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An abstract of
A thesis submitted to the Faculty of Emory College of Arts and Sciences
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Abstract

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The skeletal record reveals little information regarding the actual age at which particular conditions arise within a population. Epidemiological analyses have attempted to illuminate the effects of skeletal age on the prevalence of health disparities within skeletal samples. Paleodemography maintains a fundamental focus on age distributions in mortality profiles and understands the role of age as a confounding variable in paleoepidemiological analyses. This relationship is evaluated by comparing mortality profiles to the distribution of pathologies, trauma, and stress indicators in skeletal samples. This approach however, neglects the potential for an increase in the exposure to various health risks over time. As a proposed remedy, this study evaluates the potential for employing the person years construct (Glencross and Sawchuk 2003) as a more accurate way of gauging age-adjusted prevalence of indicators of overall health, specifically skeletal stress indicators, within skeletal samples. This method measures the length of exposure for each individual as well as the mortality profile of a given sample, while also attending to the potentially confounding effect of these two factors on the prevalence of pathologies and stress indicators. To evaluate the utility of this alternative approach, the frequency of cribra orbitalia and trauma/fractures in relation to skeletal age for several well-studied skeletal samples from Sudanese Nubia (350BC-1500+AD) was determined using three different calculations: prevalence, age-adjusted prevalence, and person-years adjusted prevalence. Throughout the study a notion of cumulative person years was devised and calculated for the two conditions as well. Results show a potential for gauging *when* particular conditions most affect a population. Further studies may have implications for improving the accuracy of interpretations of age-related patterns in overall health, trauma, and evidence of disease in skeletal samples.

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TABLE OF CONTENTS

INTRODUCTION

Many epidemiological analyses have attempted to elucidate the effects of skeletal age on the prevalence of health disparities within skeletal samples (Todd 1921; Armelagos 1969; Ubelaker 1978; Lovejoy and Heiple 1981; Van Gerven and Armelagos 1983; Glencross and Sawchuk 2003; Baker and Pearson 2006). This emphasis relates to a fundamental focus on age distributions in mortality profiles in paleodemography and to the role of age as a confounding variable in paleoepidemiological analyses. The majority of studies evaluate this relationship through comparing mortality profiles to the distribution of pathologies, trauma, and stress indicators in each skeletal sample. Use of this approach however, can neglect the potential for an increase in the exposure to various health risks over time (Lovejoy and Heiple 1981; Glencross and Sawchuk 2003). As a proposed remedy to this issue, this study evaluates the potential for employing the idea of person years (Glencross and Sawchuk 2003) as a more accurate way of gauging age-adjusted prevalence of indicators of overall health, specifically skeletal stress indicators, within skeletal samples.

This paper examines three methods for calculating prevalence of disease within a population. These approaches are examined in order to compare the potential usefulness of the proposed person years construct (Glencross and Sawchuk 2003). Each prevalence is estimated from data collected on the Nubian population. The sample populations used in this paper are from the Kulubnarti (AD 550-1500+) and Wadi Halfa areas of Ancient Nubia (Swedlung and GJ 1969; Van Gerven, Sandford et al. 1981). From the Wadi Halfa group, data from the North Argin X-Group (NAX) was examined (A.D. 350-550) (Armelagos 1969). The application of person years should prove a more accurate reconstruction of particular diseases and/or skeletal stress indicators in the Nubian population, revealing a decreased prevalence in relation to the crude prevalence.

BACKGROUND

Bioarchaeology is a discipline under which paleoepidemiology thrives. Paleoepidemiology aims to perfect epidemiological methods in order to discover disease determinants in past populations (Mendonca de Souza, de Carvalho et al. 2003), using the concepts of bioarchaeology to then reconstruct that society. Over the decades bioarchaeology has given us the tools to contextualize and reconstruct human populations from archaeological skeletal samples. It combines skeletal biology and archaeology with an anthropological perspective in order to more fully understand how people lived (Armelagos 2003; Beck 2006). Paleoepidemiology does this through examination of disease (Mendonca de Souza, de Carvalho et al. 2003).

The roots of behavioral reconstruction can be traced back to the 1800s. Anatomists and physicians like Rudolf Virchow and Julius Wolff focused on ideas of plasticity and adaptability of the human body. Others like Aleš Hrdlička improved the typological approach towards morphology (Pearson and Buikstra 2006), amassing an impressive collection of remains in order to study variation within the shapes of the femur and tibia (Buikstra 2006; Pearson and Buikstra 2006). Studies like this made it possible to develop comparative standards on which to base future findings. It was Earnest Hooton who understood what power this information held, entering into a more comprehensive study of populations.

Hooton remains was a leader in developing a biocultural reconstruction approach. He focused on incorporating archaeology and physical anthropology in order to reconstruct the lives of the individuals at Pecos Pueblo (Beck 2006; Buikstra 2006). Armelagos studied this approach in his examination of "bioarchaeology as anthropology" (Armelagos 2003), highlighting Hooton's desire to combine the two disciplines. In partnership with A. V. Kidder, Hooton pioneered a more multidisciplinary approach to reconstruct populations of the past. Hooton was also among the first to examine age differences in the prevalence of different diseases (Beck 2006), breaking ground into the realm of paleoepidemiology.

Paleodemography focuses on reconstruction at the population level (Angel 1969; Frankenberg and Konigsberg 2006). Angel (1969) saw the possibilities of discovering age composition, mortality, longevity, fecundity, family size, etc. from a partnership with other disciplines. Many agree that a cooperation with paleodemography can reveal important aspects of cultural practices or nutritional climates (Angel 1969; Buikstra and Cook 1980; Mittler and Van Gerven 1994; Meindl and Russell 1998; Armelagos; Mendonca de Souza, de Carvalho et al. 2003; Frankenberg and Konigsberg 2006; Dutour 2008), especially in regards to paleoepidemiology.

Hooton's methodologies also broke ground, working with T. Wingate Todd in order to establish age-at-death profiles (Beck 2006). At the time of Hooton's new approach, standardizations for assessments of age-at-death were also being developed. Researchers like both Todd and Hooton began to see the importance of establishing such universals as the field was beginning to orientate toward both intra- and inter-population comparisons (Beck 2006; Frankenberg and Konigsberg 2006) These standards have become an essential factor in population reconstruction and cultural analysis (Lovejoy and Heiple 1981), and remain essential to paleoepidemiology.

Some (Armelagos 2003) since have elaborated upon and critiqued Hooton's theories and approach to bioarchaeology. Others have argued that paleodemography has its limits (Bocquet-Appel and Masset 1982; Wood, Milner et al. 1992). With paleoepidemiological analyses, issues regarding demographic collection must be addressed since many interpretations rely on the influence of such data (Lovejoy and Heiple 1981; Mittler and Van Gerven 1994; Meindl and Russell 1998; Glencross and Sawchuk 2003; Mendonca de Souza, de Carvalho et al. 2003; Dutour 2008). Wood, Milner et al. (1992) focus on the reconstruction of health characteristics of past populations and the troubles such research may bring. They also concentrate on the issues of dealing with incomplete records and remains of past populations. Their notion of an "Osteological Paradox" addresses the potential problems with inferring health data of past populations considering these collection issues (Wood, Milner et al. 1992). Collection methods and levels of preservation may limit specific conclusions, though paleoepidemiological methods are striving to draw more accurate conclusions even with these errors in mind (Lovejoy and Heiple 1981; Van Gerven and Armelagos 1983; Mittler and Van Gerven 1994; Glencross and Sawchuk 2003).

Boquet-Appel and Masset (1982) are others who believe that interpretation can only go so far, and that others have attempted to extract information that does not exist. They hone in on the concept of age, asserting that the methodologies for calculating age at death are many but flawed. Their focus on the "classification error" of age structures is the basis for their argument that demographic data cannot lead to accurate cultural reconstructions. Their struggle to find merit in claims of comparative demographic anomalies forces them to conclude that paleodemography should no longer be considered an accurate approach to cultural reconstruction (Bocquet-Appel and Masset 1982). Again, issues within paleodemography inherently carry over into paleoepidemiology, as analyses of disease require an accurate demographic representation of the population. Such problems must be considered.

Van Gerven and Armelagos (1983) decided to tackle this “farewell” head-on, aiming to show that perhaps these issues with accurate data collection may not be the end-all to interpretation. They tested Boquet-Appel and Masset’s claims that skeletal samples are “passive reflections of reference populations” (Van Gerven and Armelagos 1983, 354) with two Nubian populations. Their calculations proved that skeletal age does in fact reveal much about a population and can be quite valuable in understanding age-related changes in the skeleton. Their criticism of Boquet-Appel and Masset’s dismissal of paleodemographic concepts exposed the potential for such data to actually benefit interpretations of populations rather than inhibit our understandings (Van Gerven and Armelagos 1983).

As it has been shown, paleodemographic concepts and the issues that arise with them are very much essential to a discussion of paleoepidemiology. De Souza et al. (Mendonca de Souza, de Carvalho et al. 2003) describe paleoepidemiology as a study of past epidemiological conditions; a focus on the factors that affect the health and illness of populations (Mendonca de Souza, de Carvalho et al. 2003; Dutour 2008). However without mention of age, disease and sex data hold little power. It is difficult, if not impossible, to talk about the disease conditions of the past if we do not understand *when* individuals are inflicted with or succumbing to that illness. In combination these two disciplines allow for a biocultural interpretation of populations based on trends of disease and age. Such information has the power to break down a society and permit researchers to examine the ways in which particular diseases or afflictions affect those people (Armelagos 1969; Mendonca de Souza, de Carvalho et al. 2003; Frankenberg and Konigsberg 2006; Dutour 2008).

One of the most popular ways to do this is with prevalence analysis, a measure of the total number of cases of a particular disease in a population at a given time (Mendonca de Souza, de Carvalho et al. 2003; Dutour 2008). Prevalence is a key component in the reconstruction of human populations, at least in regards to trauma and disease. Most often “crude” prevalence is used, simply examining the ratio of the number of cases of the studied pathology divided by the total number of skeletons (Glencross and Sawchuk 2003; Mendonca de Souza, de Carvalho et al. 2003; Dutour 2008). This method is certainly the most basic and does not take into account the state of preservation (Dutour 2008) or length of exposure to a particular disease or health disparity (Lovejoy and Heiple 1981; Glencross and Sawchuk 2003; Baker and Pearson 2006). In populations that present incomplete skeletons, it is impossible to record every instance of trauma or disease. Therefore calculating the crude prevalence will not reveal an accurate measurement of the distribution throughout the population. This approach to prevalence also does not take into account length of exposure, or the increased likelihood to develop a condition over time (Lovejoy and Heiple 1981; Glencross and Sawchuk 2003).

Crude prevalence is most useful for analysis of living populations when trying to measure the overall impact of an event like a flu or tuberculosis epidemic. It is also quite applicable to populations whose disease distributions are not linked to age. When the age structures of two or more populations are similar, there is no need to compensate for any discrepancies. When comparing prevalence in populations whose age distributions are not equivalent, however, age adjustments may be required (Pearson and Buikstra 2006).

Osteological preservation always poses difficulties in discussions of ageing (Lovejoy and Heiple 1981; Glencross and Sawchuk 2003; Pearson and Buikstra 2006; Dutour 2008). Because of this the age distributions of comparable populations may be very dissimilar. Age-adjusted prevalence accommodates for this notion by using a control population on which to base the analysis. This approach can be very telling when examining trends within and between populations, allowing for that necessary comparable structure. Baker and Pearson (2006) examine the impact of this approach with analysis of osteoarthritis data within the American Great Basin, highlighting the necessity for equivalent age distributions. This approach is crucial when addressing multiple populations, though it still essentially speaks of crude prevalence. With the hopes of obtaining more information from skeletal remains, methods have been proposed that consider years at risk or length of exposure.

In 1981, Lovejoy and Heiple introduced several procedures that approached prevalence data a little differently, examining traumatic lesions in skeletal populations while keeping in mind length of exposure (Lovejoy and Heiple 1981). Prior to these ideas, fracture analysis was more descriptive and less quantitative (Ortner and Putschar 1981). Instead, these two wanted to highlight the potential such fracture or trauma data could reveal. Using the Libben population from Northern Ohio they calculated fracture prevalence per set age group in order to fully understand any patterns occurring throughout the population. They stress the importance of total years at risk per age group, arguing that the “age of death of an individual with a fracture tells us nothing about the actual age at which it occurred” (Lovejoy and Heiple 1981). The analysis allowed them to see where the fractures were occurring, and at what age individuals were more likely to experience a fracture. They concluded that the fracture patterns indicated accidental trauma, and that the society experienced little intra and extra populational assault (Lovejoy and Heiple 1981).

Glencross and Sawchuk were intrigued by this paper, and expanded on the concept of years at risk. Their person-years construct (Glencross and Sawchuk 2003) measures the length of exposure for each individual as well as the mortality profile of a given sample, while also attending to the potentially confounding effect of these two factors on the prevalence of pathologies and stress indicators (Glencross and Sawchuk 2003). Glencross and Sawchuk’s use of person years in the prevalence calculation of fractures in the Indian Knoll and Late Woodland Libben sites shows a definite change from the crude prevalence rate of fractures in the same population. This illustrates that years at risk truly impacts the overall prevalence of a disease within a population. (Glencross and Sawchuk 2003).

Ultimately incidence gives more insight into a population, allowing us to examine *when* a particular disease or trauma emerges. In paleopathology, such incidence is difficult, if not impossible, to discern as skeletal evidence merely shows what occurred at the time of death (Lovejoy and Heiple 1981; Glencross and Sawchuk 2003; Baker and Pearson 2006; Dutour 2008). Lovejoy and Heiple focused on the analysis of a single population while Glencross and Sawchuk applied the notion of person years in order to develop a cross-population study. This study applies the concept of person years to individual age categories, giving an idea as to what age more fractures are occurring for every year people are living. This may not be a direct representation of incidence, but it is moving towards it.

This paper explores how interpretations of data can change according to various approaches to prevalence. There are specific health disparities for which age categorization may confound prevalence data due to their etiology. This paper focuses on two conditions, the first being bone fractures or trauma due to their association with age or risk. To recall, years at risk take into consideration that skeletal samples present a cumulative record. Without the means to specify when a particular event occurred, age at death will reveal little useful information (Mendonca de Souza, de Carvalho et al.). In the case of this paper, expressing fractures as a function of the total years each individual was subjected to risk of fracture should reveal the periods in which fractures occur at higher rates. It also may begin to shed light on the incidence of trauma throughout this population. This information could then allow for a more accurate reconstruction of the social climate.

For a biocultural reconstruction, fractures or traumas are often divided in terms of lesions on the crania and post-crania. Fractures throughout the skeleton can reveal possible causations, or even predict whether the injury was purposive or accidental (Ortner and Putschar 1981). As an example, based on the location of a fracture on the radius or ulna, one can hypothesize whether an individual fell or was fending off an assault (Lovejoy and Heiple 1981; Ortner and Putschar 1981). Cranial trauma can reveal similar patterns. Based on the severity of the blow or the locations of multiple fractures, it may be implied that an individual was a victim of a weapon blow or possible domestic abuse (Ortner and Putschar 1981). Lovejoy and Heiple (1981) were able to examine the Libben population and conclude that a number of individuals were victims of accidental trauma rather than intra or extra population assault. From this it can be seen that prevalence data has this potential to paint social climates from trauma.

The second condition this paper focuses on is cribra orbitalia. It is one of the most commonly reported pathologies (Walker, Bathurst et al. 2009) and easily recognizable by pitting and porosity in the orbital roofs. Such a reaction occurs with the expansion of the diploe (spongy bone) in response to marrow hypertrophy (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009). The causation of this particular condition has been debated for decades. The most popular interpretation of the lesions is in favor of anemia, and more specifically of iron-deficiency anemia (Stuart-Macadam 1992; Walker, Bathurst et al. 2009).

Etiologically, anemias can be either genetic or acquired (Walker, Bathurst et al. 2009). Blood loss and nutrient deficiencies tend to be common in areas with dietary deficiencies and unsanitary living conditions (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009), however other explanations include instances of prolonged breastfeeding and gastrointestinal infections. In any case, genetic anemias like thalassemia and sicklemia are more rare (Walker, Bathurst et al. 2009).

Iron is vital to maintain red blood cell (RBC) homeostasis. In areas where environmental conditions favor a poorer diet and modest living conditions, children are more often affected by anemia since they have more difficulty sustaining an increase in RBC production (Stuart-Macadam 1992; Walker, Bathurst et al. 2009). As such they are therefore more likely to display cribra orbitalia in the archaeological record than adults (Walker, Bathurst et al. 2009). A person years analysis of cribra orbitalia prevalence in younger ages could shed light on health patterns in the population studied. It may also be able to highlight its affect on the population's ability to survive the affliction. Data revealing higher numbers of adults with a recorded presence of cribra orbitalia than another population might suggest a greater buffer against anemia (Wood, Milner et al. 1992).

Political Economy and Cultural History in Nubia

The poor nutritional quality and political instability of life in Nubia is well documented (Armelagos 1969; Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995). During the time of political unity and stability, the mortality among infants and children was substantially higher. To further confound things, nutritional data shows that health was at its best during the NAX period (Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995). Fracture data also appears in the Nubian archaeological record and suggests intentional injury (Armelagos 1969).

The archaeological record indicates that the Meroitic and Christian periods experienced a cultural growth and development due to political and economic stability, whereas the NAX period saw a restructure of cultural practices. Armelagos argues, however, that the NAX period may have actually had more cultural advantageous compared to the Meroitic period (Armelagos 1969). Further pathological studies may shed light on the true nature of these periods.

MATERIALS

The sample populations used in this paper are from the Kulubnarti (AD 550-1500+) and Wadi Halfa (NAX-A.D. 350-550) sites at Nubia, which sits at the intersection of modern Egypt and Sudan (Figure 1) (Armelagos 1969; Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995). Wadi Halfa was situated in Lower Nubia where environmental conditions are quite harsh (Armelagos 1969; Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995). The NAX group was flanked by two other time periods: Meroitic (350 BC – AD 350) and Christian (AD 550-1300).

The individuals at Kulubnarti are divided into two cemeteries: S and R. Both located in Upper Nubia, the S cemetery dates to the early Christian period (AD 550-750). The second set of individuals was excavated from the R cemetery, dating to later Christian times (AD 750-1500+). These cemeteries lie within the region known as Batn el Hajar, an environmentally harsh and barren area (Hummert and Van Gerven 1983).

METHODS

The two data sets are taken from the Nubian population in the 1960s (Armelagos 1969). In the NAX population at Wadi Halfa there are 110 individuals, and at Kulubnarti there are 303 individuals divided between the two cemeteries (R and S).

The individuals in the NAX population at Wadi Halfa were aged using Todd’s developed methodology (Todd 1921) and the McKern Stewart method (Swedlung and GJ 1969). The appearances of the pubic symphyses were assigned to one of ten phases. When an individual did not fit strictly to one age category, the midpoint of multiple age brackets was assigned as the absolute age. For this paper, in an attempt to reconstruct the age displacement of the NAX population most accurately, the individuals were placed back into Todd's original age structures, with one correction. For those age categories in which overlap occurred (i.e. 27-30 and 30-35), the second category was altered to remove the overlap (i.e. 27-30 add 31-35). Additionally, when age at death for an individual was under 18 years, they were placed into a newly developed category of 0-17 years.

The individuals in the Kulubnarti population were also aged using Todd's symphyseal methodology, however the sub-adults were estimated with Ubelaeker's dental eruption charts (Ubelaker 1978). Due to the childhood nature of cribra orbitalia and the questions sought by this paper, individuals were placed into different age categories than those in the NAX population, placing more specificity in those under 18 years of age.

The NAX data set of trauma and fractures were collected from the original recording cards used during excavation that now reside at Emory University. Lesions on the crania and post-crania were recorded. Fracture/trauma data was as follows: Presence or absence of pathology (0/1), Trauma or fracture (0/1) location on the skeleton, and total number of pathologies per individual. The cribra orbitalia data was obtained from Mittler and Van Gerven (Mittler and Van Gerven 1994).

Based on the questions being asked or the nature of the particular disparity, the data was analyzed using any of three methods. Crude prevalence was calculated for both the NAX and Kulubnarti populations. Age-adjusted prevalence was used to evaluate the Kulubnarti sample for both the presence/absence and active/inactive lesion data of cribra orbitalia. Person years prevalence was applied to both populations as well. Cumulative person years was also calculated for both populations (Campbell 2010).

In order to determine the statistical significance of the prevalence equations on the cribra orbitalia data, a chi-square test was used for both crude prevalence and age-adjusted prevalence. To test for significance in regards to person years, a Poisson distribution and Z-statistic was calculated (Glencross and Sawchuk 2003). These statistics were calculated because of the comparative examination (e.g. R vs. S and Active vs. Inactive).

Because there is not a comparative study of trauma, no statistics were performed to test for significance of the NAX data.

RESULTS

Of all 110 individuals in the NAX sample population, 14 showed instances of trauma or fractures. In particular, 11 occasions of trauma were recorded; 4 cases on left parietals and 7 cases on frontal bones. There were only 3 fractures recorded, with 2 cases on left ulnas and 1 on a right radius. Of the 14 cases of trauma or fracture, 8 occurred in males and 5 occurred in females. One individual had no recorded sex. The fractures all demonstrated a process of healing.

With these numbers, the crude prevalence within the NAX population (both trauma and fracture) is 0.13 or 13%. Taking into consideration years at risk, the person years prevalence is 0.004 or 0.4%. Crude prevalence demonstrated a higher frequency of fractures in the 36-39 year age group (Figure 2) while cumulative person years suggested that the fractures occurred between the ages of 27 and 30 (Figure 3)

Of the 303 individuals in the Kulubnarti samples, 135 displayed signs of cribra orbitalia and 34 of those individuals were recorded with active lesions. The significantly (P=0.025) higher frequency of cases within the S cemetery is consistent with previous research (Mittler and Van Gerven 1994). Also, the confinement of active lesions to children under the age of 12 is statistically significant (P=0.002) and confirms previous assumptions about the childhood nature of cribra orbitalia (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009).

The age-adjusted prevalence decreases for the S cemetery (0.51-0.46 for present lesions and 0.36-0.29 for active lesions) but increases for the R cemetery (0.39-0.41 for present lesions and 0.13-0.15 for active lesions). However the age-adjusted proved not to be statistically significant (P=0.35 for present lesions and P=0.37 for active lesions). This may be due in part to a difference in age structure regarding where cribra orbitalia shows up in the archaeological record.

DISCUSSION

Trauma and fracture data can often be very telling about a population’s social culture. When presented with complete disarticulated skeletons, a fracture pattern can be discerned. From observations of fracture or trauma location, it is possible to ascertain whether the population displays a habit of accidental incidence, or if there is a trend of defensive wounds or attacks (Lovejoy and Heiple 1981; Ortner and Putschar 1981; Glencross and Sawchuk 2003). Either way the historical record along with archaeological evidence lends to a more complete interpretation. In the case of Lovejoy’s and Heiple’s

Libben population, fracture patterns indicated accidental instances of trauma (Lovejoy and Heiple 1981).

Certain biocultural reconstructions may be ascertained by the location of these cranial fractures or traumas. Typically cranial fractures located on the parietal or frontal bones point towards evidence of intentional violence rather than incidents of accident (Ortner and Putschar 1981). It could be argued that because of a majority of traumas lie on the crania in this sample, that there may be evidence of purposive violence. Distribution of sex may shed further light on this notion.

Although the instances of cranial trauma in this population were equivalent between males and females, the males demonstrated more cases of parietal trauma whereas the females showed more instances of trauma to the frontal bone. Males showed 2 cases of parietal trauma and 3 cases of frontal trauma, whereas females showed 4 cases of frontal trauma and 1 case of parietal trauma. Trauma to the front of the skull may result from a type of frontal assault or domestic abuse, whereas parietal damage could have happened as a result of fighting (Lovejoy and Heiple 1981; Ortner and Putschar 1981). In examination of the females, every fracture or trauma occurred on the crania, supporting a claim of instances of domestic violence. The latter might be explained by the feudal period during which the NAX population existed (Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995).

Although the implications of causation are an important part of the anthropological analysis of the Nubians, this paper focuses on the effect of prevalence data on the interpretation of disease or trauma data relating to age. Between crude and cumulative person years, the prevalence suggests very different scenarios. Upon looking at the graph (Figure 2) of crude prevalence, it appears that most fractures are occurring between 36 and 39 years of age. Though we must take into consideration that the recorded fracture did not necessarily happen at the age of death (Lovejoy and Heiple 1981). Figure 3 illustrates the cumulative person years prevalence broken down into the age categories.

Although we cannot retrieve incidence data from the archaeological record (Dutour 2008), cumulative person years allows us to get a better idea of at what age more fractures are occurring for every year people are living. This graph (Figure 3) suggests that in fact the fractures are more likely to occur between 27 to 30 years of age. We must consider that the majority of fractures recorded in this population are located on the crania. Although warfare might explain the presence of cranial fractures (Lovejoy and Heiple 1981; Ortner and Putschar 1981) considering the age at which these fractures are occurring, it could be argued that males may be actively involved in fighting, whereas females may also be involved but on an unintentional level.

It is also possible that high activity levels could explain fractures in this particular age group. However as mentioned before, Nubia is predominately a desert environment (Armelagos 1969; Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995), making the occurrence of fractures from a fall rather unlikely. Lovejoy and Heiple's (1981) findings confirm that the cranial location make such conclusions of activity-induced fracture improbable.

Mittler (1994) has previously examined the cribra orbitalia data from Kulubnarti, and her findings are consistent with this study. The crude prevalence of the pathology in its active state in both the R and S cemeteries is restricted to individuals under the age of

12 (See figures 6 and 7). This data is consistent with the notion that active cases of cribra orbitalia are limited to infants and children (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009). The data also confirms the idea that some adults manage to survive the affliction (Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009), showing signs of porotic lesions past the age of 12 (Figures 4 and 5)

The crude prevalence shows a lack of cases under the age of 1 for the R cemetery (Figure 4). There is also a higher death rate in the S cemetery. In relation to the Osteological Paradox (Wood, Milner et al. 1992), this suggests that everyone in the S cemetery under the age of 1 has little, if any, buffer from physiological stress. This would explain why there are more cases of crib in the first age bracket. It may not be that R cemetery is experiencing fewer conditions of crib in children less than 1 year, but rather that they are able to survive longer.

Upon examination of the cumulative person years prevalence, the data illustrates another well researched concept. It has been shown that iron deficiency is rare during the first 6 months of life as the iron stores in utero continue to work for the infant (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009). Cumulative person years in the S cemetery for active cases show a tendency for infants to become anemic before the age of 1 (Figure 9). However because the data does not always specify the age, it cannot be definitively determined if all of the infants are under 6 months of age. The R cemetery is slightly off, as the results suggest that development of anemia is not occurring until at least the age of 1 (Figure 8), though it certainly supports the notion that children develop anemia past the 6-month mark. It must be noted that this may be because we have no data before 1 yr old in this sample.

It is interesting that the majority of active cases in the S cemetery are concentrated in individuals less than 1, while children between 6 and 11 are most affected in the R cemetery (Figures 6 and 7). Not only that, but the frequency of cribra orbitalia is much higher in the S cemetery than that of the R cemetery (Figures 6 and 7). In fact the prevalence is almost double that of the R cemetery. Mittler argues that this could be due to the fact that levels of stress may have contributed to longer lasting childhood anemia in the earlier Christian period (S cemetery) in Nubia (Mittler and Van Gerven 1994). Due to the presence of anemia in both the R and S cemeteries it is obvious that poor nutrition and environmental conditions were present during both the earlier and later Christian periods. However the evidence supports Mittler's claims that those in the S cemetery were more affected (Mittler and Van Gerven 1994).

It is obvious that certain calculations of prevalence hold more water than others in regards to when they are used. For the purpose of trauma and fractures, person years and cumulative person years serve rather well. Not only do they give a more in depth look at the population in regards to fracture occurrence, but they also allow for discussion over what age more fractures are occurring for every year people are living.

In the case of cribra orbitalia, the notion of person years is not very strong. It may be more effective if juveniles under the age of 12 were examined in more detailed age groups. It does not speak much to the population as a whole, considering the affliction itself is mostly restriction to children while in its active state.

Limitations

Of course as is with any study, there are inherent limitations. Although there are many individuals in these sample populations, some of the original data cards used for collection are not complete. As is the nature with many excavations, not all elements of the collection's crania and post crania are available for observation. As such, not all cases of cribra orbitalia or trauma and fractures may have been recorded. Or, as another possibility, trauma in childhood may be concealed with the remodeling of the skeleton (Ortner and Putschar 1981), and therefore true trauma patterns may not be discerned.

These particular populations were excavated in the 1960s, at a time when standards for data collection were just hitting the scene. Todd's pubic symphysis ageing technique may have been revolutionary for the time (Beck 2006), however methodologies have since arisen that modified the criteria to better estimate age at death (Buikstra and Ubelaker 1994). In order to be more specific for these individuals with transitional symphyses, Armelagos and Van Gerven (1983) assigned a midpoint of certain phases as the absolute age. Because of this, it is uncertain whether the recorded ages are truly an accurate reflection of the population's age distribution. As a result, some individuals may have been over-aged or under-aged. Due to the nature of this paper and the need for age at heath data, it is possible that the results of this study could benefit from further research and attention.

While the concept of years at risk is not exactly new (Lovejoy and Heiple 1981), the notion of person years has not been thoroughly explored or tested. As such the calculations have had little chance to be expanded upon. It must be taking into consideration that, like with any equation, there may be room for improvement.

There is another aspect of the methodologies used in this paper that is due attention. In order to assess years at risk, age categories were derived from Todd's original pubic symphyses phases (Todd 1921). However in order to account for the absolute ages proposed by Armelagos and Van Gerven (1981), certain phases had to be altered. These categories that shared ages (i.e. 27-30 and 30-35) were changed to so that no overlap occurred (i.e. 27-30 and 31-35). Although this allows for easier data processing, the potential error in the initial ageing method further carries over into this analysis.

Cribra orbitalia is a tricky case. Research already shows nutritional deficiencies within the Nubian population (Van Gerven, Hummert et al. 1990; Van Gerven, Sheridan et al. 1995), so its presence is not what is curious. The issue with cribra orbitalia is that it is arguably a childhood disease (Stuart-Macadam 1992; Mittler and Van Gerven 1994; Walker, Bathurst et al. 2009). Its manifestation on the skeletal system does not necessarily equate to the presence of the disparity within an individual at the time of death (Lovejoy and Heiple 1981). Instead it may simply reflect the presence of cribra orbitalia within that individual during childhood. Therefore this study's reconstruction of age structures for the purpose of calculating years at risk may shed some light on the nutritional status of the Nubians, but might not show a true representation of cribra orbitalia at all age groups.

CONCLUSION

In the case of this paper, prevalence data confirms what is known about cribra orbitalia in the Nubian populations. Age-adjusted calculations simply allow for a more detailed look at the demographics of the affliction, and provide a better comparison between the two cemeteries. Person years prevalence reflected the same conclusions. For cribra orbitalia, person years appear to not be as effective as crude or age adjusted prevalence.

Person years prevalence and cumulative person years proved quite valuable for the trauma and fracture data. They manage to highlight the ages at which young adults in Nubia are more likely to obtain a fracture. Although the fracture number was relatively low in the same compared to reports from other areas of Nubia (Armelagos 1969), the results point to potential causations of warfare, domestic abuse, or accidental injury. The most interesting aspect of this research appears with the estimation of the ages at which individuals are most likely to obtain traumas.

Person years and cumulative person years should be further examined in other afflictions and other populations. Diseases such as spina bifida or Schistosomiasis may be perfect candidates for such evaluation due to their relation with age. Without trial and error it will be impossible to truly understand the furthest implications this methodology may have

It has always been considered impossible to discern incidence from the archaeological record. Although these approaches do not attempt to claim incidence, they do allow for a better of idea of at what age more fractures are occurring for every year people are living. As mentioned before, along with other disciplines paleodemography hopes to reveal the cultural framework behind a skeletal population. Methodological approaches like person years and cumulative person years are ways in which that reconstruction may become even more detailed.

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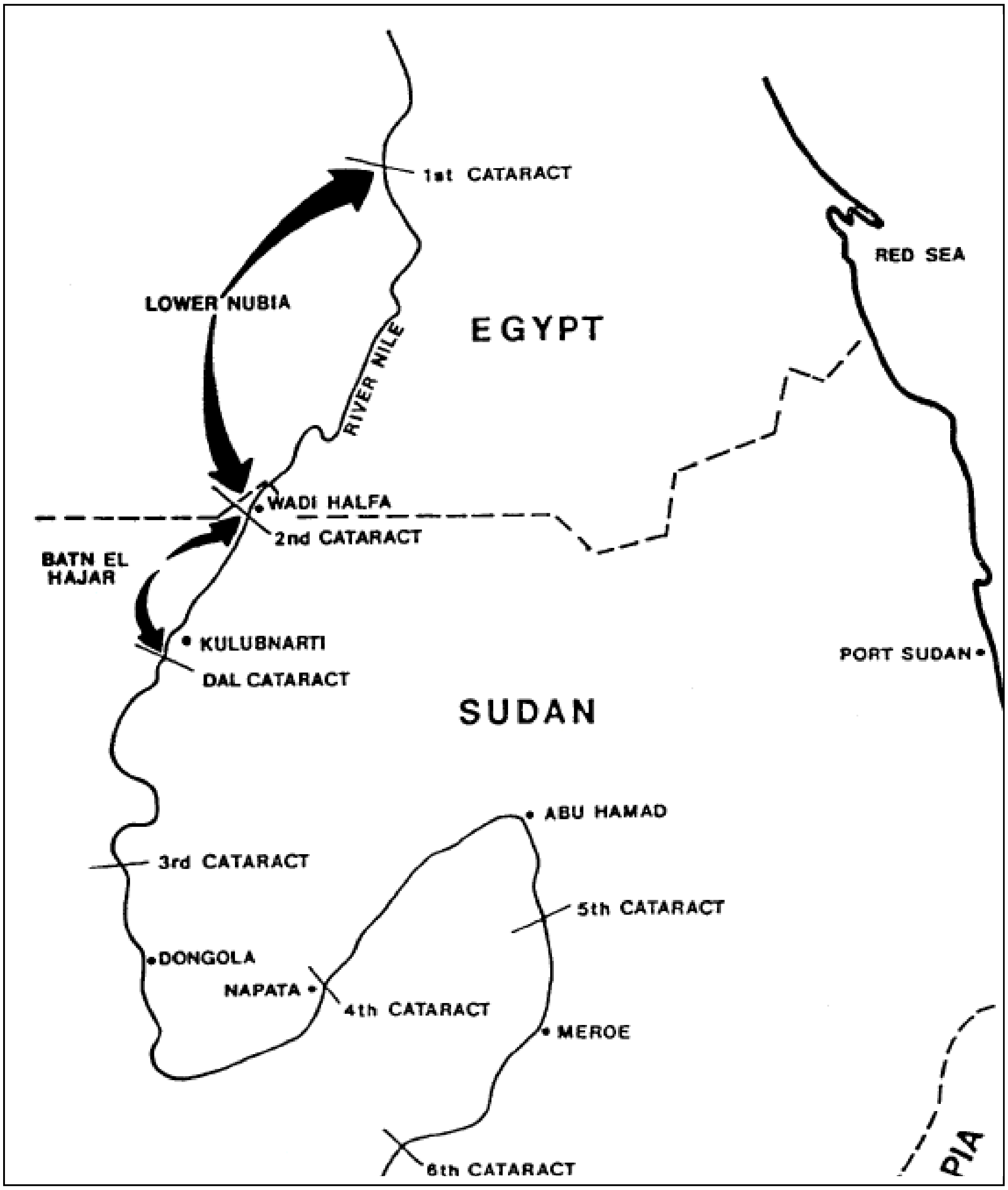
APPENDICES

Map of Ancient Nubia –
Kulubnarti (Lower Nubia)
Wadi Halfa (Upper Nubia)



Mittler and Van Gerven 1994

NAX SAMPLES

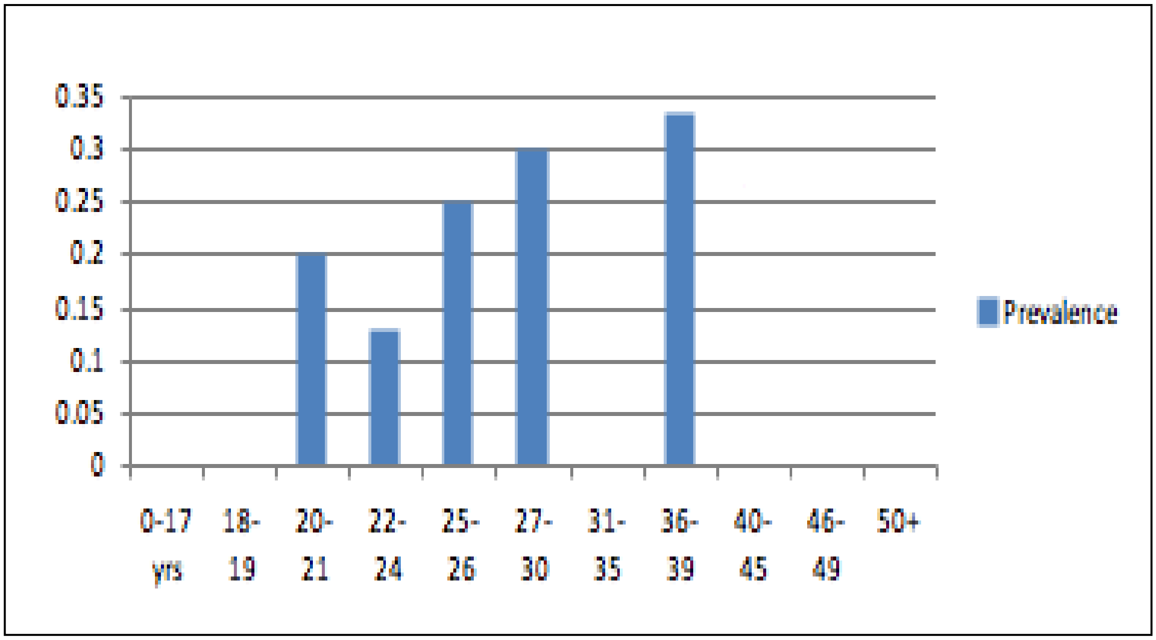


Figure 2: Graph of crude prevalence rates among NAX fracture/trauma sample

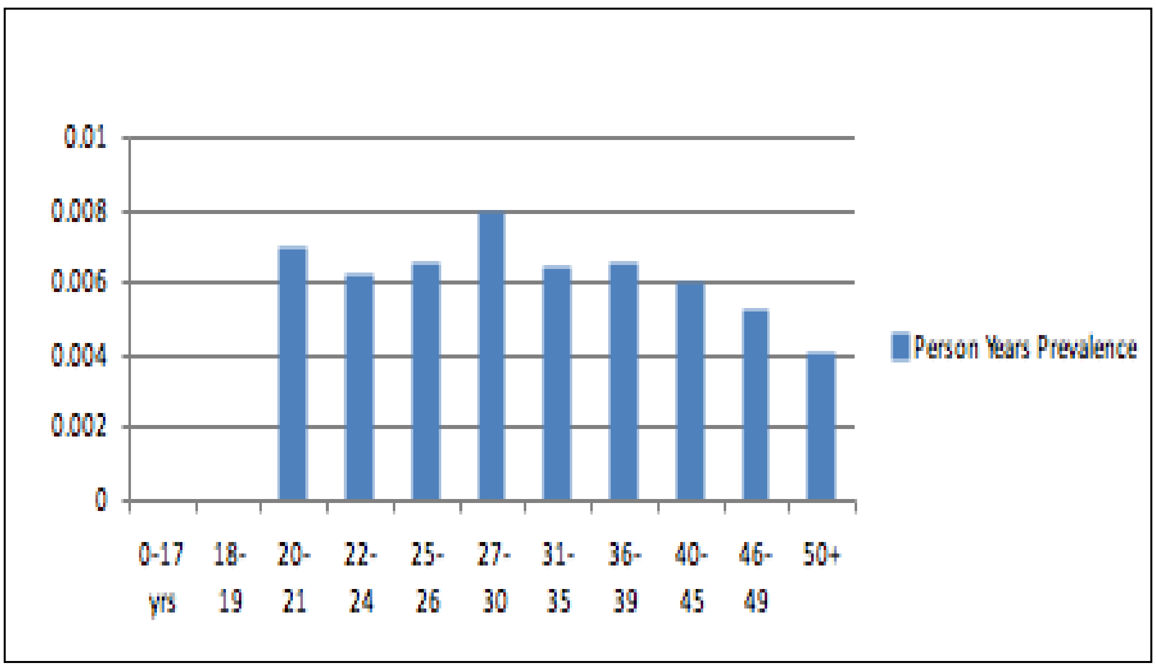


Figure 3: Graph of cumulative person years prevalence rates among NAX fracture/trauma sample

KULUBNARTI SAMPLE

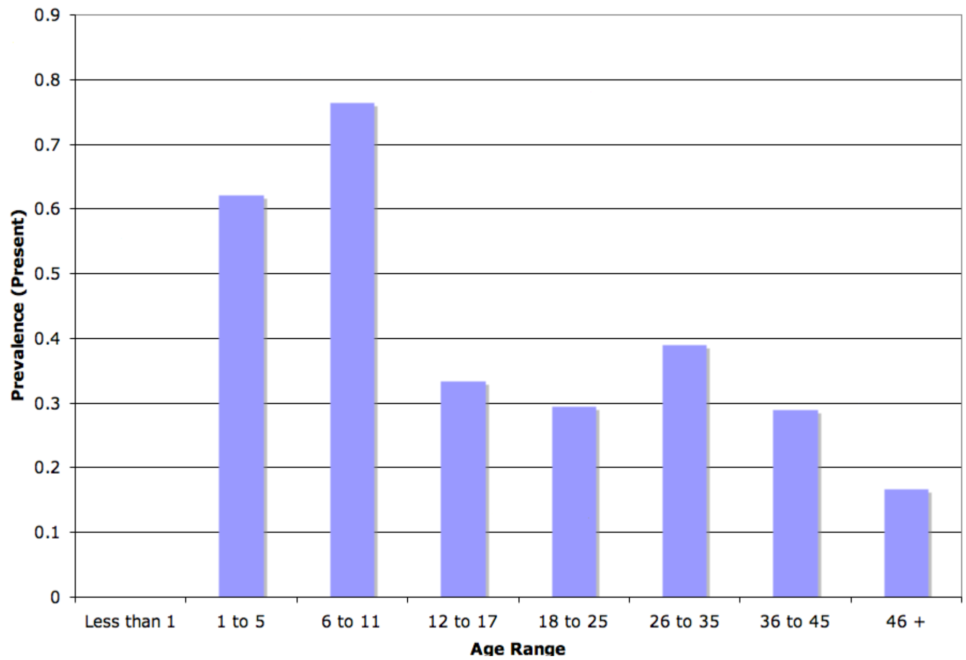


Figure 4: Graph of crude prevalence rates of present cases of cribra orbitalia among Kulubnarti R Cemetery

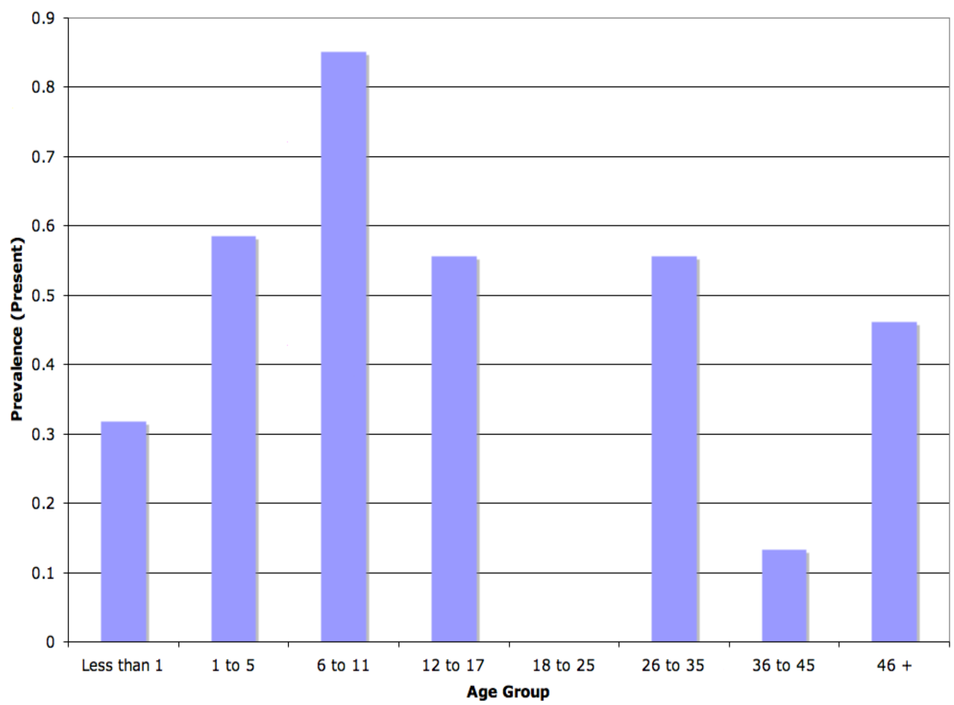


Figure 5: Graph of crude prevalence rates of present cases of cribra orbitalia among Kulubnarti S Cemetery

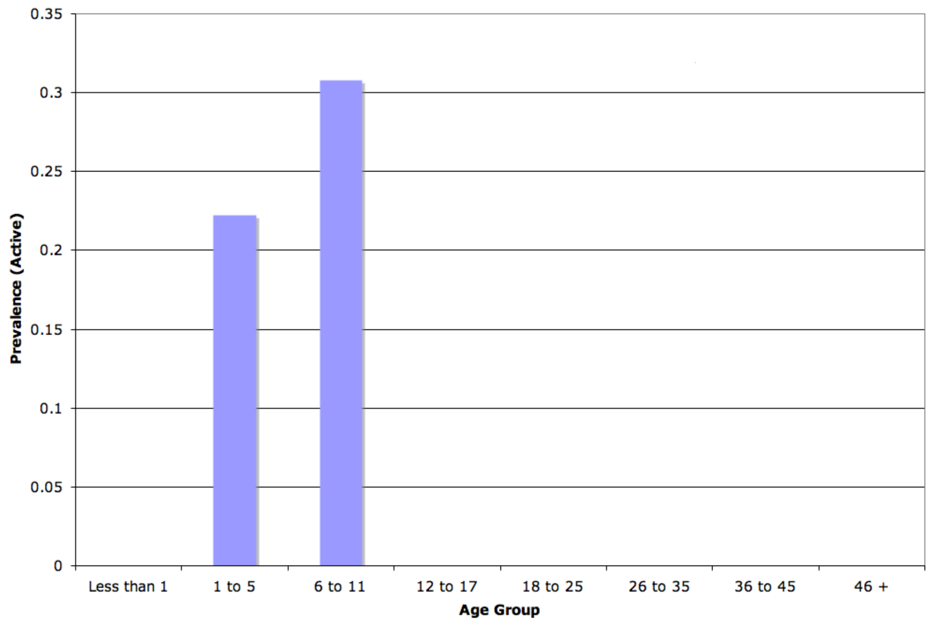


Figure 6: Graph of crude prevalence rates of active cases of cribra orbitalia among Kulubnarti R Cemetery

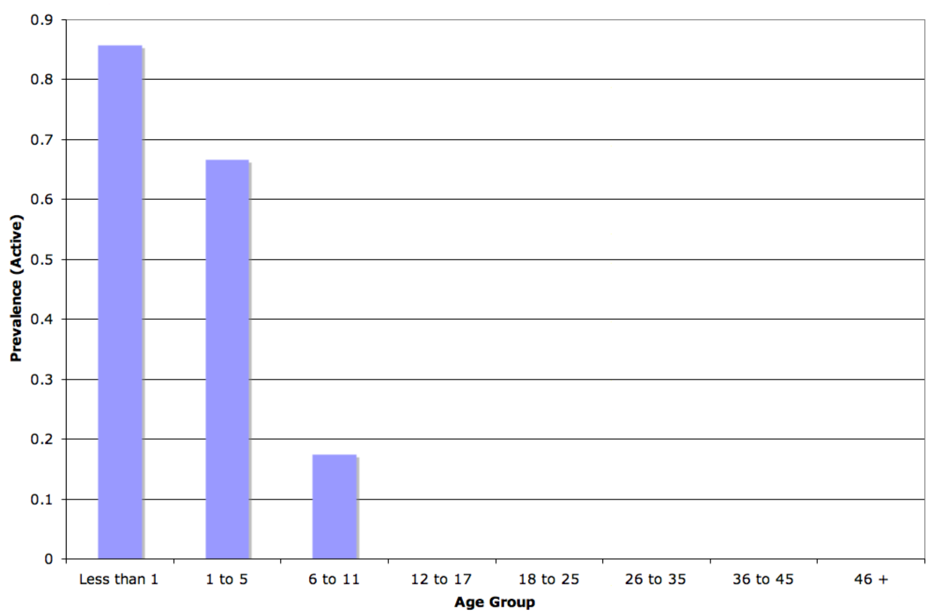


Figure 7: Graph of crude prevalence rates of active cases of cribra orbitalia among Kulubnarti S Cemetery

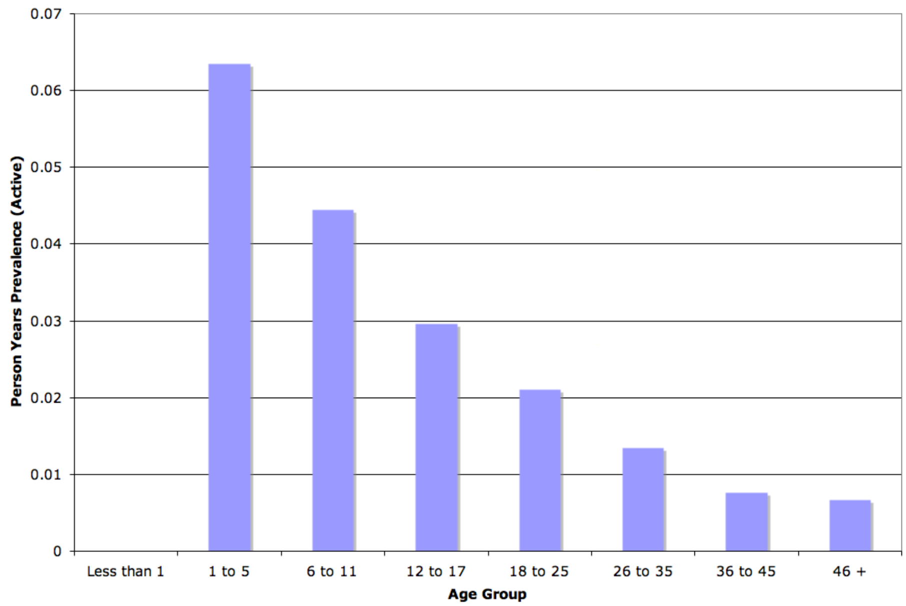


Figure 8: Graph of cumulative person years prevalence rates of active cases of cribra orbitalia among Kulubnarti R Cemetery

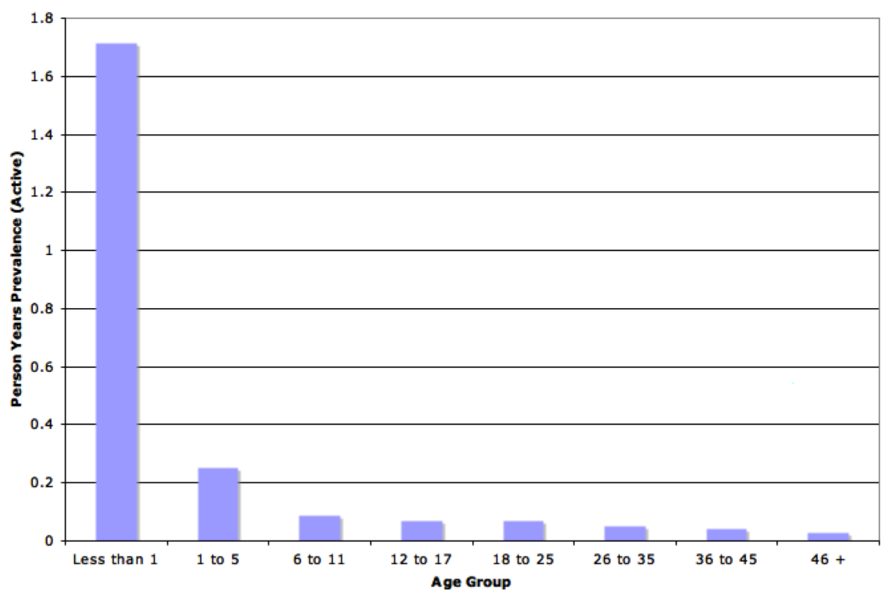


Figure 9: Graph of cumulative person years prevalence rates of active cases of cribra orbitalia among Kulubnarti S Cemetery