

THE ICE AGE WITH LITTLE EFFECT? EXPLORING STRESS IN THE DANISH BLACK FRIARS CEMETERY BEFORE AND AFTER THE TURN OF THE 14TH CENTURY

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ABSTRACT

The Little Ice Age, beginning in Europe in the 14th century, saw a period of climatic cooling and increased precipitation where food sources dwindled and famine became rampant, particularly in urban city centers. This study focuses on the Black Friars population (13th-17th centuries) to explore changes in stress in Denmark at the onset of the Little Ice Age. This study specifically explores the periods before and after the turn of the 14th century. Forty-five adult individuals were analyzed for cribra orbitalia, porotic hyperostosis, and enamel hypoplastic lesions. Results showed no statistically significant differences between the prevalence of these stress indicators between either time period; however, reduced age at death and increased lesion frequency was more prevalent post-1300. It was expected that increased stress would be evident in those buried after the turn of the 14th century due to the many challenges associated with wide spread climatic cooling; however, the reliance on nutrient rich marine resources and alms provisions may have helped lessen the burden of these stressors during this period of climatic hardship. Additionally, while famine characterized the beginning of the 14th century, agricultural rebound shortly after this period may have also influenced the stress levels observed.

1. INTRODUCTION

Before the 14th century, medieval Denmark thrived during the “climatic golden age” which saw prolific agriculture, adequate foodstuffs, and population growth across the country (Fagan 2000:21). Known as the “Medieval Warm Period”, average temperatures across Europe were increased, particular in Denmark (Hybel and Poulsen 2007). However, in AD 1315 widespread rains and cooler temperatures ushered in the Little Ice Age which lasted for the next 500 years (Jordan 1996; Fagan 2000; Hybel and Poulsen 2007). Torrential rains flattened crops and cooler temperatures caused many yields not to ripen, leading to a crisis of quality and quantity where agricultural production and demand became more disparate. These initial crop failures led to an inadequate and inconsistent food supply across the country and contributed to the loss of livestock and fertilizer resources (Fagan 2000; Yoder 2006). This Great Famine period lasted for seven years, affecting nearly 400,000 square miles of Northern Europe (Jordan 1996). By AD 1322 the brunt of the Great Famine had subsided which allowed for some agricultural and population rebound in Denmark; however, this rebound was quickly interrupted by the devastation of the Black Death in AD 1349 (Benedictow 2004). The multiple culminating factors of the Great Famine, long term climate change, land desertion, and a decreased workforce lead to the Late Medieval Agrarian Crisis (Gissel 1981; Jäger 1981). During this period in Denmark, no new towns were established and the standard of living was dire for most (Andrén 1989).

This paper explores the influence of the Little Ice Age on patterns of stress in urban Denmark using cribra orbitalia, porotic hyperostosis, and enamel hypoplastic lesions to compare those who died before the turn of the 14th century and those who died after AD 1300. We hypothesize that those who died after AD 1300 will show more evidence of stress due to the far-reaching effects of the Great Famine and the Late Medieval Agrarian Crisis.

2. BLACK FRIARS HISTORY AND CEMETERY

The Black Friars monastery was established in AD 1239 in the Danish city of Odense (established as a town proper after AD 1100) on the island of Fyn and remained in use until AD 1607 (Christensen 1988; Becher 1999; Møntegården Odense bys Museer 2010; Runge and Henriksen 2018). The monastery and associated cemetery were located in the northeastern part of the city center and dominated the medieval landscape (Christensen 1988). After the Protestant Reformation in AD 1536, the monastery was closed and the church was demolished (Becher 1999). With the destruction of the church, the Black Friars cemetery was turned over to the city in AD 1551 and remained in use until AD 1607 (Christensen 1988; Becher 1999; Boldsen and Møllerup 2006). During the medieval period, the cemetery would have been dominated by lower middle class individuals interred within and along the eastern and southern perimeters of the church proper, whereas late and post-medieval burials were primarily interred within the central cemetery (Figure 1) (Jakobsen 2008).

While those buried within the church proper and along its eastern and southern borders represent the medieval period, they can be further subdivided into more specific temporal groups based on distinct changes in arm position before and directly after the turn of the 14th century (Kieffer-Olsen 1993; Jantzen et al. 1994). Up until the 14th century individuals were buried with their arms at their sides (arm position A) which transitioned into the arms being cross over the pelvis (arm position B) up until AD ~1350 (Figure 2) (Møllerup and Boldsen 2010). After the mid-14th century, arms were crossed over the abdomen and finally crossed over the chest in the later part of the 16th century (Møllerup and Boldsen 2010).

3. MATERIALS AND METHODS

Forty-five adult individuals were analyzed in this study, 20 individuals with arm position A and 25 individuals with arm position B (Table 1). To further ensure those analyzed represent the medieval period, only those that were recovered from inside the church proper or those buried along the eastern or southern perimeters of the church were studied, as interments outside of this area (i.e., central cemetery and cloister) are generally regarded as post-medieval. This small sample size is a direct result of the mortuary data collected at the time of excavation. While burial location was identified for all individuals, arm position was not, drastically reducing the number of individuals that could definitively be placed within the two assigned temporal categories. Further, arm position was not recorded for any of the subadults precluding their inclusion in this study. Age estimation and sex determination were completed using established osteological standards for the pelvis, cranium, and femur (Phenice 1969; Meindl and Lovejoy 1989; St. Hovme and İscan 1989; Brooks and Suchey 1990; Buikstra and Ubelaker 1994; Walker 2005; Milner and Boldsen 2012). Cribra orbitalia and porotic hyperostosis were scored based on a four-stage classification system developed from Stuart-Macadam (1982) and Ribot and Roberts (1996) (Table 2). Enamel hypoplastic lesions were macroscopically scored using the left mandibular canine. This tooth was selected as it captures the longest period of childhood in which these lesions may form (1.4 – 6.2 years) and using only one tooth ensures the same stress event is not counted multiple times (see Boldsen 2007). EHL location was not recorded as this was outside the scope of this project.

4. RESULTS

It is recognized as a result of the sample criteria for stricter temporal control that the sample sizes in this analysis are small and may not be fully representative of the once living population. However, we have attempted to minimize any potential sample size error in the analysis conducted. Using a Fisher's exact test there were no statistically significant differences between the presence or absence of each stress indicator when divided by arm position (CO $p=0.269$; PH $p=0.177$; EHL $p=1.000$) (Figure 3). When further divided by sex using a Fisher's exact test, there were also no significant differences (Tables 3 and 4). When comparing stress manifestation between arm positions using a Fisher's exact test there were no significant differences between the level of manifestation of each indicator across time period (CO $p=0.682$; PH $p=0.374$; EHL $p=0.420$). When divided by sex using a Kendall's tau b test, there were no significant differences in stress manifestation levels between arm positions (Tables 5). There were also no significant differences when analyzing the number of stressors present per individual divided by arm position ($p=0.267$). However, the only individuals with all three stressors present had arm position B. Partial correlation analysis between CO, PH, and EHL could not be completed because small cell counts violated the assumptions of a loglinear analysis and would have significantly reduced the statistical significance of this test (Garson 2013). However, in a previous study of the Black Friars population with a much larger sample size (see Scott and Hoppa 2018), loglinear analysis demonstrated no correlation between stress indicators. Additionally, when comparing the average age at death for those with and without stress lesions present, divided by sex and time period showed no significant differences (Table 6); however, those with arm position B consistently had a lower average age at death across all indicators, except for females with PH (Table 7). When comparing the number of lesions present and the average age at death across time period those with arm position B were consistently dying at a younger age (Figure 4) and only those with arm position B had all three indicators present.

5. DISCUSSION

It was expected that poorer health would be evident in those buried after the turn of the 14th century; however, the results of this research suggest that while there were some differences between these two groups they were not statistically significant in this analysis. In general, stress, as determined from the presence of lesions, was high in both groups with 39 out of 45 individuals having at least one type of stress lesion present. Nevertheless, the data do show a slight trend towards increased stress for those with arm position B not only in the level of manifestation but also the number of indicators present (see Scott and Hoppa 2018 for a full discussion of stress manifestation and hidden heterogeneity). While the percentage of individuals with EHL is similar between those with arm position A and arm position B, CO and PH are far more prevalent in the later time period (Table 8). Comparatively, the frequency of CO for those with arm position B is more similar to other medieval studies in Europe (see Kozak et al. 2002; Obertová and Thurzo 2008; Beňuš et al. 2010; Jatautis et al. 2011; Novak et al. 2012). This suggests that the level of stress experienced by the Black Friars individuals before AD 1300 was relatively low. This trend is also similar to the medieval Ribe population in western Denmark where before the turn of the 14th century the percentage of individuals affected by CO and PH was relatively low at 21% and 3%, respectively (Yoder 2006). Further, Yoder, found no significant differences between CO and PH prevalence between the sexes. Additionally, in the contemporaneous Tirup sample from Denmark, 9% of individuals had evidence of CO and 66.7% showed evidence of at least one EHL (Boldsen 2007) similar to the trends observed in the pre-1300 Black Friars group.

Interestingly, when assessing the average age at death for those with each type of stress lesion present, individuals with arm position B consistently show a reduced mean age at death as compared to those with arm position A. When assessing the impact of multiple indicators on average age at death, in general those with more indicators present died earlier; however, within this trend, it is clear that those with arm position B were dying even younger when multiple indicators were present (Figure 4). Despite this trend for those with arm positions B, no significant differences in the average age-at-death were observed between periods, but does hint at inherent differences in susceptibility to stress. Again, this is similar to the results of Yoder (2006) who found no significant differences between the average age at death and the presence of CO or PH in the medieval Ribe population. Interestingly however, the younger average age at death for those with no skeleton lesions mirrors the trend in the Black Friars population, particularly in males (Table 7). This suggests that even with an increased stress load during childhood, individuals were able to survive into the adult years and lesions alone are not predictive of a younger average age at death, at least in this particular study. This is similar to the chronic stress environment in the post-medieval Subačiaus Lithuanian population where elevated morbidity was not associated with elevated mortality (Palubeckaitė et al. 2002). Urban dwelling in the medieval period exposed children from birth, to various stressors such as increased pathogen exposure, overcrowding, poor sanitation, and an unreliable water supply (Dyer 1989; Landers 1993) which likely contributed to individual heterogeneity in terms of frailty affecting overall mortality rates (Eisenberg 1992; Palubeckaitė et al. 2002; Boldsen 2007).

With these results in mind, there is a need to explore why there seems to be a relatively small change in stress patterns between those who died before the turn of the 14th century and those who died directly afterward. While early medieval Denmark was regarded as an agricultural ‘golden age’, the stresses associated with urban living likely contributed to the many examples of skeletal stress within this population, particularly with regards to diet. While CO,

PH, and EHL are considered non-specific indicators of stress, all three have been broadly linked with dietary deficiencies during the subadult years of life (Sweeney et al. 1969; El-Najjar et al. 1978; Nikiforuk and Fraser 1981; Huss-Ashmore et al. 1982; Goodman and Armelagos 1988; Stuart-Macadam 1992; Walker et al. 2009; Gamble et al. 2017). During the early medieval period, diet consisted of local foodstuffs with rye and barely being the primary agricultural crops in Denmark (Fagan 2000; Adamson 2004; Poulsen 2013) and fruit and vegetables supplied from local gardens (Yoder 2010). Terrestrial meat and dairy products were available to the majority of the population but enjoyed more frequently by the upper tiers of society (Yoder 2010; Poulsen 2013). Fish (i.e. cod and herring) was an important dietary supplement for the middle and lower classes due to its cheaper cost (Dyer 1994; Adamson 2004). The coastal geography of Denmark and large trade networks also created easy access for most inland settlements to these important marine foodstuffs (Sawyer and Sawyer 1993; Poulsen 2013). Additionally, religious sanctions on holy days (approximately 135 days/year) created more demand for fish throughout the country (Hoffman 2001). However, there was leniency towards fasting for children who were given dispensation and allowed to eat full meals, including terrestrial meats during holy periods (Albala 2011). Therefore, while many foodstuffs were abundant before the turn of the 14th century and even after the onset of the Great Famine, access and affordability were likely factors affecting the distribution and consumption of these foods.

During the Great Famine, those living in urban environments were most at risk. With crop failure and more and more individuals moving into urban centers, over-crowding and poor living conditions elevated the demand on a limited food supply (Fagan 2000). Additionally, efforts to stretch foodstuffs such as mixing wheat with bark, lead to constant outbreaks of diarrheal diseases (Fagan 2000; Poulsen 2013). With adults fed first in the majority of households, children during this period only consumed around 943 kcal/day (Muldrew 2011) with their diet consisting mainly of plant-based foodstuffs (Mays 2007). While most children began to participate in adult activities around ten to 12 years of age, some children were working as early as six years of age (Hanawalt 2002; Gilchrist 2013). In a resting environment, children between four and six years of age require approximately 1379 +/- 290 kcal/day (Goran et al. 1993); therefore, the majority of Danish children during this period were likely malnourished lacking essential iron and B12, potentially leading to the higher manifestation of CO, PH, and EHL. Additionally, women and girls were likely receiving less food than males by as much as 700 kcal/day (Muldrew 2011). While sex-based differences were not significantly different in this study, females showed elevated stress manifestation and more indicators present than males. Similarly, Gamble and colleagues (2017) explored early life stress events and their impact on adult longevity finding that increased stress reduced survivorship in males but had the opposite effect in females. This disparity between the sexes is likely associated with sexual buffering where females are biological less susceptible to the negative effects of stress (DeWitte 2010) but are arguably more vulnerable to social and cultural stress effects. The social, economic, and legal status of women and girls during the medieval period was based on marital status limiting a woman's ability to find lucrative work and forced many into heavy labour occupations, sometimes from a very young age (Jacobsen 1983). With the baseline caloric intake for women at 1900 kcal/day, the demands of domestic work and child rearing required 4900 kcal/day (Muldrew 2011). With women only receiving approximately 3215 kcal/day there were considerable deficits beyond that of males (Muldrew 2011) that likely also affected young girls as they entered into the workforce.

While the Great Famine was driven by the loss of agricultural crops which in turn affected livestock herds and access to meat and dairy products (Fagan 2000), marine resources remained abundant during this period and supplemented the diet of many, specifically fish and water fowl (Jordan 1996). In Denmark, the fish markets of Skåne were an important trading hub for herring and remained popular from the mid-13th century up until Reformation (Poulsen 2013). However, the price of fish skyrocketed due to the high cost of salt used in processing (Jordan 1996). Therefore, while fish was one of the most important commodities of the Great Famine period, it contributed fewer calories to the standard diet due to inflated costs (Rosen 2014). Similar to the results of this study, stable isotope analysis of the 12th to 16th century population from Viborg demonstrates that there was not a large shift in the Danish diet from the 14th century period onward and that those in an urban environment relied heavily on marine and terrestrial animal resources (Yoder 2010). As Yoder (2010) discusses, the expected changes in diet related to the events of the Great Famine and the Late Medieval Agrarian Crisis are not visible isotopically; however, changes in food type and preparation across broad isotopic categories may explain this seemingly large disparity between the historical records outlining dietary hardships and skeletal evidence of dietary shifts.

Social charities may have also contributed to some of the stress similarities across time period where the provision of alms by the church across much of Europe would have supplied those most in need with food, drink, shelter, and clothing (Jordan 1996; 2010). During the medieval period “people displayed an eager desire to participate in religious life” (Little 1978:206). Alms giving was important for personal salvation and provided necessary supplies for the poor (Brodman 2009). However, alms were not abundant for most and were “never to extend beyond what an individual requires. It [was] better to help the many than to satiate a few” (Brodman 2009:27). As Dyer (1989) explores, in 15th century England, social charities were only able to help approximately three percent of the urban population, leaving many to fend for themselves. However, cookshops in England countered this as legislation was put in place to control the price of hot food, allowing the urban poor to obtain decent food at a reasonable price (Carlin 1998). Additionally, many alms were only provided to the deserving poor or those considered “most holy, or [were] of most use to the community” (Brodman 2009:27) and dwindled as the Great Famine continued (Jordan 1996; 2010). Nevertheless social programs such as alms giving did provide some relief from the stresses associated with this economic shift in 14th century Denmark.

An additional consideration is the timeline of the Great Famine. While the famine characterized the beginning of the Little Ice Age period, there was nearly 30 years of favorable climatic conditions after AD 1322 that saw the increase of agricultural production and food resources (Jordan 1996). Because the Black Friars cemetery was continually in use throughout the medieval period, some of the individuals with arm position B likely lived some of their early years of life during this time of resource rebound. Further, because this study focuses on childhood stressors in adult skeletal remains, some of the individuals represented by arm position B may have spent their formative years in pre-Ice Age Denmark, influencing their exposure to various stressors. Additionally, those represented by arm position A may have also encountered unfavorable conditions from early famine periods in Denmark, most notably those in AD 1225-1226 and 1283 (Hybel and Poulsen 2007). While not as devastating as the effects of the Great Famine, the period before AD 1300 was not ubiquitously free of stressors. Unfortunately, without comparable temporal control of the subadult sample, comparing survivor and non-

survivor differences between time periods is not possible and leaves many questions unanswered about the true impact of these favourable conditions in this particular Danish sample.

6. CONCLUSIONS

The Little Ice Age ushered in a period of economic turmoil for Europe. As crops failed and food supplies dwindled, the Great Famine tightened its grip on the urban masses. In looking at a small sample of the Black Friars cemetery population, while patterns of stress did not significantly increase with the onset of the Little Age, there was a clear trend of increased stress after AD 1300 which impacted survivorship, as reflected in mean age at death estimates. Interestingly, the recorded levels of stress during this 14th century period match contemporaneous European examples likely demonstrating the large-scale effect of this economic shift. The lack of statistically evident change in stress patterns after the onset of the Little Ice Age was likely influenced by broad buffering factors such as the continued availability of marine resources and the work of social charities highlighting the importance of considering the influence of both biological and social factors in assessments of stress.

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LIST OF FIGURES

Figure 1 Map of the Black Friars cemetery with the Church proper, Cloister, and Central cemetery highlighted (modified from Scott 2015)

Figure 2 Distinction between arm position A (before AD 1300) and arm position B (AD ~1300-1350) with arms at the side of the body and arms crossed over the pelvis, respectively (modified from Mollerup and Boldsen 2010)

Figure 3 Number of individuals with each type of stress present or absent divided by arm position

Figure 4 Average age at death for those with 0 to 3 lesion-types present divided by arm position

Figure 1

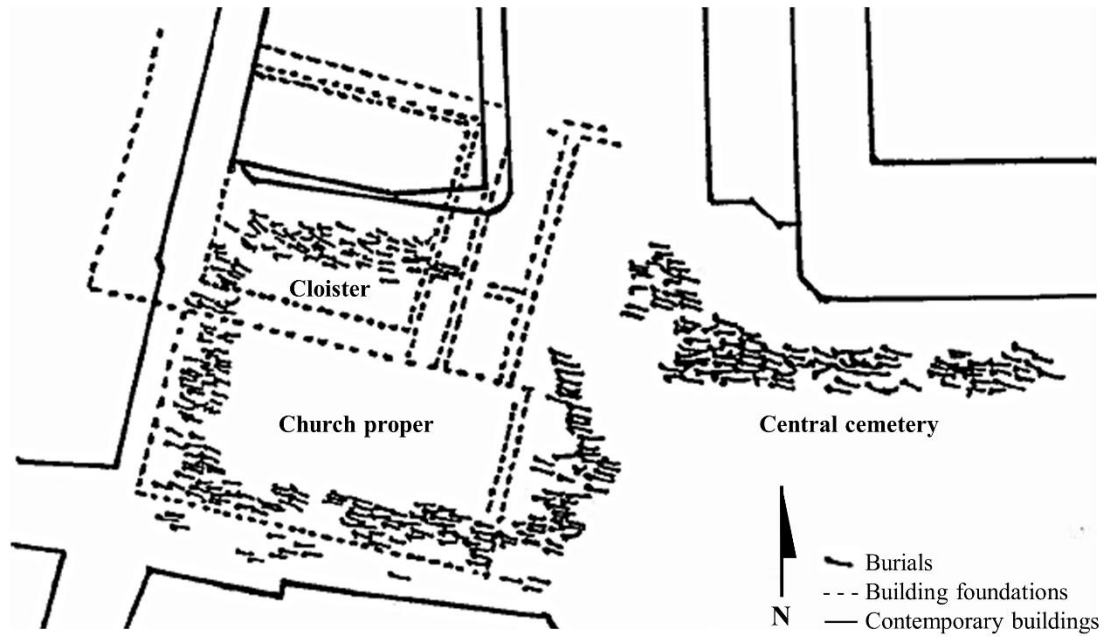
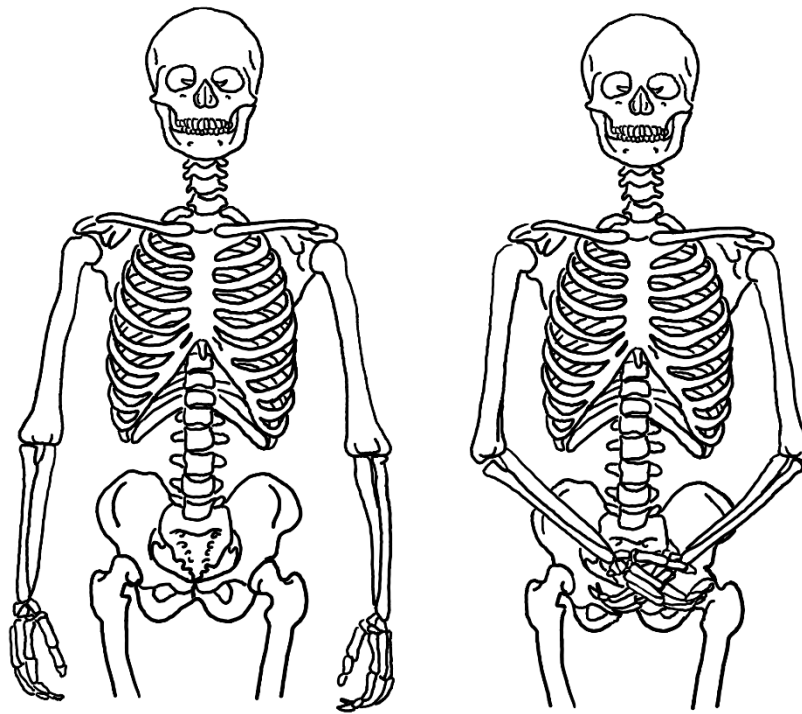


Figure 2



Arm Position A

Arm Position B

Figure 3

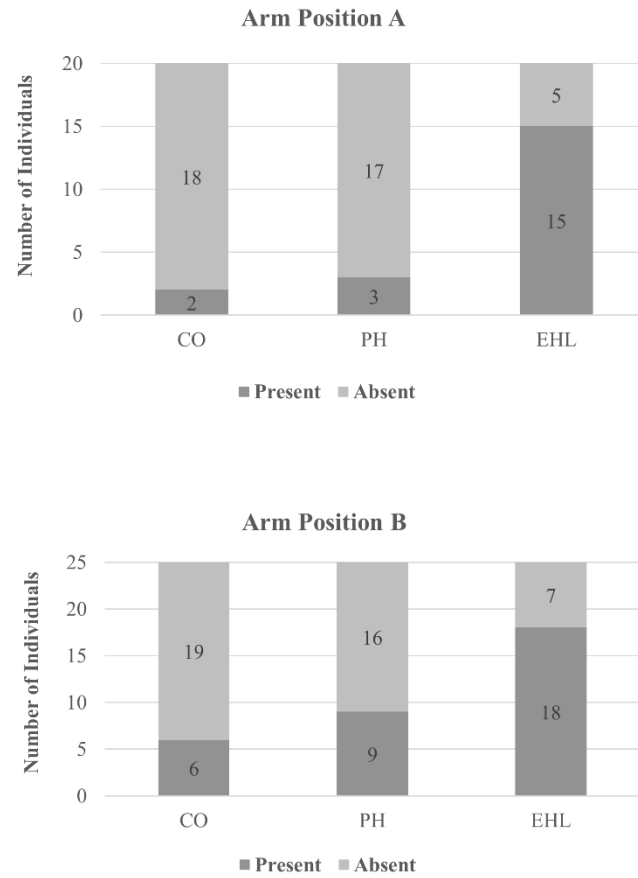
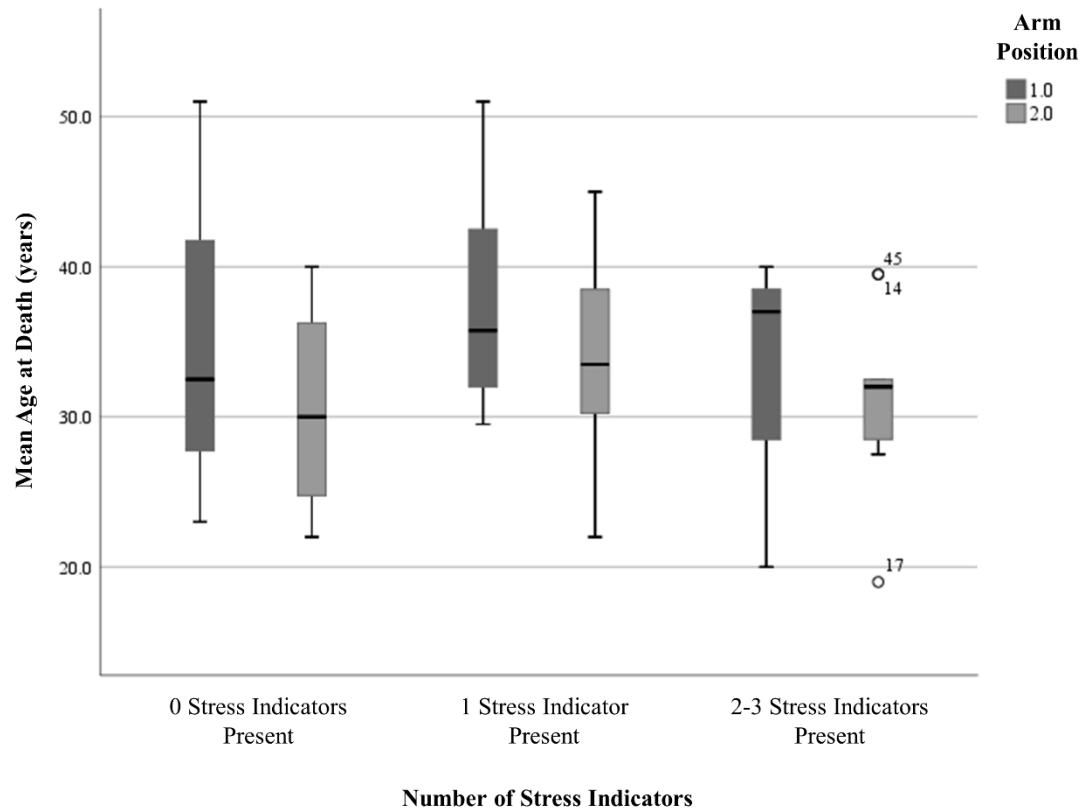


Figure 4



LIST OF TABLES

Table 1 Sex distribution and mean age at death of the Black Friars medieval sample divided by arm position

		Number of Individuals	Mean Age at Death
Arm Position A	Males	14	37.29
	Females	6	33.50
Arm Position B	Males	13	32.58
	Females	12	32.29

Table 2 Cribra orbitalia and porotic hyperostosis scoring criteria following Stuart-Macadam (1982) and Ribot and Roberts (1996)

Category	Description
Absent	No evidence of lesions
Mild	Slight pitting, no expansion of bone, scattered small foramina
Moderate	Moderate pitting, no expansion of bone, scattered large and small foramina
Advanced	Substantial pitting, expansion of bone, foramina have coalesced and are linked to trabecular bone
Severe	Severe pitting, gross expansion of bone and loss of normal contour, substantial coalescence of foramina with trabecular exposure

Table 3 Number of individuals with each type of stress indicator present divided by arm position and sex

		CO	PH	EHL
MALES	Arm Position A (n=14)	1	1	10
	Arm Position B (n=13)	2	4	8
FEMALES	Arm Position A (n=6)	1	2	5
	Arm Position B (n=9)	4	5	10

Table 4 Fisher's exact test comparing the presence and absence of stress indicators between individuals with arm position A and arm position B divided by sex

	Stress indicator	Exact Sig. (2-tailed)
MALES	Cribra orbitalia	0.596
	Porotic hyperostosis	0.165
	Enamel hypoplastic lesions	0.695
FEMALES	Cribra orbitalia	0.615
	Porotic hyperostosis	1.000
	Enamel hypoplastic lesions	1.000

Table 5 Kendall's tau b test comparing the severity of each stress indicator between individuals with arm position A and arm position B divided by sex

	Stress indicator	Exact Sig. (2-tailed)
MALES	Cribra orbitalia	0.730
	Porotic hyperostosis	0.066
	Enamel hypoplastic lesions	0.699
FEMALES	Cribra orbitalia	0.476
	Porotic hyperostosis	1.000
	Enamel hypoplastic lesions	0.144

Table 6 Independent samples t-test comparing the average age at death across arm position between individuals with and without each stress indicator present

		CO	PH	EHL
		Sig. (2-tailed)		
MALES	Absent	0.185 (t=1.370; df=22)	0.352 (t=0.953; df=20)	0.241 (t=1.282; df=7)
	Present	0.546 (t=0.866; df=1)	0.421 (t=0.930; df=3)	0.466 (t=0.747; df=16)
	Absent	0.686 (t=-0.415; df=11)	0.271 (t=1.172; df=9)	0.981 (t=-0.030; df=1)
	Present	0.307 (t=1.228; df=3)	0.521 (t=-0.690; df=5)	0.707 (t=0.385; df=13)

Table 7 Average age at death (years) for males and females with evidence of each stress lesion compared by arm position

		CO	PH	EHL
MALES	Arm position A	42.5	37.0	38.1
	Arm position B	33.5	29.4	34.9
FEMALES	Arm position A	40.0	26.0	33.8
	Arm position B	29.5	30.4	32.3

Table 8 Percentage of individuals with arm position A and arm position B that show evidence of CO, PH, and EHL

	CO	PH	EHL
Arm position A	10%	15%	75%
Arm position B	24%	36%	72%