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RESEARCH ARTICLE

The embodiment of colonial strategy: Osteoarthritis in ancient Nubia

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Abstract

The Egyptian Empire conquered and colonized Nubia, what is today northern Sudan, on multiple occasions. The colonization strategy employed was highly variable through time, ranging from the construction of militarized fortresses (Middle Kingdom 2050–1650 BCE) to an amicable co-existence approach (New Kingdom 1550–1050 BCE). Egyptian tactics also varied spatially, depending on several factors including a colonized community's utility to the empire and the potential for revolt. Using a large dataset ($n = 341$), this paper compares osteoarthritis between seven Nubian communities to (1) evaluate whether imperial strategy impacted osteoarthritis severity and (2) assess whether rates of osteoarthritis differed between colonized communities.

Age-controlled analysis of covariance (ANCOVA) suggests there was significant variation in the frequency and severity of osteoarthritis throughout the empire. The Middle Kingdom C-Group, an indigenous Nubian population that lived outside the Egyptian-built and -occupied fortresses, displayed the highest rates of osteoarthritis for nearly all joint systems. Osteoarthritis then decreased during the postcolonial Second Intermediate Period (1650–1550 BCE) and again increased during the recolonization of the New Kingdom. However, there is significant variation of osteoarthritis at three New Kingdom sites, each of which experienced a differing colonization approach. This study suggests that the varying imperial strategies utilized by the Egyptian Empire may have impacted the physical activities and daily lives of Nubians and that these tactics were not equal throughout Nubia but were tailored to communities. It is therefore difficult to discuss a singular outcome of colonization; rather, these interpretations need to be nuanced with community-level archaeological context.

KEYWORDS
activity, Egypt, empire, imperialism, Sudan

1 | INTRODUCTION

At its most basic definition, an empire is a territorially expansive polity that, through diverse means—including economic, political, ideological, and/or military power—controls other localities (Alcock et al., 2009). The degree of imperial influence can range from indirect rule to complete colonization depending on imperial interests, geopolitical location of incorporated areas, and social context. Previous bioarchaeological research has shown that imperial expansion contributed to an increase in disease, workload, and interpersonal violence, as well as a decrease in overall health in peripheral areas as empires enforce policies such as tribute demands and surplus extraction (Andrushko et al., 2006; Klaus et al., 2009; Larsen, 2001; Murphy & Klaus, 2017; Tung, 2012). The experience of local populations is highly variable, however. For example, Williams and Murphy found that quality of life, assessed via nonspecific stress indicators, and diet at the cemetery of Puruchuco–Huaquerones (central coast, Peru) did not change with Inka annexation (Williams & Murphy, 2013, see also: Becker & Goldstein, 2018). Marklein reports no significant differences in stress markers between senatorial and imperial sites in peripheral Rome (Marklein, 2020). These bioarchaeological studies illustrate how the impact of colonial strategy can vary dramatically and, importantly, how it can be skeletally embodied (Tung, 2012).

Ancient Egypt presents an interesting context in which we can study this variation because Egypt colonized Nubia, using diverse tactics, on multiple occasions (see Table 1 for a summary of these events). Nubia can be divided into two regions, Lower Nubia, spanning the First to Second Cataracts (also known as Wawat), and Upper Nubia, extending from the Second Cataract to the Fourth Cataract (also known as Kush; Figure 1). Nubia posed a serious threat to the unity and imperial success of Egypt (Knoblauch, 2019). To counter this threat, Egypt expanded southward, beyond the traditional border at the First Cataract, into Nubia during the Middle Kingdom (Table 1). This approach was militarized in that a series of at least 17 massive fortresses were constructed defining Egypt's new southern border, controlling Nilotic trade, and monitoring the local Nubian population (Smith, 1991). These fortresses housed Egyptian administrators and soldiers, while the indigenous Lower Nubians, known as the C-Group, lived outside the fortress walls. Archaeological evidence suggests material interaction between the C-Group Nubians and Egyptians who occupied the fortresses was minimal at this time and that C-Group Nubians maintained their own cultural traditions, despite colonization (Hafsaas, 2021; Smith, 1995, 1997).

Due to increasing political fragmentation that is characterized by the Second Intermediate Period (1650–1550 BCE; Table 1), Egypt relinquished control of the fortresses. C-Group peoples, Egyptian

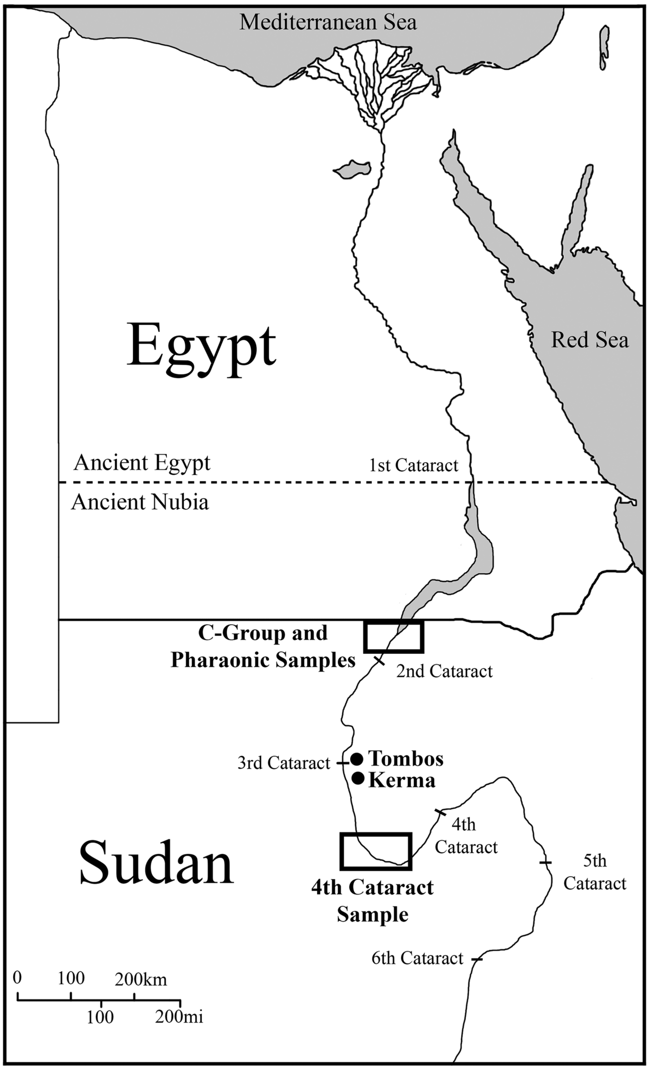

FIGURE 1 Map of Nile Valley and samples analysed

TABLE 1 Summary of colonial strategy per time period

Time period and colonization status	Date	Cultural groups and location	Imperial strategy
Kerma Period (precolonization)	<2500–2050 BCE	Indigenous C-Group and Kerma Nubians	None
Middle Kingdom (colonization)	2050–1650 BCE	Egyptian colonization of Lower Nubia	Militarization (separate settlement enclaves of C-Group communities and Egyptian fortresses)
Second Intermediate Period (postcolonization)	1650–1550 BCE	Nubian reclamation of Lower Nubia	Cohabitation of C-Group Nubians, Egyptian expatriates, and Kushites within fortresses
New Kingdom (recolonization)	1550–1070 BCE	Egyptian colonization of Lower and Upper Nubia	Coexistence (indigenous culture largely, but not completely, changes to colonial culture)

expatriates, and possibly Kushites from Upper Nubia, co-existed and repurposed the fortresses as domestic spaces during this time (Edwards, 2004; Smith, 1995, 1997). The material record suggests a multi-cultural landscape, with an increase in Nubian-style ceramics, jewelry, and figurines inside the fortresses and, at the same time, an increase in Egyptian-style ceramics in C-Group domestic contexts (Säve-Söderbergh, 1989; Smith, 2003).

Before long, the Egyptian Empire reunified under the New Kingdom Period and prioritized the recolonization of Nubia. Within 50 years, Egyptian forces had recolonized the Second Cataract fortresses, reclaiming the Middle Kingdom southern border. The New Kingdom pharaohs went even further than their Middle Kingdom predecessors and colonized Upper Nubia up to the Fourth Cataract, quashing Kush (Edwards, 2004). After an initial period of military force, Egypt adopted a novel coexistence approach through the construction of new Egyptian-inspired communities, known as temple towns. Egyptian administrators, civil officials, priests, artisans, and others are known to have transplanted from Egypt to Nubia with the directive of cooperation and diplomacy (Edwards, 2004; Smith, 1997, 2003). Once this policy of coexistence was put in place, the material and mortuary record in Nubia largely reflects Egyptian religious and cultural practices; however, it is important to note that some individuals continued Nubian-style burial practices despite Egyptian colonization. Stuart Tyson Smith and Michele Buzon's work nuance this interaction and suggest biological and cultural entanglements were at play during (and after) the New Kingdom colonial period (Buzon et al., 2016; Smith, 2003).

The differing imperial strategies of the Middle Kingdom and New Kingdom are clear (Table 1). However, the impact these strategies had on colonized individuals and their daily lives remains unknown. While other scholars have bioarchaeologically examined the impact of colonial strategy, these comparisons have been between either two periods or two sites (e.g., Buzon & Richman, 2007; Kyle et al., 2020). This study contributes to this discussion by including four time periods and seven archaeological sites to broaden our perspective on the impacts of colonial strategy. More specifically, this research addresses how physical activities, assessed through degenerative changes to joint systems, changed diachronically and spatially in scenarios of precolonization, colonization, postcolonization, and recolonization. While osteoarthritis does have a multifactorial aetiology, hard labor, which has been a documented embodied outcome of colonization on indigenous peoples, can be a contributing factor (Becker, 2019). Using this robust dataset, we can begin to address how these diverse colonial strategies impacted the lived experience of those under imperial control.

2 | MATERIALS AND METHODS

2.1 | Materials

To my knowledge, no one skeletal collection spans the precolonization, colonization, postcolonization, and recolonization periods (the Kerma, Middle Kingdom, Second Intermediate, and New Kingdom periods, respectively). Therefore, seven populations were analysed: two from the precolonial Kerma period (Kerma, Fourth Cataract), one from the colonial Middle Kingdom (C-Group Middle Kingdom), one from the postcolonial Second Intermediate Period (C-Group Second Intermediate Period), and three from the recolonial New Kingdom Period (C-Group New Kingdom, Pharaonic, and Tombos; Table 2).

2.1.1 | Precolonization samples

In order to assess what indigenous Nubian life was like prior to colonization, two precolonial contexts are examined: Kerma and The Fourth Cataract.

Kerma

The Kerma collection is from capital city of the Kushite culture, Kerma, and more specifically the Eastern Cemetery, which served as the necropolis for the rulers of Nubia ($N = 169$; females = 98, males = 71; Bonnet, 2019). In addition to elite rulers, individuals of nonelite status were also interred at the Eastern Cemetery. These individuals may have been involved in activities such as agropastoral practices, construction efforts, and may have served in the famous Kushite military (Schrader, 2015). Previous analysis of entheseal changes did find significant differences between the elite and nonelite individuals at Kerma (Schrader, 2015). Therefore, elite individuals were not included here as they may bias interpretation. For additional details about the Kerma skeletal collection as well as previous bioarchaeological analysis, please see: Buzon & Judd, 2008; Judd, 2004; Judd & Irish, 2009. The Kerma collection is housed at the Duckworth Laboratory, University of Cambridge.

The Fourth Cataract

The Fourth Cataract collection is comprised of skeletal remains from six sites (4-K-203, 4-K-204, 4-L-100, 4-L-2, 4-L-88, O16/P37), which were excavated during the Northern Dongola Reach Survey project (1993–1997; $N = 50$; females = 20, males = 30; Judd, 2001; Welsby, 2001). These sites are considered to be small villages and hamlets on the frontier of the Kushite state. These populations were practicing agropastoralism in a fringe desertic environment. They have

TABLE 2 Skeletal collections and chronology

Collection	Colonization status	Chronology
Kerma	Precolonization	1750–1500 BCE
Fourth cataract	Precolonization	2500–1650 BCE
C-Group	Colonization	2000–1650 BCE
	Postcolonization	1650–1550 BCE
	Recolonization	1550–1450 BCE
Pharaonic	Recolonization	1550–1300 BCE
Tombos	Recolonization	1550–1069 BCE

been considered as a single unit that is representative of rural lifeways in previous bioarchaeological research (see Judd, 2002, 2006). Although the collection spans nearly one millennia, it has been argued that lifeways did not change in these small communities during this time (Welsby, 2001). The Fourth Cataract skeletal collection is now housed at The British Museum.

2.1.2 | Colonization, postcolonization, and recolonization

The C-Group collection spans the colonization, postcolonization, and recolonization periods, and is defined by the continuation of indigenous mortuary practices. The Pharaonic collection is from the recolonization period; these individuals lived in the same area as, and were contemporary with, the recolonization C-Group peoples, but the Pharaonic sample adopted Egyptian funerary practices. Lastly, Tombos is also a recolonization sample, but from Upper Nubia.

C-Group

The Lower Nubian C-Group skeletal collection originates from three cemetery sites, within close proximity to one another, between the First and Second Cataracts of the Nile River (Shirfadik, Nag' el-Leithi, Kashkush). They were excavated as part of a salvage campaign, the Scandinavian Joint Expedition to Sudanese Nubia (1963–1964), in preparation for imminent flooding due to the construction of the Aswan High Dam (Säve-Söderbergh, 1989). This collection was identified as C-Group based on mortuary practices (i.e., flexed burial position, C-Group artefacts) and can be divided into three periods: Middle Kingdom colonization (2000–1650 BCE; $N = 34$; females = 17, males = 17), Second Intermediate Period postcolonization (1650–1550 BCE; $N = 17$; females = 9, males = 8), and New Kingdom recolonization (1550–1450 BCE; $N = 12$; females = 11, males = 1). While other populations (e.g., Tombos, Pharaonic) largely adopted Egyptian culture during the New Kingdom, the C-Group New Kingdom sample seemingly rejected these cultural entanglements (Smith, 2003). This chronology was determined by ceramic seriation and later confirmed by carbon-14 dating (Säve-Söderbergh, 1989). The C-Group skeletal collection is curated at the Panum Institute (University of Copenhagen).

Pharaonic

The Pharaonic skeletal collection also originates from the salvage mission of the Scandinavian Joint Expedition ($N = 30$; females = 16, males = 14). Unlike C-Group burials, Pharaonic burials were interred in an Egyptian burial style (e.g., supine burial position, evidence for wrapping, Egyptian artefacts including jewelry and pottery; Edwards, 2020; Säve-Söderbergh, 1989). These individuals are thought to be Egyptianized Nubians having adopted the colonizers cultural practices. The Pharaonic material dates exclusively to the New Kingdom period of recolonization (1550–1300 BCE) and is housed at the Panum Institute (University of Copenhagen).

Tombos

Tombos is located on the Third Cataract of the Nile and was constructed early in the New Kingdom as a southerly border of direct control during recolonization ($N = 29$; females = 18, males = 11; Smith, 2003). In line with the coexistence approach implemented by the Egyptians, there is biological and cultural evidence to suggest that both Egyptians and Nubians cohabited this space (Buzon, 2006; Buzon & Simonetti, 2013; Smith, 2003; Smith & Buzon, 2017). Tombos likely functioned as an administrative center, with Egyptian bureaucrats and officials, such as the Reckoner of Kush, as well as Egyptonubian artisans, scribes, and prosperous servants. The Tombos skeletal collection is curated at Purdue University.

2.2 | Methods

Osteoarthritis is a degenerative joint condition that is characterized by the breakdown of synovial cartilage, leading to skeletal alterations; it is highly complex and has numerous contributing factors including, but not exclusive to, age, physical activity, obesity, trauma, and genetic predisposition (Rogers & Waldron, 1995). Age, above all other contributing factors, is consistently positively correlated with osteoarthritis in both modern and ancient populations. Skeletal degeneration is typically associated with marginal osteophytes (i.e., lipping), pitting on the joint surface (i.e., porosity), and bone on bone abrasion and polishing (i.e., eburnation; Buikstra & Ubelaker, 1994; Rogers & Waldron, 1995). Per Buikstra and Ubelaker (1994), mild lipping was considered barely discernable, moderate lipping was defined by the presence of sharp ridges, and severe lipping included extensive spicule formation; mild porosity was defined by pinpoint holes in the joint surface, moderate porosity included coalesced pits, and severe porosity was defined by both pinpoint and coalesced pits; eburnation was considered mild if it was barely discernable, moderate when there was polish only, and severe if there was polish with grooves (Buikstra & Ubelaker, 1994, p. 122; Figures 2–4). An ordinal scale for osteoarthritis severity was adopted (0 = osteoarthritis absent; 1 = mild lipping and porosity, or moderate lipping without porosity; 2 = moderate lipping and moderate porosity; 3 = eburnation present). The joint systems analysed are as follows: shoulder (glenoid fossa, proximal humerus), elbow (distal humerus, proximal ulna, proximal radius), wrist (distal ulna, distal radius), hip (acetabulum, proximal femur), and knee (distal femur, proximal tibia). The ankle was not analysed here due to small sample sizes of the distal tibia and articulating talus.

Sex was estimated using accepted cranial and pelvic morphological features (Buikstra & Ubelaker, 1994; Table 3). Age was estimated using pubic symphyseal and auricular degeneration (Buikstra & Ubelaker, 1994; Lovejoy et al., 1985). Individuals were categorized as young (20–34 years), middle (35–49 years), or old (50+ years) adult. Nonadult individuals were not included in this study. Specimens that exhibited trauma or pathological conditions that could have contributed to osteoarthritis were excluded.

FIGURE 2 Mild lipping of the distal humerus [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 3 Moderate lipping with moderate porosity of the proximal ulna [Colour figure can be viewed at wileyonlinelibrary.com]

Analysis of covariance (ANCOVA) was used to assess differences in osteoarthritis severity between populations. ANCOVA is a combination of analysis of variance (ANOVA) and regression, but unlike ANOVA, allows the user to control for a singular variable by minimizing the bias caused by the said variable (otherwise known as the covariate). This covariate can be a variable that the user is not interested in, or a variable that might influence the results to such an extent that results of other variables are obscured by this predominant variable. The covariate is held at a constant, essentially an average value, thereby subtracting the effects of the variable, allowing the user to focus on the other variables under question (Vogt, 1999). Here, age was considered the covariate and controlled for, limiting the strong positive association between age-at-death and osteoarthritis severity. While ANCOVA analysis is typically reserved for continuous data, it has been shown to be effective with ordinal data, as is used here, and is particularly applicable to bioarchaeological studies of age progressive conditions, such as osteoarthritis (Cheverko & Hubbe, 2017; Schrader & Buzon, 2017). If age could not be determined the individual was not included in the sample. Power analysis values are also presented to avoid interpretation as a result of Type II errors (i.e., false negative). Alpha levels at $p \leq 0.1$ are considered indicative of statistical significance (Valeggia & Fernández-Duque, 2022). The skeletal samples were not sizable enough to control for sex as well as age and, thus, males and females were grouped together. This limits the ability for discussion of sexual division of labor, however, owing to sample size limitations, statistical analysis would not have been possible without this pooling.

3 | RESULTS

The severity of osteoarthritis was variable between populations and joint systems. Mean osteoarthritis values for the C-Group Middle Kingdom (colonization) and the C-Group New Kingdom (recolonization) are particularly elevated compared with the other comparative samples (Table 4; also see Table S1 for sample size per

FIGURE 4 Eburnation of the distal femur [Colour figure can be viewed at wileyonlinelibrary.com]

joint and standard deviation). The Pharaonic and Tombos (recolonization) samples stand out with low mean osteoarthritis scores. ANCOVA results indicate significant variation between populations at the left and right shoulder, left elbow, left and right wrist, left and right hip, and left and right knee.

Rates of osteoarthritis at the two precolonization samples, Kerma and the Fourth Cataract, are similar. The Fourth Cataract sample has significantly higher osteoarthritis scores in the left elbow as well as the left and right wrist (Table 5). All other joint systems display similar levels of osteoarthritis. In comparing the precolonial Nubian samples, Kerma and the Fourth Cataract, to the militarized colonized sample, C-Group Middle Kingdom, there is a marked increase in mean osteoarthritis scores. Osteoarthritis was significantly more severe in all joint systems for the C-Group Middle Kingdom sample, with the exception of the left and right elbow when compared with the Fourth Cataract sample, and the right elbow when compared with the Kerma sample.

TABLE 3 Demographic distribution

		Female			Male			
		Young adult	Middle adult	Old adult	Young adult	Middle adult	Old adult	*n*
Kerma	Precolonial Kushite	23	57	18	9	45	17	169
4th cataract	Precolonial Kushite	4	11	5	7	18	5	50
C-Group	Middle Kingdom colonization	5	10	2	6	8	3	34
	Second Intermediate Period postcolonial	5	4	0	2	4	2	17
	New Kingdom recolonization	4	3	4	0	1	0	12
Pharaonic	New Kingdom recolonization	4	5	7	2	5	7	30
Tombos	New Kingdom recolonization	3	6	9	1	5	5	29
n		48	96	45	27	86	39	341

TABLE 4 Population means and ANCOVA

	C-Group MK	C-Group 2IP	C-Group NK	Pharaonic NK	Tombos	Kerma	4th cataract	ANCOVA			
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	*df*	*f*	*p*	Power
Shoulder (left)	0.77	0.08	0.67	0.27	0.23	0.34	0.32	6	2.87	0.01	0.886
Shoulder (right)	0.85	0.80	1.00	0.53	0.17	0.43	0.53	6	4.31	0.00	0.981
Elbow (left)	0.44	0.17	0.36	0.43	0.21	0.14	0.41	6	2.58	0.02	0.845
Elbow (right)	0.20	0.18	0.67	0.21	0.21	0.23	0.31	6	0.67	0.67	0.266
Wrist (left)	--	0.50	--	0.07	0.20	0.10	0.26	4	1.92	0.09	0.640
Wrist (right)	--	0.50	--	0.39	0.33	0.07	0.33	4	4.39	0.02	0.931
Hip (left)	0.58	0.08	0.67	0.18	0.26	0.39	0.31	6	2.34	0.03	0.802
Hip (right)	0.96	0.30	1.00	0.27	0.32	0.30	0.37	6	4.08	0.00	0.974
Knee (left)	1.00	0.36	0.50	0.89	0.25	0.28	0.26	6	3.72	0.00	0.958
Knee (right)	1.08	0.20	1.00	0.83	0.58	0.26	0.27	6	3.96	0.00	0.970

(statistical significance $p \leq 0.1$ in bold).

TABLE 5 Pairwise mean differences

	C-Group MK						C-Group 2IP				
	C-Group 2IP	C-Group NK	Pharaonic NK	Tombos	Kerma	4th cataract	C-Group NK	Pharaonic NK	Tombos	Kerma	4th cataract
Shoulder (left)	**0.75**	0.02	**0.62**	**0.64**	**0.47**	**0.48**	**0.73**	0.13	0.11	0.28	0.27
Shoulder (right)	0.04	0.03	**0.47**	**0.81**	**0.48**	**0.34**	0.00	**0.43**	**0.77**	**0.44**	0.31
Elbow (left)	0.22	0.30	0.05	0.28	**0.31**	0.04	0.19	0.17	0.06	0.08	0.18
Elbow (right)	0.03	0.35	0.05	0.07	0.01	0.10	0.38	0.02	0.04	0.03	0.13
Wrist (left)	--	--	--	--	--	--	--	**0.46**	0.32	**0.40**	0.24
Wrist (right)	--	--	--	--	--	--	--	0.19	0.23	**0.43**	0.17
Hip (left)	**0.54**	0.14	**0.66**	**0.54**	**0.30**	**0.37**	0.39	0.12	0.00	0.24	0.17
Hip (right)	**0.48**	0.10	**0.77**	**0.69**	**0.63**	**0.55**	0.38	0.29	0.22	0.15	0.07
Knee (left)	0.28	0.26	0.36	**0.95**	**0.84**	**0.82**	0.13	0.22	0.37	0.27	0.25
Knee (right)	**0.76**	0.20	0.33	**0.58**	**0.81**	**0.78**	0.56	0.49	0.18	0.04	0.02

Note: Statistical significance $p \leq 0.1$ in bold. Colour version available online. Orange= Pairwise value ≥ 0.70; Green= Pairwise value 0.40-0.69; Purple= Pairwise value 0.20-0.39; Blue= Pairwise value ≤ 0.19.

TABLE 5 (Continued)

	C-Group NK				Pharaonic NK			Tombos		Kerma
	Pharaonic NK	Tombos	Kerma	4th cataract	Tombos	Kerma	4th cataract	Kerma	4th cataract	4th cataract
Shoulder (left)	**0.60**	**0.62**	0.45	0.46	0.02	0.15	0.14	0.17	0.17	0.00
Shoulder (right)	0.44	**0.77**	0.44	0.31	**0.33**	0.01	0.13	**0.33**	**0.46**	0.13
Elbow (left)	0.02	0.25	0.28	0.10	0.23	**0.26**	0.01	0.02	**0.24**	**0.27**
Elbow (right)	0.40	0.42	0.35	0.25	0.02	0.05	0.15	0.07	0.17	0.10
Wrist (left)	--	--	--	--	0.14	0.06	**0.22**	0.08	0.08	**0.16**
Wrist (right)	--	--	--	--	0.05	**0.25**	0.03	**0.20**	0.07	**0.27**
Hip (left)	**0.52**	**0.40**	0.16	0.23	0.12	**0.36**	**0.29**	**0.24**	0.17	0.07
Hip (right)	**0.67**	**0.60**	**0.53**	0.45	0.08	0.14	0.22	0.06	0.15	0.08
Knee (left)	0.21	0.38	0.28	0.26	**0.59**	**0.48**	**0.46**	0.10	0.12	0.02
Knee (right)	0.12	0.38	0.61	0.58	0.26	**0.48**	**0.46**	0.22	0.20	0.02

Note: Statistical significance $p \leq 0.1$ in bold. Colour version available online. Orange= Pairwise value ≥ 0.70; Green= Pairwise value 0.40-0.69; Purple= Pairwise value 0.20-0.39; Blue= Pairwise value ≤ 0.19.

When the C-Group Middle Kingdom sample (militarized colonization) is compared with the C-Group Second Intermediate Period sample (postcolonization), the former illustrates higher mean osteoarthritis scores for all joint systems. The left shoulder, left and right hip, as well as the right knee are all significantly higher in the C-Group Middle Kingdom sample than the C-Group Second Intermediate Period sample. The Kerma and Fourth Cataract samples (precolonization, indigenous Nubian) are juxtaposed with the C-Group Second Intermediate Period (postcolonization) and report similar mean values between the three groups. Exceptions include the right shoulder, and the left and right wrist, which were all statistically significantly higher in the C-Group Second Intermediate Period than Kerma.

When the C-Group Second Intermediate Period (postcolonization) is compared with the C-Group New Kingdom (recolonization), the latter has high mean osteoarthritis values for all joint systems, one of which is statistically significant (left shoulder). However it should be noted that several joint systems display elevated mean difference values (right elbow, left and right hip, right knee), although these are not statistically significant. When the C-Group Second Intermediate Period is compared with the Pharaonic and Tombos samples, there are similar mean osteoarthritis values for most joint systems. However, the elevated right shoulder mean value for the C-Group Second Intermediate Period sample ($\bar{x} = 0.80$) contributes to statistical significance when compared with both the Pharaonic and Tombos samples. Similarly, the high left wrist values for the Second Intermediate Period sample ($\bar{x} = 0.50$) also result in a significant difference when compared with the Pharaonic sample.

For a deeper analysis of concurrent New Kingdom samples, the C-Group New Kingdom, Pharaonic, and Tombos samples are compared. For most joint systems, the C-Group New Kingdom exhibits higher mean values. The left shoulder and left and right hip are significantly higher in the C-Group New Kingdom sample than the Pharaonic sample. The left and right shoulder as well as the left and right hip are significantly higher in the C-Group New Kingdom sample than the Tombos sample. A direct comparison of the Pharaonic and Tombos samples indicates select joint systems are significantly higher in the Pharaonic sample (right shoulder, left knee); however, for the most part, the mean osteoarthritis scores are relatively similar between these two coexistence groups.

When the C-Group Middle Kingdom sample is compared with the C-Group New Kingdom sample, mean osteoarthritis values are similar, with no statistical differences. The C-Group Middle Kingdom also has higher mean values than the Pharaonic and Tombos samples, lending to statistically significant differences between these populations for nearly all joint systems (exceptions include the left and right elbow for both Pharaonic and Tombos as well as the left and right knee for the Pharaonic).

It should be noted that in some populations (e.g., Kerma, C-Group New Kingdom), males and females are not proportional. This could be skewing the results and subsequent interpretations, as the distribution of labor and biological predisposition to osteoarthritis may have differed between males and females.

4 | DISCUSSION

The data presented here suggest that the Egyptian colonization of Nubia may have impacted the severity of osteoarthritis for local Nubians. Osteoarthritis appears to vary through time with differing colonial approaches, but also through space within the strategy of coexistence. These findings are congruent with the archaeological record and provide evidence for variation in the lived experience of colonization.

4.1 | Militarized colonization

There was a significant increase in osteoarthritis between the precolonial and militarized colonization samples. While osteoarthritis does have a complex and multifactorial aetiology, bioarchaeologists have interpreted degenerative joint changes to be at least partially influenced by physically strenuous labor and activity (Austin, 2017; Becker & Goldstein, 2018; Palmer et al., 2016; Schrader, 2019). From this perspective we can posit that the dramatic and significant increase in osteoarthritis may be, at least partially, due to changes in activity, which colonizing Egypt may have imposed. Others have reported an increase in osteological indicators of activity between precolonized and colonized samples in various contexts (Klaus et al., 2009; Larsen, 2001, 2002; Peck, 2009; Reinhard et al., 1994). Given the inherently unequal nature of colonization, it is not altogether surprising that colonial powers would manipulate and control indigenous populations and their bodies as a labor resource (Murphy & Klaus, 2017).

Within the context of Middle Kingdom Egyptian colonization of Nubia, it has been suggested that Egypt colonized this area to control Nilotic trade from sub-Saharan Africa (e.g., ebony, ivory, incense, ostrich feathers, slaves), as well as tapping into local amethyst, diorite, gold, and copper resources (Adams, 1977; Edwards, 2004; Knoblauch, 2019; Smith, 1991). It is no coincidence that some of the largest fortresses that were built during the Middle Kingdom were located near major quarries and population centers, suggesting Egypt may have been motived both by natural resources, but may have also had an eye towards controlling and surveilling the local C-Group peoples (Hafsaas, 2010, 2021; Klemm & Klemm, 2012). Previous authors have suggested Nubians may have been conscripted into mining and/or washing the precious stones and minerals (Adams, 1977; Berlev, 1987; Hafsaas, 2021; Harrell & Mittelstaedt, 2015; Trigger, 1965).

A Middle Kingdom stela of an Egyptian man, Sahathor, provides further evidence with an inscription that indicates Nubians may have also been forced to wash gold (Klemm et al., 2019). Although there are no ancient Egyptian records that document how gold was extracted, the Greek author *Agatharchides* (second century BCE) writes that rock was broken up with fire and hammers; it was then crushed into powder using mortars and grinding stones (James, 1972). These actions would have been very labor intensive, involving bilateral upper and lower body movements, and also may have included other mine-related tasks (e.g., digging of mine shafts, extracting raw materials with hand axes and pounders, and moving heavy loads). This might explain the significant differences we see between the precolonial Kerma/Fourth Cataract and the C-Group Middle Kingdom samples (bilateral shoulder, elbow, hip, knee). Several clinical studies of osteoarthritis in miners indicate a positive and significant relationship between the intensive manual labor involved and degenerative changes to synovial joints as well as the vertebrae (Kellgren & Lawrence, 1952; Lawrence, 1955; McMillan & Nichols, 2005).

While there is a good argument for C-Group involvement in mining activities, there are also other potential explanations for the elevated rates of osteoarthritis. The Egyptians may have placed high tribute and production demands on local Nubians, which then increased labor (Säve-Söderbergh, 1941). In addition to the local natural resources (i.e., gold, copper, and precious stones), there is some evidence for large-scale pottery workshops (Knoblauch, 2019). It has also been suggested that the C-Group may have been forced by the Egyptians to construct the fortresses (Hafsaas, 2021; Harrell & Mittelstaedt, 2015). Lastly, it is also possible that the Egyptians enlisted C-Group Nubians to unload and load cargo, from smaller to larger vessels, as well as off-load material onto donkeys for land transport (Hafsaas, 2006). Like mining, these activities would have also involved bilateral upper and lower body, complex movements. While it is impossible to say what activities specifically contributed to higher rates of osteoarthritis for the C-Group during the Middle Kingdom, the data presented here suggest these individuals were engaging in more intensive and repetitive complex movements when compared with their predecessors, which could include any one or a combination of the activities described above.

4.2 | Postcolonial period

The high C-Group Middle Kingdom mean values, exhibited in all joint systems, are frequently significantly higher than the latter postcolonial C-Group Second Intermediate Period sample. This suggests the C-Group peoples may have returned to more traditional and less-intensive forms of labor after colonization. Nubiologists have argued that the C-Group peoples may have been agropastoralists, consuming secondary products of their herds (e.g., blood, milk), and maintaining a somewhat mobile lifestyle (Gatto, 2012; Haaland, 1991; Hafsaas, 2006, 2010). The data presented here could indicate the renewal of indigenous agropastoral practices. This hypothesis is further supported by the similarity in osteoarthritis mean scores between the C-Group Second Intermediate Period and the precolonial Kerma and the Fourth Cataract samples, two other populations who may have at least partially, relied on pastoralism.

Ethnographic research indicates daily activities of African pastoralists include herding cattle, which can entail walking long distances, collecting water, and household chores (Little, 1989; Sperling & Galaty, 1990). While the physical activities of pastoralists have been described as moderate to vigorous, these activities can be characterized as low-intensity and high-endurance (Sayre et al., 2019). Recent clinical research into the pathogenesis of osteoarthritis suggests that repetitive, high-intensity movements are more likely to cause joint injury and degeneration (Buckwalter & Lane, 1997; Hunter & Eckstein, 2009; however, it should be noted that the aetology of osteoarthritis is still debated, see Berenbaum et al., 2018; Dometh et al., 2017; Urban & Little, 2018). If the C-Group Second Intermediate Period population returned to more traditional agropastoral lifeways this might result in a decrease in osteoarthritis given the low-intensity activities involved in African pastoralism and could explain the decrease in bilateral shoulder, hip, and knee osteoarthritis seen here.

While several authors have addressed the bioarchaeology of pastoral groups (see Pechenkina & Oxenham, 2013; Sawchuk et al., 2019; Stojanowski, 2019), few have studied osteoarthritis as an indicator of activity in these populations. In a bioarchaeological approach to activity and pastoralism, Eng compares osteoarthritis between a Bronze Age pastoral/mixed economy sample and an Iron Age mounted pastoralist sample from China and Mongolia (Eng, 2016). Although higher rates of lower body osteoarthritis were found in the Bronze Age sample and higher rates of vertebral and upper limb osteoarthritis were found in the Iron Age sample, these differences were not statistically significant. Eng suggests that there was diversity and flexibility in the physical activities these pastoralists were engaging in, contributing to no clear statistical distinction between the two samples (Eng, 2016; see also Becker & Goldstein, 2018).

There are also no significant differences in mean osteoarthritis scores between the C-Group Second Intermediate Period and the Fourth Cataract sample, which may have also relied on pastoralism. The Fourth Cataract sample reflects a population that was living on the fringes of the Kushite state in a desert environment. Welsby suggests these groups may have been at least partially reliant upon transhumant practices (Welsby, 2001). Furthermore, both the C-Group Second Intermediate Period and Fourth Cataract samples have moderate osteoarthritis mean values for all joint systems, with most mean scores falling between 0.2 and 0.5. This may reflect the varied and low-intensity forms of activity associated with pastoralism.

The Kerma sample, on the other hand, has significantly lower osteoarthritis mean scores when compared with the C-Group Second Intermediate Period (right shoulder, left and right wrist). It is possible that the Kerma sample may have been of a higher socioeconomic status than the C-Group Second Intermediate Period sample. Even though the known high-status individuals were removed from the Kerma Sample (see Materials), it is possible that the remaining individuals were still relatively privileged, given the fact that they were buried close to the Ruler of Kerma (Minor, 2012; Reisner, 1923).

It is equally possible that the C-Group Second Intermediate Period population was engaging in activities that put increased stress on the right shoulder, and left and right wrists, as these values are relatively elevated in this population ($\bar{x} = 0.80$, $\bar{x} = 0.50$, $\bar{x} = 0.50$, respectively) when compared with other joint systems within the same population as well as comparative noncolonized samples. This may have included more agricultural activities than pastoral ones, as we would expect more unilateral upper body stress in agriculture and more lower body stress in long-distance pastoralism. C-Group-style ceramic and craft production, which can be attested to archaeologically, could also explain the relatively high mean wrist values for the C-Group Second Intermediate Period (Hafsaas, 2010). However, it should be noted that due to low sample size of distal ulnae and radii in the C-Group Middle Kingdom and C-Group New Kingdom samples, this comparison of wrist values is only partial. Additionally, the small sample sizes of some populations in particular limit within site comparisons of sides (left versus right).

One could argue that differences in landscape may have contributed to these findings, as others have indicated variation in osteoarthritis prevalence with contrasting terrains (see al-Oumaoui et al., 2004; Austin, 2017). Kerma was located on a very fertile and flat floodplain, arguably the most agriculturally productive area of Upper Nubia (Edwards, 2004). The Fourth Cataract sites discussed here are all desertic and relatively level (Welsby, 2001). This is drastically different than the First-Second Cataract region, which is notoriously rocky and known as *Batn al Haj'r*, or Belly of the Rock. However, the osteoarthritis data itself would seem to contradict the notion that the rocky First-Second Cataract contributed to joint degeneration. First, all significant differences between Kerma and the C-Group are all upper body joint systems. Additionally, there appears to be more variation within the C-Group (e.g., Middle Kingdom, Second Intermediate Period, and New Kingdom) than between the C-Group and other sites (discussed further below). Together, these points suggest that, while terrain differences did exist between these populations, there may have been larger biocultural factors impacting osteoarthritis prevalence.

While it cannot definitively be determined whether the C-Group Second Intermediate Period Nubians were engaging in an agropastoral lifestyle, these data do suggest a decrease in physical activity from the militarized colonial period to the postcolonial period, with the exception of a few joint systems. This may have also been influenced by the nullification of tribute, a decrease in mining activities, and/or less intensive forms of production.

4.3 | Recolonization period

In some scenarios, the recolonization that took place during the New Kingdom Period may have contributed to another increase in osteoarthritis (C-Group New Kingdom), but in other samples there was no such increase (Pharaonic, Tombos), rather there is a continuation of similar mean values. This may reflect varying responses to colonization on behalf of the colonized as well as differing imperial tactics.

Imperial tactics certainly differed between the Middle Kingdom and the New Kingdom periods, with the former characterized by physical and cultural separation between the colonizer and the colonized and the latter incorporating a coexistence and entanglement approach (Buzon et al., 2016; Smith & Buzon, 2017). Of course, local populations remain agentive in these scenarios of colonization and respond in various ways through a multitude of means (Joyce & Lopiparo, 2005; Silliman, 2001; Voss, 2008). The C-Group New Kingdom sample can be considered resistors in many ways because, while some New Kingdom individuals adopted Egyptian culture (e.g., Pharaonic, Tombos), so much so that they were buried in an Egyptian style, some of the population rejected this pattern (e.g., C-Group New Kingdom). This begs the question, did adopting the colonizers cultural practices bestow an advantage? Smith and Buzon have discussed this within the case of Tombos and have argued that there may have been direct benefits of adopting Egyptian cultural practices (Smith & Buzon, 2014). Egyptianized Nubians may have had access to political power, higher socioeconomic standing, and status occupations (e.g., bureaucrats, managerial positions, and traders). In turn, this Egyptianization may have contributed to less strenuous forms of manual labor and, subsequently, lower rates of osteoarthritis. Like Tombos, this may have also been the case for the Pharaonic sample in Lower Nubia. Hafsaas-Tsakos reports that C-Group elites and local chiefs took on Egyptian cultural practices in exchange for status, influence, and high office positions (Hafsaas, 2006, 2021). If buried in an Egyptian-style, these C-Group chiefs/elites would be classified as Pharaonic according to the Scandinavian Joint Expedition. In the data presented here, we see markedly low levels of osteoarthritis—oftentimes the lowest of this dataset—in the Egyptian-presenting colonized samples (i.e., Pharaonic and Tombos). The resistors, or C-Group New Kingdom, had significantly higher mean osteoarthritis values when compared with Tombos and Pharaonic. In fact, the C-Group New Kingdom values are similar to, and not significantly different from, C-Group Middle Kingdom. Thus, it is possible that the indigenous Nubians that refused to adopt Egyptian culture where either forced into, or limited to, occupations and duties that were physically strenuous, thus contributing to higher levels of osteoarthritis. For the C-Group New Kingdom population, this may have included a return to mining, construction, and production activities, enforced by the empire, thereby explaining the increased bilateral upper and lower body osteoarthritis.

Future research should include additional colonial and noncolonial populations from these time periods to gain a broader perspective on the embodied effects of imperialism. Additionally, entheseal changes and geometric morphometric analyses could provide supplementary evidence for labor, activity, and lifeways during this time. These methods each have advantages and disadvantages, however, the more information gleaned from the skeleton, the more holistic image we have of lived experience in colonial and postcolonial periods.

5 | CONCLUSIONS

This study has demonstrated that there are differences in the severity of osteoarthritis between the precolonization, colonization, postcolonization, and recolonization periods in Ancient Nubia. The militarization strategy of the Middle Kingdom included increased tribute and production demands (e.g., mining), which in turn may have contributed to higher rates of osteoarthritis for the C-Group Nubians. During the Second Intermediate Period, there is a decrease in osteoarthritis among the C-Group, possibly illustrating a return to agropastoral lifeways. Later, during the New Kingdom coexistence model of colonization, there are seemingly differential experiences among the colonized; those who embraced Egyptian cultural practices (Pharaonic, Tombos) had significantly lower rates of osteoarthritis compared with those that resisted colonial culture (C-Group New Kingdom). This longue durée approach to colonial strategy offers a broader lens with which we can examine trends in bioarchaeological data and better assess the lived experience, agency, and identity of ancient populations.

Additionally, archaeologists have highlighted the importance of researching labor in colonial scenarios (Lightfoot, 2015; Silliman, 2001, 2005; Voss, 2008). Deagan asks "… what is the materiality of labor? … Who controls the implements, the natural world, and indeed the labor power of people? How does ideology embodied in laws, beliefs, religion, and identities justify and legitimate inequities, inequalities, and exploitation in labor relations? Who ultimately benefits from these relations and who suffers?" (Deagan in response to Voss, 2008, p. 882). These are questions that bioarchaeological data can not only speak to but also offer unique insight into the embodiment of labor. While recent research has highlighted the multifactorial aetiology of osteoarthritis, there is a large body of literature that continually finds statistical correlation between intensive and strenuous activities and osteoarthritis (Kwon et al., 2019; Parsons et al., 2020; Perry et al., 2020; Solovieva et al., 2018). Although these data should be used with a degree of caution, bioarchaeological data, using the archaeological contexts as leverage, can be interpreted as materiality of labor (Schrader, 2019).

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Data for this publication are available on Zenodo (http://doi.org/10.5281/zenodo.6350397).

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