (Gratien, 1998; Strouhal, 1999: 326–327), the results from Abu Fatima allow for insights into different body techniques of load-carrying and their gender background.

4. Methods

The multi-proxy approach was utilized to examine specific body techniques of load-carrying. This involved examining 17 skeletal modifications (Table 1) associated with carrying loads, such as cranial modifications, joint changes, and musculoskeletal remodeling (Carballo-Pérez, 2023; Schrader, 2019). Therefore, entheseal changes, osteoarthritis, vertebral pathology, and unintentional cranial modifications have been included in this approach (Khudaverdyan, 2018; Lambert, 1979).

4.1. Sex and age estimation

In this paper, the adjectives “male/female” are used to refer to evidence obtained from the osteological sex estimated from the skeletons. In the discussion section, where questions related to gender are addressed, the terms “man/woman” are used (Agarwal & Wesp, 2017; Geller, 2017; Schiebinger & Klinge, 2020; Sofaer, 2006; Zuckerman, 2020). Osteological sex was determined by analyzing cranial and pelvic morphologies, following established methods. Age estimation involved standard methods focused on the closure of cranial sutures, and changes in the auricular surfaces and pubic symphysis (Buikstra & Ubelaker, 1994). Based on these observations, individuals were categorized into three age groups: 5 young adults (18–29), 12 middle-aged adults (30–45), and 13 old adults (45–60). In light of developmental and degenerative factors, it is recommended that preadult individuals and those over 60 years of age should be excluded from the analysis, as their skeletal modifications are significantly influenced by processes related to growth and aging (Mariotti et al., 2007; Santana-Cabrera, 2011;

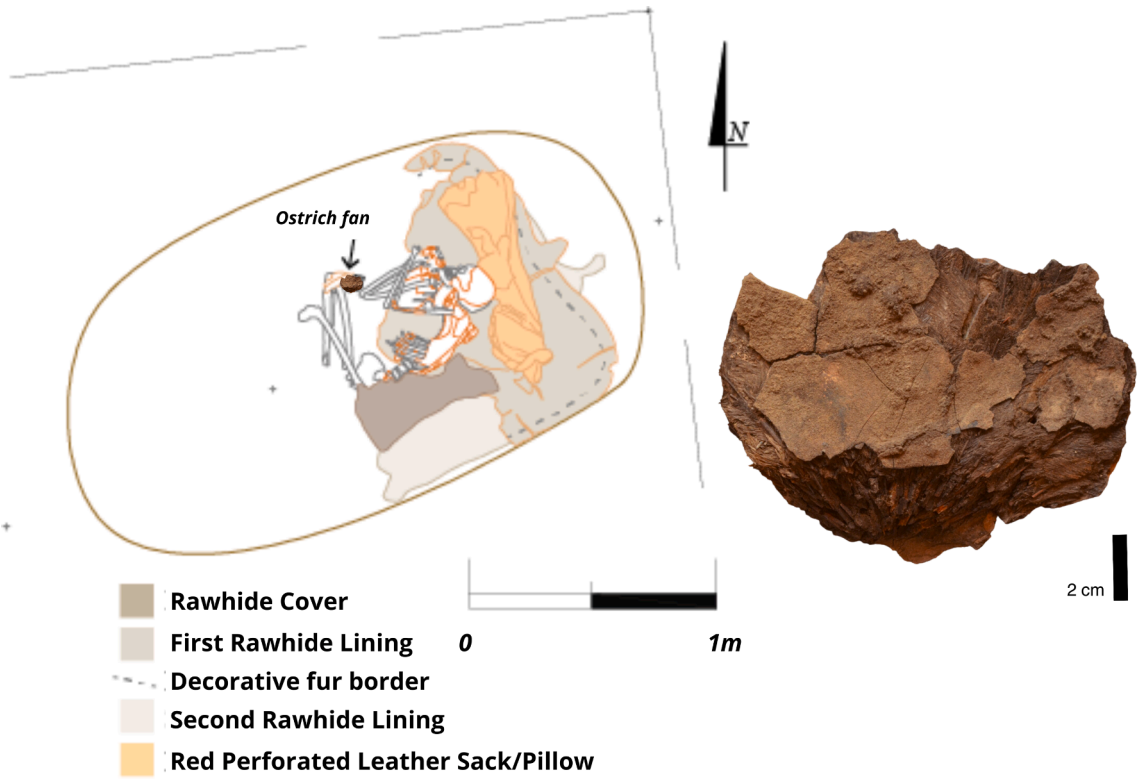

Fig. 2. Illustration of Unit 8A2, the burial of one of the female individuals included in this study, along with the photograph of the ostrich feather fan found in this tomb (redrawn by STS adapted from originals by project surveyor/architect Nadejda Reshetnikova).

TABLE 1
Skeletal modifications analyzed in the Abu Fatima sample (abbreviation and type).

Bone	Abbreviation	Marker	Abbreviation	Type of marker
Humerus	ECSB	*Subscapularis*	HUMEC	Entheseal changes
	ECIF	*Infraspinatus*		
	ECTM	*Teres major*		
	ECPM	*Pectoralis major*		
	ECLD	*Latissimus dorsi*		
	ECDT	Deltoid		
	OAHSJ	Humeroscapular joint	HUMOA	Osteoarthritis
Vertebra	VPCSN	Schmörl's nodes (cervical)	VPC	Vertebral pathology
	VPCSA	Spondyloarthritis (cervical)		
	VPTSN	Schmörl's nodes (thoracic)	VPT	
	VPTSA	Spondyloarthritis (thoracic)		
	VPLSN	Schmörl's nodes (lumbar)	VPL	
	VPLSA	Spondyloarthritis (lumbar)		
Cranium	UCDPCD	*Postcoronal depression*	UCM	Unintentional cranial modifications
	UCMTOT	*Tubercle in the occipital torus*		
	UCMRP	*Retromastoid process*		
	UCMTSM	*Tubercle in the posterior supramastoid*		

Schrader, 2019).

4.2. Entheseal changes

Entheseal changes, also known as musculoskeletal stress markers, refer to alterations in bone structure and morphology at the attachment sites of muscles, tendons, and ligaments to the skeleton. Their interpretation is complex due to factors such as age-related changes, sexual dimorphism, anatomical variations, and metabolic influences (Bakirci et al., 2020; Cardoso and Henderson, 2010; Santana-Cabrera et al., 2015; Villotte et al., 2021). Recent advancements in morphometric methods have enhanced the reliability of entheses as indicators of physical activity in ancient populations (Karakostis et al., 2019; Schrader, 2019).

Seven humeral entheses were analyzed to understand musculoskeletal attachment changes in shoulder and back muscles. Due to their clear correlations with physical activity, fibrocartilaginous entheses (Henderson, 2013) were emphasized and fibrous entheses were also included (Carballo-Pérez and Schrader, 2023; Santana-Cabrera et al., 2013). Entheses selection followed established methods, and a five-degree scale for evaluation was used (Galtés & Malgosa, 2007; Hawkey and Merbs, 1995; Mariotti et al., 2007; Santana-Cabrera et al., 2013) (Fig. 3a).

4.3. Osteoarthritis

Osteoarthritis is a common condition characterized by the deterioration of soft tissues and bone structures in and around joints. Both clinical and anthropological research have discussed the factors that influence its appearance, such as physically strenuous labor, age, and body size (Becker, 2020; Busija et al., 2010; Larsen, 2015; Wallace et al., 2022).

Osteoarthritis in the humeroscapular joint was analyzed to understand the influence of carrying heavy loads on the shoulder. A grading

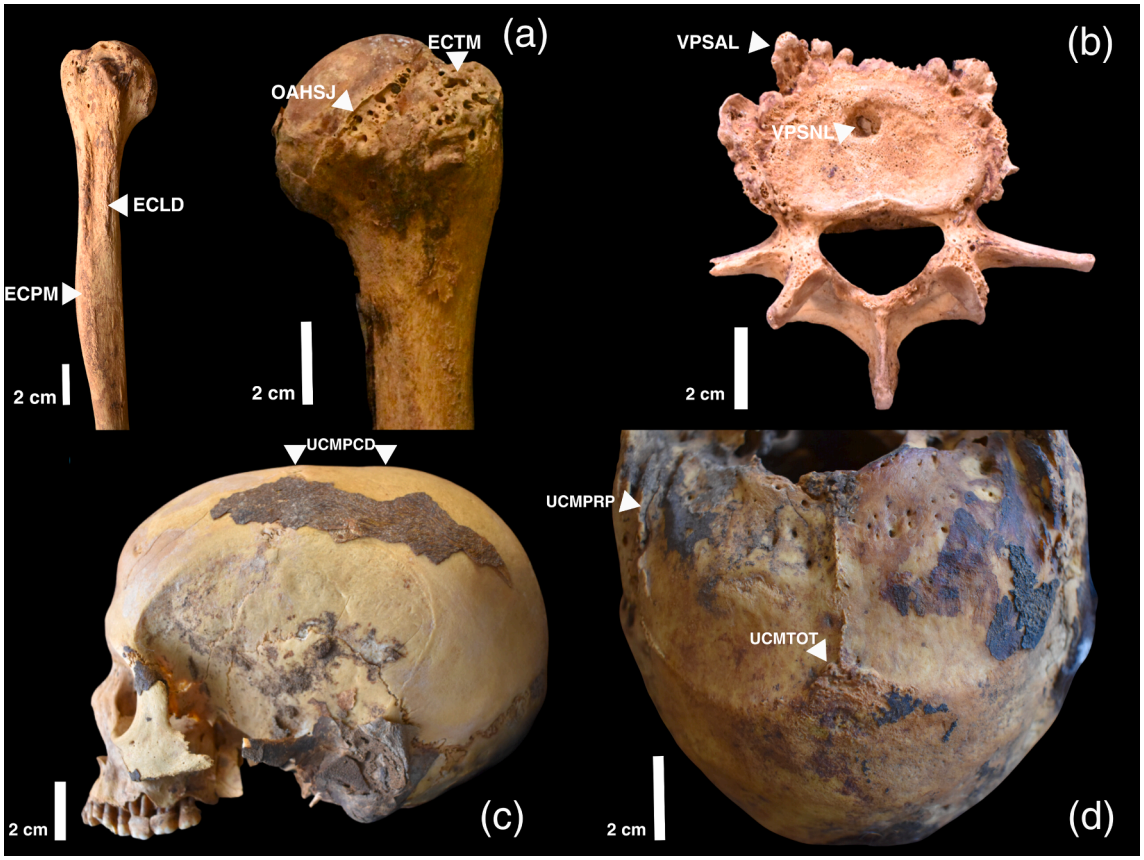

Fig. 3. Examples of different localized bone modifications in the Abu Fatima sample: Humerus of Individual 9A1, a mature adult male, showing pathological enthesal changes in the insertion of the *latissimus dorsi* (ECLD) and *teres major* (ECTM) with moderate changes in the *pectoralis major* (ECPM), and medium-grade humeroscapular joint osteoarthritis with lipping (OAHSJ) (a); Lumbar vertebra 4 of Individual 1F1, a middle-aged adult woman, exhibiting a Schmörl's node (VPSNL) and high-grade spondyloarthritis (VPSAL) (b); Cranium of Individual 8A2, a mature adult woman, displaying a postcoronal depression (UCMPCD) (c); and the cranium of Individual 7E1, a young adult male, with pronounced signs of bone remodeling in the retromastoid process (UCMRP) and the tubercle of the occipital torus (UCMTOT) (d).

system consisting of five levels was employed for evaluating changes, which considered visual and tactile criteria. Grade 0 indicates an absence of expression, with smooth joint surfaces and unaltered edges. Grade 1 signifies incipient expression, where mild discontinuities emerge tactically while edges remain unchanged. Progressing to Grade 2, moderate robust expression manifests with visually discernible surface discontinuities forming slight protrusions, next to developing margins resembling labiations. Grade 3 denotes significant robust expression, showcasing a spectrum of degenerative signs including well-defined protrusions, varying-sized porosities, and more developed labiations along the edges, presenting a robust joint appearance. Finally, Grade 4 represents pathological expression, with additional osteophytes on joint edges and surface polishing from eburnation due to direct bone-to-bone friction in cases of extreme wear, without cartilage protection (Fig. 3a). Established standards along with recent research informed these assessments (Becker & Goldstein, 2017; Buikstra & Ubelaker, 1994; Campillo, 2001; Carballo-Pérez & Jiménez-Brobeil, 2020; Cheverko & Bartelink, 2017; Rogers & Waldron, 1995).

4.4. Degenerative changes of the vertebrae

Degenerative changes in the vertebral column have also been examined; although they are closely linked to osteoarthritic processes, intervertebral joints are cartilaginous and, thus, differ from the other synovial joints systems (Roberts & Manchester, 2007). The prevalence of osteophytosis and spondyloarthritis in spinal vertebrae is often attributed to changes in force distribution (Bridges, 1994; Jurmain & Kilgore, 1995). A five-level grading system has been utilized to assess morphological alterations in the vertebral surface, including porosities and osteophytic lipping, with an adapted evaluation scale of five degrees (0–4). The grading system considers visual and tactile criteria such as porosities, which refer to varying-sized pores or openings in the bone surface, or osteophytic lipping, which involves the formation of bony outgrowths or protuberances at the joint margins (Carballo-Pérez & Jiménez-Brobeil, 2020; González-Reimers et al., 2021) (Fig. 3b).

Additionally, the presence of Schmorl's nodes, which are commonly associated with prolonged excessive strain, minor injuries, heritable conditions, and metabolic factors (González-Reimers et al., 2021), were assessed in conjunction with vertical herniations of the nucleus pulposus within vertebral bodies. A grading system consisting of five levels was utilized to assess these conditions, following the methodology described in Knüsel et al. (1997) and Pfirmann and Resnick (2001) (Fig. 3b).

4.5. Unintentional cranial modifications

The postcoronal depression manifests as a concavity of the coronal plane, situated posterior to the coronal suture. Prior studies have suggested a link between this morphological change and the use of tumplines for load carrying across the parietal bones (Khudaverdyan, 2016; Lambert, 1979; Molleson, 2007: 52) (Fig. 3c). The analysis included examination of variations in the occipital and temporal bone, including the external occipital protuberance and occipital torus, as well as other cranial structures, potentially associated mechanical factors and muscle attachments. The prominence of the occipital torus is correlated with the

increased trapezius muscle function, which plays a significant role in scapula stability during object carrying. Furthermore, the involvement of muscles like the oblique capitis superior, responsible for head movement and posture, can be observed through the examination of the retromastoid processes. These structures are located where the superior oblique muscles insert, specifically below the inferior nuchal line and lateral to the rectus capitis muscles and are distinct from the mastoid processes found on the temporal bone (Bowden & Bosden, 2005; Hamill & Knutzen, 1995; Heathcote et al., 2014).

The presence/absence of post-coronal depressions were recorded following descriptions in previous studies (Khudaverdyan, 2018; Lambert, 1979). The methods also included a comparative analysis of varying tumpline positions, examining morphological changes across different regions, including the frontal and coronal sutures. This ensured consideration of cultural and practical variations in band placement, enhancing the robustness of the suggested interpretations. Changes in the occipital torus and retromastoid processes were graded using Heathcote and colleagues' (1996) 0–4 scale (Fig. 3d).

4.6. Statistical analysis

The primary aim of the conducted statistical analysis was to compare groups with unknown data distributions. Non-parametric techniques are recommended by Auerbach (2018) as the most suitable methodology, and supported by previous studies (Cardoso & Henderson, 2010; Refai, 2019). Firstly, the Mann-Whitney *U* test was conducted to assess heterogeneity between groups based on osteological sex and laterality. Additionally, the Kruskal-Wallis H test was conducted to explore age group differences. Even though this is not the most conventional approach for ordinal data, this study follows the analytical procedures of prior research (e.g., Carballo-Pérez & Schrader, 2023; Santana-Cabrera et al., 2015; Villotte et al., 2010) and summarizes the results using mean values. Lastly, bilateral asymmetry coefficients [(Xr − Xl)/100] and the MDI parameter [(Xm − Xf)/100] were employed to provide clearer visualizations of differences in robustness across sex and laterality groups (Eshed et al., 2004; Refai, 2019).

5. Results

The results of the Mann-Whitney test showed no significant differences between the individuals assessed as osteologically female or male groups across the 17 skeletal markers analyzed (Table 2). Post-coronal modifications ($U(n_F = 3, n_M = 10) = 7.00$; $z = -1.50$; $p = 0.13$), cervical spondyloarthritis ($U(n_F = 11, n_M = 12) = 66.00$; $z = -1.42$; $p = 0.15$), and supramastoid torus modifications ($U(n_F = 3, n_M = 7) = 6.00$; $z = 1.28$; $p = 0.19$) did not exhibit statistically significant differences according to the Mann-Whitney test, although there are certain trends and variations in average values per sex group. Therefore, the results indicate subtle yet interesting differences in the occurrence and variability of bone alterations (Fig. 3) within the analyzed population subsets. Figs. 4, 5, and 6 present the data on entheseal changes with combined lateralities, while Fig. 7 shows the bilateral asymmetry coefficients resulting from their comparison. It could be observed that 58.82 % of the markers display higher values among female individuals, while the remaining 41.18 % are concentrated in the male group. When comparing the averages of both groups, it is evident that there are relatively lower values of bone remodeling in the male group ($\bar{x} = 1.10$) compared to the female group ($\bar{x} = 1.21$).

The sexual dimorphism coefficients (%MDI) corroborate these data, demonstrating a total average value tending towards the female group ($\bar{x}$ = -0.0011; σ = 0.88)). In this context, the average coefficients according to marker type (Fig. 4) indicate that the highest values of entheseal changes ($\bar{x}$ = 0.0027; σ = 0.99) and osteoarthritis in the proximal humerus area ($\bar{x}$ = 0.0019; σ = 0.97) are found in the male group. Conversely, those related to vertebral pathology in the cervical ($\bar{x} = -0.0046$; σ = 0.85), thoracic ($\bar{x}$ = -0.0019; σ = 1.13), and lumbar areas ($\bar{x}$ = -0.0016; σ = 0.94), as well as unintentional cranial modifications ($\bar{x} = -0.0051$; σ = 0,56), suggest that their highest values tend towards female individuals.

Regarding the standard deviation for sex-estimated groups, the total average indicates an apparent balance in the distribution of values between the female (σ = 0.88) and male (σ = 0.84) groups. However, focusing on the comparison of values according to skeletal marker type (Fig. 8), there is a slightly higher deviation in entheseal changes (σ = 0.99), humeral osteoarthritis (σ = 0.97), lumbar pathology (σ = 1.10), and cranial modifications (σ = 0.65) among male individuals. On the other hand, standard deviation values for cervical (σ = 0.85) and thoracic (σ = 1.13) pathological changes are much higher among female individuals.

The Kruskal-Wallis test did not reveal any statistically significant differences in the occurrence and variability of bone alterations among different age groups (Table 3). It is worth mentioning that there were some differences observed in the retromastoid processes ($H(n_Y = 3, n_M = 3, n_{O=}4) = 0.07$; $p = 0.12$), latissimus dorsi muscle ($H(n_Y = 8, n_M = 11, n_{O=}17) = 2.90$; $p = 0.30$), and deltoid muscle ($H(n_Y = 7, n_M = 15, n_{O=}18) = 3.10$; $p = 0.34$). Overall, the average values suggest that old

TABLE 2
Results of the skeletal markers for the Abu Fatima sample classified by sex and p-values for significant differences (Mann-Whitney test).

	Female			Male			MDI%	Mann-Whitney test		
	n	**Mean**	***S***	***n***	**Mean**	***S***		***U***	***Z***	***p***
ECSB	16	1.37	0.87	22	1.97	1.06	0.0060	36.25	−1.103	0.42
ECIF	16	2.03	1.51	20	1.79	1.24	−0.0024	30.75	−0.890	0.40
ECTM	20	1.34	0.81	21	1.50	1.04	0.0017	50.75	−0.458	0.64
ECPM	19	1.80	0.84	23	2.04	0.77	0.0023	48.00	−0.710	0.49
ECLD	17	0.70	0.69	21	1.51	1.16	0.0081	35.75	−1.336	0.33
ECDT	21	1.39	1.02	21	1.46	0.71	0.0007	56.50	−0.173	0.86
OAHSJ	17	1.41	0.53	20	1.61	0.97	0.0019	36.25	−0.631	0.52
VPCSN	11	0.00	0.000	13	0.08	0.277	0.0008	66.00	−0.920	0.35
VPTSN	13	0.62	1.261	13	0.54	1.198	−0.0008	83.50	−0.070	0.94
VPLSN	12	0.42	0.900	13	0.38	0.870	−0.0003	76.50	−0.109	0.91
VPCSA	11	1.91	1.700	12	0.92	0.996	−0.0099	44.00	−1.421	0.15
VPTSA	13	1.00	1.000	13	0.69	0.751	−0.0031	71.00	−0.739	0.46
VPLSA	12	1.67	0.985	13	1.38	1.325	−0.0028	69.00	−0.508	0.61
UCMPCD	3	1.33	1.155	10	0.40	0.516	−0.0093	7.00	−1.497	0.13
UCMTOT	4	1.25	0.500	10	1.00	0.816	−0.0025	16.50	−0.538	0.59
UCMRP	3	1.33	0.577	10	0.90	0.738	−0.0043	10.00	−0.931	0.35
UCMTSM	3	1.00	0.000	7	0.57	0.535	−0.0043	6.00	−1.286	0.19
TOTAL		**1.21**	**0.840**		**1.10**	**0.880**	**−0.0011**			

n = number/*S* = standard deviation/*p* = p-value/MDI%= sexual dimorphism coefficient.

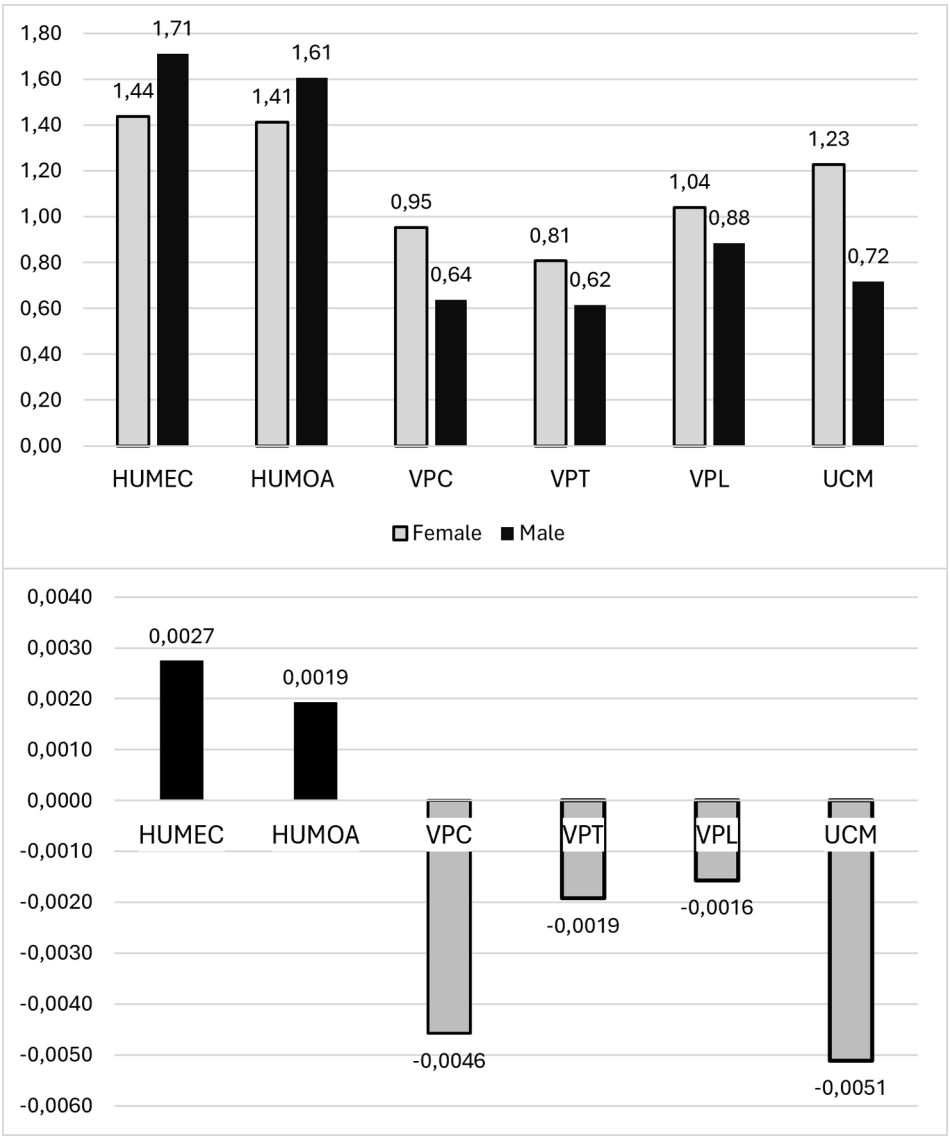

Fig. 4. Compared results of average values of each skeletal modification type between sex groups (above), and the sexual dimorphism values in the Abu Fatima sample, organized by modification type (below). Abbrevia: HUMEC = Humeral Entheseal Changes; HUMOA = Humeral Osteoarthritis; VPC = Vertebral Pathology Cervical; VPT = Vertebral Pathology Thoracic; VPL = Vertebral Pathology Lumbar; UMC = Unintentional Cranial Modifications.

adults have the highest values ($\bar{x} = 1.28$), while middle-aged adults ($\bar{x} = 1.17$) exhibit higher ranges compared to young adults ($\bar{x} = 0.72$). This trend is also evident when comparing average values based on marker type, particularly for pathological conditions of the cervical spine and unintentional cranial modifications (Fig. 6).

In analyzing the bilateral asymmetry coefficients by osteological sex and age (Fig. 7) in adequately sized groups (excluding the 5 young adults due to sample insufficiency), it is interesting to note that female individuals maintain low values of right lateral asymmetry both in the middle-aged adult group ($\bar{x} = 0.0026$) and in the old adult group ($\bar{x} = 0.0030$). However, among male individuals, a change can be observed from middle-aged adults with right asymmetry ($\bar{x} = 0.0036$) to old adults with left lateral asymmetry ($\bar{x} = -0.0036$).

6. Discussion

The results of this study provide valuable insights into the gendered aspects of load-carrying practices and their impact on the skeletal remains of the Bronze Age Nubian population buried in Abu Fatima. It is possible that certain body techniques for carrying heavy loads could have influenced the distribution and severity of bone modifications. Although statistical significance was not achieved in the non-parametric tests, their absence does not negate the possibility of differences. Recent discussions on statistical significance warn against overreliance on these values and recommend interpreting data within a broader spectrum of potential explanations (Armhein et al., 2019; Wasserstein et al., 2019). Factors such as the evidence background, limitations of statistical significance tests, sample size, and the complexity of skeletal variation could outweigh statistical measures like *p*-values.

In this context, the evidence supports Hypothesis 1, as the observed osseous changes in the cervical vertebrae and cranial structures among females suggest the use of tumplines, consistent with patterns seen in other cultures. Similarly, Hypothesis 2 is validated by the distinct differences in skeletal modifications between males and females, indicating gendered differences in load-carrying techniques. These results align with broader cross-cultural evidence and enhance our understanding of the gendered division of labor in Bronze Age Nubia.

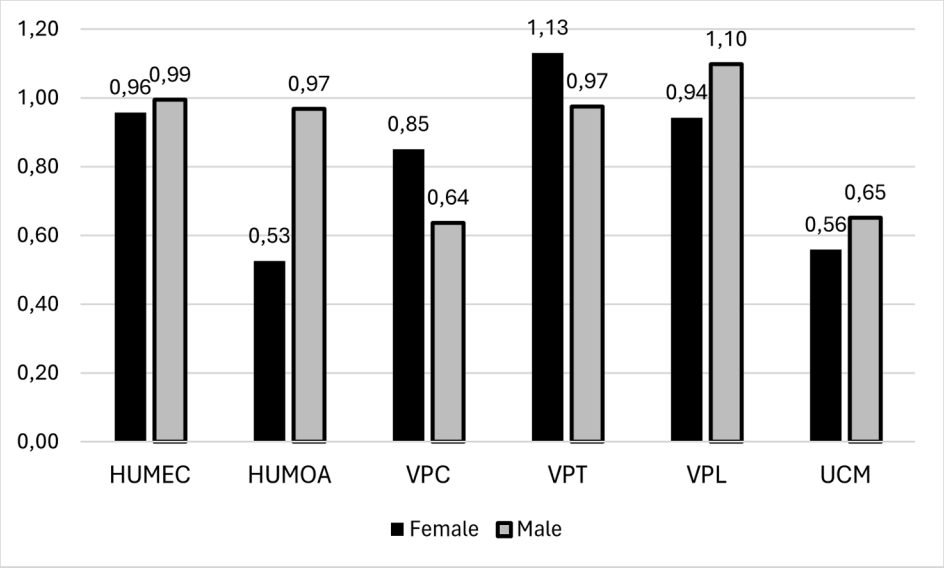

Fig. 5. Compared results of the standard deviation averages from each type of skeletal modification, organized by sex groups. Abbrevia: HUMEC = Humeral Entheseal Changes; HUMOA = Humeral Osteoarthritis; VPC = Vertebral Pathology Cervical; VPT = Vertebral Pathology Thoracic; VPL = Vertebral Pathology Lumbar; UMC = Unintentional Cranial Modifications.

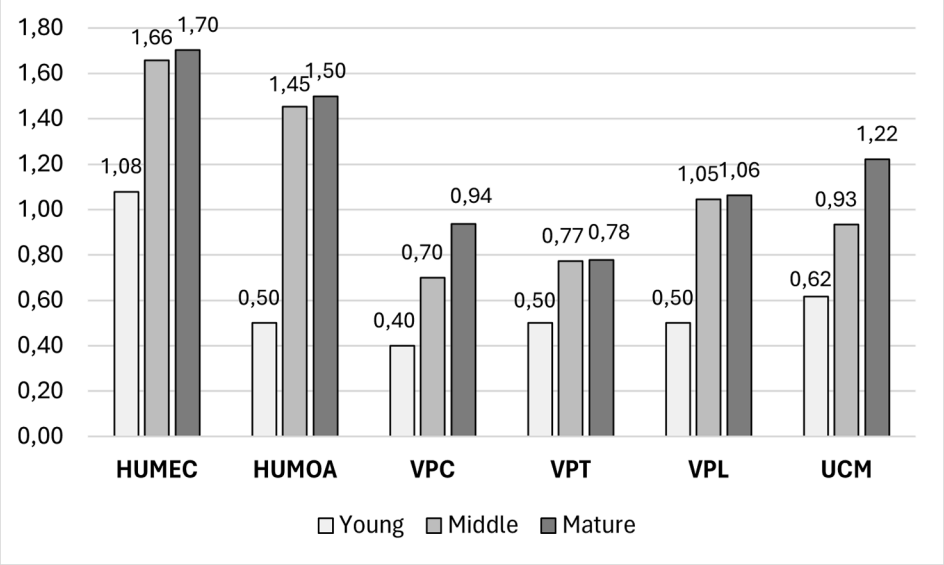

Fig. 6. Compared results of the skeletal modifications averages sorted by age groups in the Abu Fatima sample. Abbrevia: HUMEC = Humeral Entheseal Changes; HUMOA = Humeral Osteoarthritis; VPC = Vertebral Pathology Cervical; VPT = Vertebral Pathology Thoracic; VPL = Vertebral Pathology Lumbar; UMC = Unintentional Cranial Modifications.

6.1. Getting older: age as a biocultural factor

Age is a significant factor considered in the conducted analysis, and it has a crucial impact on physical activity due to its influence on growth and degeneration processes. Furthermore, age differences can signify cultural behaviors associated with social age (Milella et al., 2012; Prout, 2000; Yonemoto, 2016). There is a noticeable pattern of increased bone remodeling with advancing age. However, even individuals up to the age of 21 exhibit moderate levels of intensity in their shoulder muscles. This could be attributed to the physical learning processes that occur in child populations as they transition into adulthood, which aligns with observations made in numerous pre-industrial societies (Janssen & Janssen, 2007; Plummer et al., 2007). Nonetheless, exponential growth can be observed in the occurrence of higher degrees of bone modifications from young adults to old adults, especially among middle-aged adults.

Extensive research has been conducted on the correlation between age and entheseal remodeling (e.g., Milella et al., 2012; Villotte et al., 2010; Villotte et al., 2021; Yonemoto, 2016). Osteological and clinical data have shown that excessive mechanical stress can cause bone responses in fibrocartilaginous entheses of young individuals. Nevertheless, due to the fibrocartilaginous nature of some of the attachments, they are more susceptible to being affected by degenerative processes, so pathological signs could become more common from the age of 40 due to the gradual limitation of bone tissue regeneration (Benjamin et al., 2006). After the sixth decade of life, the physical properties of the enthesis organ deteriorate due to reduced vascularization of tendons, leading to the formation of calcifications and erosions (Villotte &

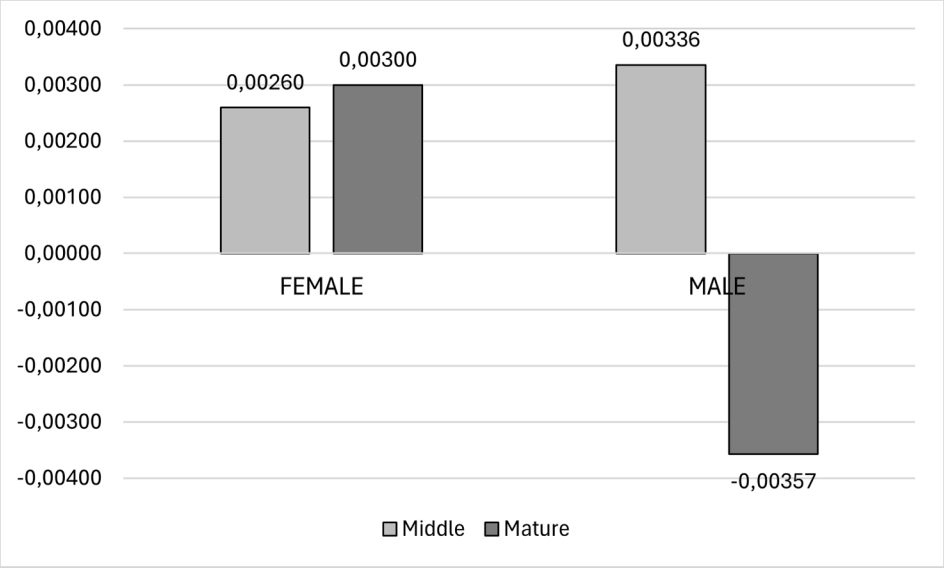

Fig. 7. Compared results of average bilateral asymmetry values between sex groups, organized by age groups with sufficient case counts (juvenile group excluded).

Fig. 8. Ojibwe woman carrying a child with the help of a tumpline (The Canadian Encyclopedia) (a); Kikuyu women carrying firewood with the help of tumplines (Visual Photos) (b & c).

Knüsel, 2013).

However, the presence of elderly individuals in Abu Fatima is very low, and the effect of degenerative variables does not seem to be significant in the transition from middle-aged to old adults. Thus, the overall exponential growth in bone modifications appears to be explained by a combination of mechanical and cumulative factors, particularly in the transition from young to middle-aged adults. On the other hand, the results of bilateral asymmetry suggest age differences between men and women in Abu Fatima. While women seem to maintain consistent activity patterns throughout their lives, reflected in relatively constant limb asymmetry, old adult men show a noticeable shift towards increased left-sided laterality. This might indicate an adaptation in the daily activities of old adult men, possibly involving heightened engagement or effort in using the left limb for specific tasks

TABLE 3
Results of the skeletal markers from the Abu Fatima sample classified by age and p-values for significant differences (Kruskal-Wallis' test).

	Young			Middle			Old			Kruskal-Wallis test	
	n	**M**	***S***	***n***	**M**	***S***	***n***	**M**	***S***	**H**	***p***
ECSB	8	1.13	0.25	12	2.00	0.79	16	1.69	1.28	3.181	0.48
ECIF	7	1.25	1.15	10	2.57	1.60	17	1.76	1.30	1.752	0.49
ECTM	9	0.90	0.80	13	1.30	0.70	17	1.83	0.94	4.553	0.36
ECPM	9	1.55	0.74	14	2.17	1.08	17	1.94	0.66	1.584	0.50
ECLD	8	0.75	0.70	11	0.56	0.39	17	1.38	1.20	2.904	0.30
ECDT	7	0.90	0.22	15	1.36	0.86	18	1.61	0.92	3.105	0.34
OAHSJ	8	0.50	1.29	10	1.45	0.56	18	1.50	0.71	0.396	0.82
VPCSN	5	0.00	0.00	10	0.10	0.32	8	0.00	0.00	1.300	0.52
VPTSN	4	0.50	1.00	11	0.55	1.29	9	0.78	1.39	0.426	0.81
VPLSN	4	0.25	0.50	11	0.45	0.93	8	0.38	1.06	0.420	0.81
VPCSA	5	0.80	0.83	10	1.30	1.57	8	1.88	1.55	1.633	0.44
VPTSA	4	0.50	0.57	11	1.00	1.09	9	0.78	0.83	0.561	0.75
VPLSA	4	0.75	1.50	11	1.64	1.21	8	1.75	1.03	1.739	0.42
UCDPCD	4	0.25	0.50	5	0.60	0.89	4	1.00	0.82	2.006	0.37
UCDTOT	5	1.00	0.70	5	1.20	0.84	4	1.00	0.82	0.257	0.88
UCDRP	5	0.60	0.54	5	1.00	0.71	3	1.67	0.57	4.267	0.12
UCDTSM	3	0.67	0.57	3	0.67	0.58	4	0.75	0.50	0.071	0.96
TOTAL		**0.72**	**0.70**		**1.17**	**0.91**		**1.28**	**0.92**		

n = number/*S* = standard deviation/*p* = p-value/MDI%= sexual dimorphism coefficient.

as they age. Additionally, this shift could be a consequence of cumulative wear and tear on the right side, particularly in the shoulder region, which may lead to a compensatory shift in load-bearing activities to the left side. A priori, this difference in bilateral asymmetry could hint at changes in work practices or requirements for men transitioning into old adulthood in Abu Fatima. However, these variations may also result from a bias caused by the limited sample size in specific age and sex groups. For example, only 1 middle-aged adult man and 4 old adult men have humeri from both sides, so special caution is needed in assessing these age variations in the male group. Therefore, the data from a better-represented female group are more consistent with previous research on Bronze Age Nubia, which indicates that these populations maintained consistent work patterns throughout their lives, with no drastic changes observed in the transition from middle to old adulthood (Carballo-Pérez, 2023; Martin, 2015). Furthermore, we should note that these changes are unlikely to be caused by temporal factors. As previously explained, 70 % of the sample corresponds to the Old Kerma phase, with only one middle-aged male adult from the Middle Kerma phase and one young adult male from the Classic Kerma phase.

Behavioral changes have traditionally been explored through patterns of bilateral asymmetry in the upper extremities, as they reflect the ways of manipulating and processing objects (Lieverse et al., 2009; Sládek et al., 2007). Studies examining bilateral asymmetry in upper extremities consistently show a preference towards right-sided laterality, linked with early brain development (Ledger et al., 2000; White et al., 1994). Despite manual activities potentially affecting both arms (Bridges, 1991), analyses of extremity changes in Nile Valley populations indicate symmetry, suggesting diverse engagement of both limbs (Carballo-Pérez, 2023; Refai, 2019). For example, previous analyses of entheseal changes in the upper extremities revealed relative symmetry, indicating that presumed agricultural tasks involved both limbs (Eshed et al., 2004; Santana-Cabrera, 2011), as observed also among the women of different ages from Abu Fatima. In this sense, other coefficients observed in the geometric properties of long bones from previous studies also suggest that specific unilateral tasks had a significant impact, particularly in men who engaged in more unilateral activities with the dominant right arm, whereas women could have performed more varied, bilateral tasks (Sládek et al., 2007).

6.2. Head and shoulders: engendered load-carrying techniques?

Muscular changes identified in seven back and shoulder muscles, along with the presence of humeroscapular osteoarthritis among the men from Abu Fatima, suggest a pattern associated with activities demanding substantial shoulder use. These activities potentially involve tasks like heavy load carrying or intense physical labor. Additionally, the data suggests a relatively broader range of biomechanical profiles in this body area among men. This pattern echoes findings observed in other regions, including communities within ancient Egypt and the kingdom of Kush (Carballo-Pérez & Schrader, 2023; Martin, 2015; Refai, 2019; Zabecki, 2009).

The results on vertebral pathological conditions and unintentional cranial modifications suggest that women endured greater loads on the spinal column and head compared to men, possibly indicating a higher involvement in load-bearing and transportation activities. It is worth noting that hormonal mechanisms of bone resorption in males tend to result in increased muscle mass during adolescence (Cureton et al., 1988). However, the higher physical demands on women may lead to earlier muscle development compared to men if they are performing more intense activities, suggesting a specific difference in the bodily response to physical strain (Sofaer-Derevenski, 2000).

Thus, the data suggests that women from Abu Fatima bore more loads in their spinal column, especially in the cervical region, although the thoracic and lumbar regions appear somewhat more balanced, albeit with slightly more skeletal changes observed in women. Furthermore, women exhibit a higher diversity in vertebral wear profiles in the cervical and thoracic regions, suggesting potential variations with tasks involving the carrying of objects and possibly children, likely using head support. A similar pattern of mechanical load distribution in the spine has been observed in two populations from the Northern Dongola Reach cemeteries (O16 and P37; Fig. 4), however demonstrating that men exhibited a greater impact in the thoracic area than in the lumbar region (Carballo-Pérez, 2023). Nonetheless, it is evident that women from both Abu Fatima and Northern Dongola Reach predominantly experienced consistent loads in the cervical region. How these practices might have been performed will be suggested based on cranial, pictorial, and ethnographic evidence.

The evidence of pathological conditions in the vertebrae could be linked to unintentional cranial modifications. In particular, a correlation between postcoronal changes and bone remodeling at nuchal muscle insertions was slightly more prominent in preserved crania of women from Abu Fatima. This observed pattern aligns with findings from Bronze and Iron Age Armenian communities, where such cranial modifications were more prevalent in women and were interpreted as evidence for the use of tumplines or headbands (Khudaverdyan, 2018; Khudaverdyan et al., 2019).

The use of tumplines for carrying heavy loads is a widespread practice that results in prolonged high mechanical stress on specific areas of the body (Denbow, 2013; Heathcote et al., 2014; Maloiy et al., 1986; Steen & Lane, 1998). The word tump is of Algonquin origin and was used to describe both chest and forehead straps (Prentice, 1986: 241). Tumplines effectively shift loads to a stronger point on the body's frame, allowing for the carrying of greater loads. There is abundant cross-cultural ethnographic and historic evidence of tumpline usage among the Kaibab Paiute Indians of northern Arizona (Bright, 1992, 810), Indige communities in California and the Great Basin (Tulloch, 1999: 151; Wilde & Tasa, 1991), Wyandot Indians (Tooker, 1991: 59), the Lenape, Timicuan Indians of Florida (Prentice, 1986: 241), Haudenosaunee women (Prentice, 1986: 241), ancient Mesoamericans (Prentice, 1986: 241), the Yucatan Mayan traders (Ardren & Lowry, 2011; Hammond et al., 1979), the modern Mexican community of San Cristóbal de las Casas (Ruta, 2001: 117) and the Ojibwe (Fig. 8a). According to ethnographic observations, transport using tumplines in Guatemala limits the carried weight to 38-40 kg (Reina & Hill, 1978: 208).

Tumplines are also observed in Africa (Lagercrantz, 1950: 241–246). In southern Congo, women from Loubomo employed woven baskets and tumplines during foraging activities, attaching significant cultural and gendered identity to these objects. For them, tumpline baskets symbolized women's daily struggles and work, holding more aesthetic value than those made for tourists (Denbow, 2013: 13). Examples from the Kikuyu tribe of Eastern Africa (Fig. 8) illustrate that women used tumplines for carrying heavy loads. These women demonstrated the capacity to carry up to 20 % of their body weight without incurring significant energetic costs, thanks to their learned techniques of tumpline usage, which nevertheless caused anatomical changes (Maloiy et al., 1986: 668–669).

6.3. Tumplines in ancient Nubia: iconographic evidence

At present, there are no known visual representations of women using tumplines for carrying loads from Bronze Age Nubia. However, it should be stressed that there is a general low number of human representations in Bronze Age Nubia. Although Nubian women have been depicted in ancient Egyptian iconography since the Middle Kingdom, the representations of this period do not depict them with tumplines. Middle Kingdom images depict women of Nubian descent, who are shown either as household servants or as wives of Egyptian pharaohs (e.g., Mentuhotep II of 11th Dynasty, ca. 2060–2010 BCE). In fact, they are dressed as Egyptian women in these depictions (Liszka, 2018).

In New Kingdom Egyptian iconography (ca. 1550–1077 BCE), slightly later than the latest graves of Abu Fatima cemetery (ca. 1700–1550 BCE), imprisoned Nubian women were often depicted carrying one to two children in baskets, aided by a tumpline for support (Fig. 9a-b). The forehead straps would be attached to the basket and placed over the top of the head. This is supported by various depictions of Nubian women found in tribute scenes from 18th Dynasty Theban tombs, such as the tomb of Rekhmire (TT 100) from the reign of Thutmose III-Amenhotep II and the tomb of Huy (TT 40) from the reign of Tutankhamun, as well as several other New Kingdom tombs (Hallmann, 2006; Matić, 2015) (Fig. 9a). It is crucial to emphasize the context of these representations. The tribute scenes depict idealized

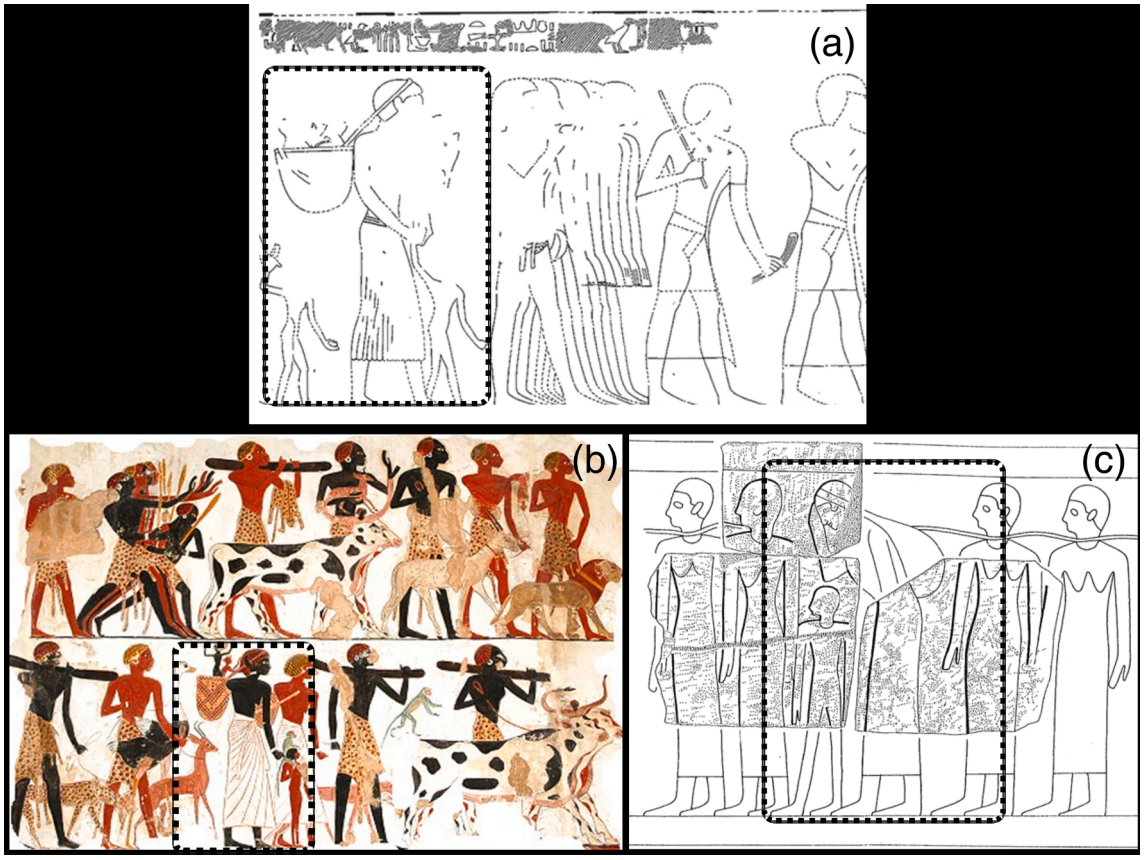

Fig. 9. Nubian women depicted carrying children on the baskets on their back with the help of a tumpline, tomb of Rekhmire (TT 100), Thebes, 18th Dynasty (redrawn after Davies & Davies, 1943: Plates XXI, XXII; XXIII) (a); Nubian woman depicted carrying children on the basket on her back with the help of a tumpline, plaster cast of a relief from Beit el-Wali temple of Ramesses II, British Museum (redrawn after, https://www.flickr.com/photos/menesje/12567512035) (b); Relief blocks (fragments 943 + 185 + 180 and 222) of the south wall of temple M250 in ancient Meroe (1st century CE) with fragmented depictions of imprisoned women and children, line drawing (redrawn after Hinkel, 2001: C11) (c).

representations of annual court events where the pharaoh would receive emissaries from various regions such as the Aegean, the Levant, Nubia, and Punt. Thus, not only were the processions of foreigners during these events ideologically structured by the strict Egyptian court procedures but the images themselves were supposed to present the events as they should have occurred (Matić, 2012; Smith, 2017). Thus, tribute scenes do not provide a complete depiction of all body techniques of load carrying that may have been present in Nubia. Instead, they provide a perspective that is slanted by strict court procedures and their manipulated representations. In such a context, foreigners are supposed to look a certain way to meet the expectations of the observers. When it comes to Nubian women depicted using tumplines in these scenes, they are labeled in accompanying texts as spoils of war (Matić, 2017). Nubian women dressed as Egyptian elite are also known in such scenes, such as the tribute scene from the tomb of Huy (TT 40). However, they are accompanying Hekanefer, the Nubian prince of Miam, himself also being an official in Egyptian service (Matić, 2020; Pemler, 2018). These elite Nubian women differ from enslaved Nubian women brought by Hekanefer and his entourage to the Egyptian pharaoh. Enslaved Nubian women are depicted in traditional Nubian skirts made of leather, upper body nude, and adorned with bead necklaces. Such depictions are known in Egypt in the Middle Kingdom but are also known from Kerma, where a burial of a woman dressed in this manner was found in subsidiary grave K1053 of royal tumulus KX (Minor, 2018), and at Abu Fatima, where a particularly well-preserved example of this dress style was found in situ on an individual labeled as 4D, who is included in the analytical sample for this study. Thus, the imprisoned Nubian women in New Kingdom Egyptian iconography are depicted in traditional Nubian dress which is attested in both Egyptian and Nubian iconography and archaeological record since the early second millennium BCE. Consequently, the use of tumplines by imprisoned Nubian women to carry baskets with children, can be interpreted as a traditional Nubian body technique for load carrying, since neither Egyptian nor Levantine women are depicted using tumplines.

Interestingly, the same method of carrying children is depicted approximately 1500 years later on the walls of temple M250 in Meroe, where imprisoned Nubian women are shown using tumplines (Fig. 9c), the capital city of the Meroitic kingdom in Sudan. These representations are dated to the reign of Akinidad who ruled in the 1st century CE (Matić, 2023: 105-112). This might be a stock scene or a motif that was copied over centuries, starting from New Kingdom Egyptian temples and extending to Napatan and eventually Meroitic temples. Namely, the first millennium BCE Kushite rulers of the Napatan period and 25th Dynasty built their temples on the sites of existing temples built during the New Kingdom in Nubia. They drew inspiration from existing iconography. Similarly, the successor kingdom of Meroe drew inspiration from Napatan period temples. However, the representations of Nubian women using tumplines in Meroitic temple M250, could also reflect a long-standing tradition. It is important to stress that Nubian men are never depicted using tumplines, neither in ancient Egyptian nor in Meroitic iconography. Therefore, iconographic evidence indicates a gendered pattern behind the use of tumplines in Nubia, just as the bio-archaeological evidence from Abu Fatima presented in this paper.

Nubian women are sometimes depicted carrying two children in their baskets supported by tumplines (see Hallmann, 2006). This observation is crucial from an osteological perspective. Carrying a single child or two children in a basket with a tumpline, at least until they can walk, might not be sufficient to cause significant body modifications. However, if these women simultaneously carried additional loads alongside the children, the total weight they bore could have been heavier. For anatomic changes to leave traces on the bones, an extended period of near constant carrying would be required. As an example, we point to the osteobiography (Robb et al., 2019) of an individual labeled 8A2 in Abu Fatima cemetery, a woman more than 50 years old who was buried in a grave dated between the Early and the Middle Kerma phases. Her burial was consistent with Kerman practice, but more elaborate than most of her contemporaries. She was placed upon not one but two carefully prepared hides, one with a fur border and a third covering the burial. She was also provided with an ostrich feather fan and a likely pillow of finely crafted perforated leather filled with plant material, a feature that also appears at Kerma (Fig. 2). Her case provides clear evidence of cranial and cervical modifications related to tumpline use. She exhibits pathological evidence of porosities and labiations developed from spondyloarthritis in the cervical vertebrae, as well as elevated modifications in postcoronal deformations, tubercles on the occipital torus, and in the retromastoid processes. These changes could be attributed to the early effects of degenerative aging, but more significantly, to the cumulative loads from carrying heavy items from the forehead to the back. Strontium isotopes analysis suggests that she was a non-local individual, perhaps from the Second Cataract, which is approximately 270 km downstream from Abu Fatima. The presence of non-local individuals in Abu Fatima, including six others with non-local 87Sr/86Sr ratios, suggests a pattern of residential migration between the center of Kerma and its borders (Schrader et al., 2019). Recent studies on entheseal changes in different anatomical areas from Abu Fatima suggest that women who were local to the area may have been more involved in handcraft activities, while non-local women showed higher levels of leg mobility (van den Hoorn & Schrader, 2023). This pattern in non-local women is inferred from remodeling at muscle insertions due to repetitive actions performed in their daily lives. It is influenced not only by long-distance migrations but also by daily mobility involving various tasks within the immediate surroundings, such as herding livestock, collecting resources like fuel and water, or transporting heavy loads between different areas (Carballo-Pérez, 2023; Hondras et al., 2016; Zabecki, 2009). Alongside a lifetime of heavy-load transportation, the women like the individual labeled as 8A2 potentially could have carried one or more children for their initial years over long distances (Fig. 10).

6.4. Limitations of the study

The ethnographic and iconographic evidence discussed in this paper highlights the widespread use of tumplines across various cultures, including ancient Nubia. This evidence strongly suggests that the osseous changes observed in the cervical region of females from Abu Fatima may be a result of similar load-carrying practices. The comparison of these findings with cross-cultural examples not only supports the hypotheses but also underscores the role of these body techniques in reinforcing socially structured gender roles in Bronze Age Nubia. However, these insights must be understood within their limitations. Comparisons with ancient iconography and modern ethnographic studies, while useful, may not fully capture the specific cultural and social practices of the Abu Fatima community. Secondly, the absence of statistical significance in our tests suggests that broader archaeological explanations beyond the statistical data must be considered. The variations observed might be due to factors not captured by the statistical methods used, highlighting the need for qualitative interpretations alongside quantitative analyses (Armhein et al., 2019; Wasserstein et al., 2019). Thirdly, age significantly affects the biosocial interpretation of physical activities and skeletal changes. The increasing bone remodeling with age could be attributed to both mechanical stress and degenerative processes, complicating the distinction between natural aging and specific physical activities (Villotte et al., 2010; Yonemoto, 2016).

Future research into bilateral asymmetry is essential for a deeper understanding of shifts in daily activities and work practices. The observed patterns of asymmetry may reflect specific task specializations and changes in labor dynamics (Carballo-Pérez, 2023; Sládek et al., 2007). However, the inconsistent preservation of humeri in the sample may limit the accuracy of these interpretations, as incomplete or degraded bones can hinder the assessment of bilateral asymmetry and other skeletal markers. Additionally, as mentioned earlier, almost half of the analyzed individuals were missing their crania, which undoubtedly affects our conclusions regarding cranial modifications. The small

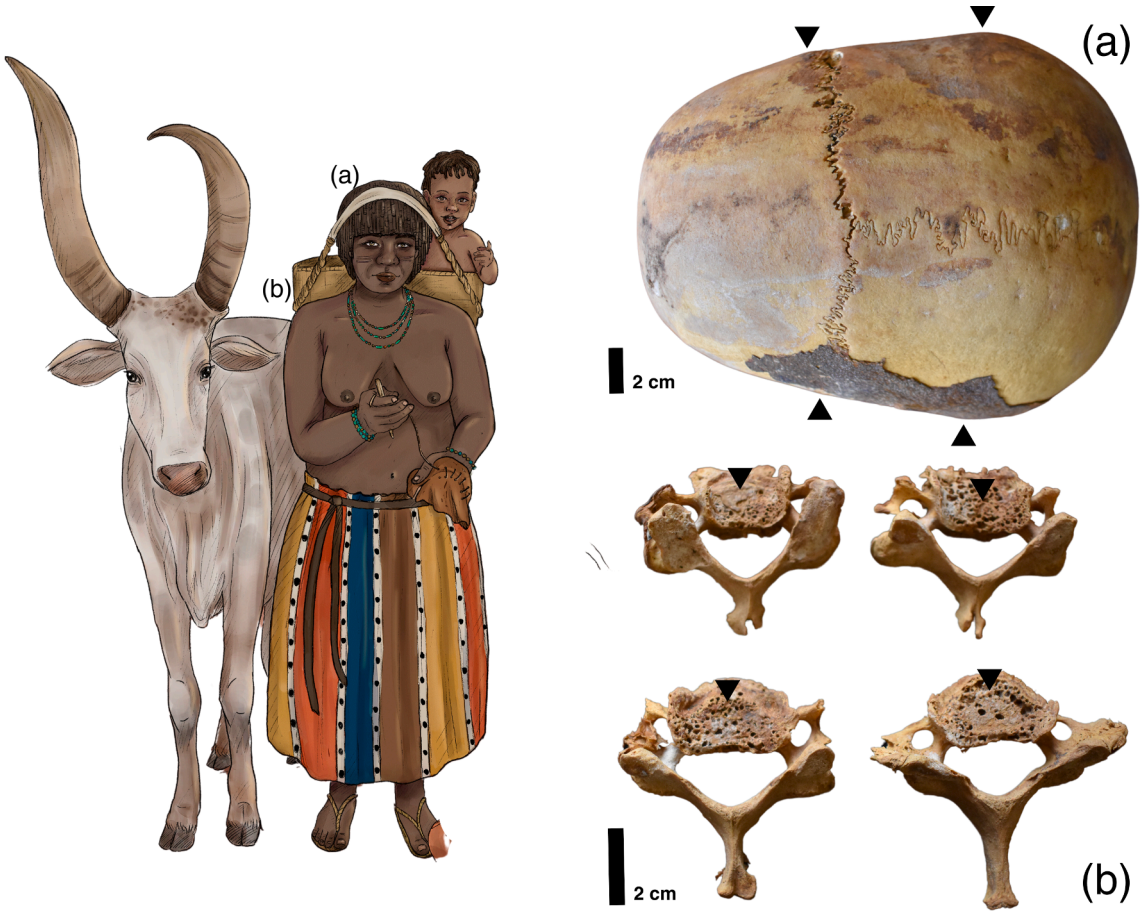

Fig. 10. Artist's illustration of Individual 8A2, a mature adult woman, engaged in high-mobility activities such as herding while carrying an infant in a basket using a tumpline, a few years before being interred in the Abu Fatima necropolis (Illustration: Silvia Jiménez-Amorós and Jared Carballo-Pérez). These bodily practices, among others, could have eventually led to the observed postcoronal depression in her skull (a), as well as pathological levels of spondyloarthritis with lytic lesions in her cervical vertebrae (b).

sample size of 30 individuals limits the robustness of statistical analyses and the generalizability of the findings to a broader population. The unequal distribution of individuals by sex, age, and chronological phases further constrains meaningful comparisons and the identification of clear patterns in load-bearing practices and physical activities. Future research should aim to increase the sample size to enhance the representativeness and statistical validity of the results, allowing for more definitive conclusions about the socio-cultural dynamics of this Bronze Age Nubian community.

7. Conclusions

This study utilized integrated analysis of skeletal, iconographic, and ethnographic evidence to understand body techniques of load carrying in Abu Fatima, Bronze Age Nubia. The skeletal analysis included a sample of 30 individuals from this Kerma culture cemetery. By combining unintentional cranial modifications, vertebral pathology, osteoarthritis, and entheseal changes, it brings together this detailed set of skeletal modifications for the first time. The results indicate that:

1. The anatomical differences such as shoulder strain in males and head and neck strain in females, reflect socially structured gender roles and culturally specific load-bearing practices of people buried in Bronze Age Abu Fatima. They illustrate that societal norms can shape physical adaptations. Body techniques are structured through repetition as a habit, which at the same time can also reinforce social structures through learned practices.
2. Age significantly affects the biosocial interpretation of physical activities and skeletal changes. Further research into bilateral asymmetry is essential for a deeper understanding of shifts in daily activities and work practices.
3. Interpreting the observations of a correlation between postcoronal changes and bone remodeling at nuchal muscle requires caution. One has to consider potential influences of extra-masticatory activities such as fiber and hide work, alongside genetic predispositions to entheseal remodeling in these regions (Mizoguchi, 2012). The results of this study highlight osseous changes in the cervical region of females buried in Abu Fatima, potentially resulting from carrying heavy items using their heads. However, it is crucial to interpret these pathological conditions in a broader context of body techniques, and not just tumplines, as indicated by ancient Egyptian and Nubian iconography. This could also include activities like carrying objects directly on top of the head. Therefore, alongside considering the impact of tumpline use, the interpretations should also encompass these broader physical practices, acknowledging the complex nature of cultural representations.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors have used Generative Pre-trained Transformer-4 by Open AI to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the

publication.

CRediT authorship contribution statement

Jared Carballo-Pérez: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Uroš Matić:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Data curation, Conceptualization. **Rachael Hall:** Writing – review & editing, Resources, Methodology, Investigation, Formal analysis, Data curation. **Stuart T. Smith:** Writing – review & editing, Resources, Project administration, Funding acquisition, Data curation. **Sarah A. Schrader:** Writing – review & editing, Resources, Project administration, Funding acquisition, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2024.101652.

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