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Preliminary investigations of the bioarchaeology of Medieval Giecz (XI–XII c.): examples of trauma and stress

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Abstract: Human skeletal remains from past populations are an invaluable source to objectively study biological history. The combined biological and cultural assessment of bioarchaeology offers a unique perspective on the adaptation of people to their environment. This study summarizes a portion of ongoing work to decipher trends related to health and lifestyle in early medieval (XI-XII c.) Giecz, Poland. The skeletal assemblage from Giecz, the "Giecz Collection", represents a community positioned at a major center of political, economic, and religious power during this important time in Polish history. Non-violent traumatic injuries were investigated to elucidate trends related to possible types and rigor of activities and linear femoral growth trends were analyzed to assess patterns of stress. Preliminary results suggest that all members of the community (men, women, and adolescents) contributed to a lifestyle characterized by repetitive hard-work. Furthermore, it appears that most individuals suffered from health insults negatively affecting their development and perhaps their mortality.

Key words: Eastern Europe, fracture, growth, lifestyle, Poland

Introduction

Bioarchaeology involves the study of human remains from an archaeological context and utilizes a multidisciplinary approach, integrating biological data with relevant cultural data to better understand people of the past (Roberts 2012). As such, bioarchaeology contributes to the contextualized understanding of social identities as a discipline that bridges biological and social sciences. Analyzing skeletal material from an archaeological context not only aids in the understanding of past and present populations, but promotes substantial theoretical contri-

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butions to otherwise broadly conceived social sciences (Knudson and Stanjanowski 2008).

Through bioarchaeology, evaluations of injuries observed on archaeological human remains bring to light the general lifestyle conditions of past societies. Different lifestyles will affect the prevalence of skeletal injuries by element type as well as regional patterns. Not only can the immediate injuries result in skeletal defects, but the perpetuated manifestations such as arthritis or infection, are observable for those who lived with the injury thereafter (Larsen 1997).

Evaluations of stress are common in bioarchaeology, particularly in how these stresses affect growth and stature, an indicator of population health and social status. Temporal trends indicate that an increase in economic improvement and greater nutrition result in an increase in stature, and vice versa (Larsen 1997). Growth retardation is generally associated with physiological stressors, such as poor nutrition and disease, as well as genetic influences and growth hormone deficiencies (as discussed in Larsen 1997; Lewis 2007; Steckel and Rose 2002).

The aim of this work is to summarize preliminary analyses on trauma and stress in the medieval population from Giecz, Poland to identify the lifestyle and general health during this time.

Materials and Methods

Site history

The medieval time period marks an important turning point in the history of Poland. Mieszko I, of the Piast dynasty, adopted Christianity in A.D. 966, using it as a strategy to unite Polania tribes and build military strength to conquer regions of Wielkopolska (Manteuffel 1982). Under Mieszko's guidance, an independent Polish state was created in which a feudal economic system was adopted, resulting in a hierarchy of social classes and centralized power (Barford 2005; Górecki 1992). Giecz was fortified as a military center by Piast rulers as early as the 10th century (Barford 2001). However, there were at least two phases of stronghold construction at Giecz; a smaller one dating to the 9th century (pre-state hood) and a larger expansion dating to the late 10th century (Krąpiec and Krysztofiak 2003; Krysztofiak 2007). The stronghold at Giecz played an important role in formation of the Polish state and by the 11th century it served not only a military purpose, but also as a center for political administration and exchange, in addition to a residential area (Barford 2001). Since it was located along a main trade route, it was frequented by representatives of the Piast dynasty, including an associated strong military presence and those of elite status (i.e., clergymen, bishops, etc.) (Buko 2005).

According to the works of Gallus Anonymous (12th c.), Gesta Principum Polonorum (translated by Knoll and Schaer 2003), Giecz held great rank for providing some of the largest numbers of armed warriors to the Piast rulers (Buko 2008). It is reported that 300 knights and as many as 2000 foot soldiers from Giecz were mustered in the days of Bolesław the Glorious (Knoll and Schaer 2003). Duke Mieszko III claimed he had specialized laborers (decimi) in Giecz in the middle of the 12th century, although they later were released from his control (Górecki 1992). However, it is thought that most of the common residents engaged in farming and trade activities (Kostrzewski 1964).

Giecz is revered as one of Poland's most important towns between the 11th and 12th centuries (Hensel 1987; Kozak 1997). However, in A.D 1038, during the revolt of the pagans, the Czech prince Brzetysław I captured Giecz (Davies 1982) and exiled the surrendered inhabitants to Czech lands, according to Cosmas of Prague (12th c.) Chronica Boemorum (translated by Wolverton 2009). After the invasion, Giecz was once again resettled and the new inhabitants took advantage of the previously destroyed settlement site for interring their dead, at least through the 12th century (Krysztofiak 2007; Krysztofiak 2008).

The early medieval cemetery at Giecz (site Gz4) dates from the 11th–12th centuries A.D. and is located in the Wielkopolska (Greater Poland) region in Western Central Poland. Although the first excavations at Giecz were part of the Millennium project in 1949, occurring intermittently until 1966, intensive excavation of the site did not begin until 1999 and continued through 2008. The authors (AMA and HMJ) were responsible for excavation of most of the graves to-date, although it is estimated that a large portion of the cemetery remains interred. Curation and data collection of the human skeletal remains began in 2003 and continues to be directed by AMA and HMJ (Justus 2005; Justus and Agnew 2005). The skeletons excavated from site Gz4 are referred to hereafter as the Giecz Collection.

Sample

The Giecz Collection includes at least 275 burials, many of which are included in further analyses throughout this manuscript and is generally well-preserved. Taphonomic changes can mostly be attributed to modern agricultural activity. Surface finds indicate that the more shallow graves were likely destroyed and scattered. Skeletal elements with no provenience are not included in this study. However, many skeletons from deeper graves remain undisturbed with only minimal intrusion from plows. Only those burials that were largely intact and identified as belonging to a defined grave are included here.

Sex and age estimation was based on standard anthropological protocols (see Buikstra and Ubelaker 1994; Steckel et al. 2006). Methods were chosen based on tested accuracy and availability of skeletal elements. Differences in pelvic morphology was the preferred method for adult sex determination, but cranial traits were also used (see Ascádi and Nemeskéri 1970; Buikstra and Ubelaker 1994; Loth and Henneberg 1996; Sutherland and Suchey 1991). Metric methods for sex determination included measurements of the femoral, humeral (Stewart 1979) and radial (Berrizbeitia 1989) heads. To estimate adult age-at-death, methods based on pubic symphysis (Brooks and Suchey 1990; Todd 1921a; Todd 1921b) and auricular surface degeneration (Lovejoy et al. 1985; Osborne et al. 2004) were employed. Age estimation methods utilizing degenerative changes at the costochondral junction (İşcan et al. 1984; İşcan et al. 1985) were used to supplement those based on pelvic changes. Age categories were created for adult comparisons representing Young (17–34 years), Middle (34–49), and Older (50+ years) adults.

Subadult sex cannot accurately be determined from gross morphological or metric traits (Scheuer and Black

2000) and was, therefore, not attempted for the Giecz Collection. Estimation of subadult age-at-death was primarily based on gross observation of dental eruption (Ubelaker 1989) and root and crown formation (Moorrees et al. 1963; Smith 1991). Additionally, diaphyseal lengths and epiphyseal union were also considered (Fazekas and Kósa 1978; Scheuer et al. 1980; Scheuer and Black 2000). Histomorphometric techniques were also employed (Agnew et al. 2007; Streeter 2010).

Table 1 displays frequencies of individuals in each age-at-death category for the entire sample (N=275). The majority of individuals, 65%, lived to adulthood, while 35% died before reaching maturity. Most individuals died in the Middle Adult (31%) and Young Adult (20%) years, however the frequency of infant deaths is also high (17%). The large number of infant deaths is not surprising during the medieval period since the immune system is weak and especially susceptible to insults during this growth stage (Goodman and Armelagos 1989). In fact, infant mortality comprises 50% of subadult deaths in Giecz. Similarly, 47% of all adult deaths are in the Middle Adult range. Other medieval populations from Central/Eastern Europe report very low life expectancies (e.g., Hrnčířová and Jarošová 2007; Obertová and Thurzo 2008).

Table 2 provides age-at-death frequencies within each sex. Of the adults in the Giecz Collection, 58% are determined to be males and 31% females. The age distribution within each sex is similar in the Younger and Middle Adult categories, with only slightly more males (34%) dying in the Younger Adult age range than females (28%). This difference is also reflected in the frequency of Older Adults, with females representing more of this category (11%) than males (3%). This suggests that males were more likely to die younger, while females were more likely to live longer in medieval Giecz. This trend becomes more obvious if the age-at-death categories are divided by sex, rather than the sexes being divided by age. Of those that died in the Young Adult range, 67% are males and 30% are females. Within the

Table 1. Frequency table for age-at-death categories

	Age range	N	% of total N[1]	% of age-matched N[2]
Fetal	≤ birth	4	1	4
Infant	0–4 yrs	48	17	50
Child	5–10 yrs	27	10	28
Adolescent	11–16 yrs	17	6	18
Subadult Total		96	35	100
Young Adult	17–34 yrs	54	20	30
Middle Adult	35–49 yrs	84	31	47
Older Adult	50+ yrs	10	4	6
Undetermined Adult	17+	31	11	17
Adult Total		179	65	100
Total		275	100	–

[1]"% of total N" = (age category N/total number of individuals in the sample)*100.
[2]"% of age-matched N" = (age category N/number of individuals in the subadult or adult group only)*100.

Table 2. Frequency table for adult age-at-death categories by sex

	Male		Female		Undetermined	
	N	%	N	%	N	%
All Adults	105	58	56	31	17	11
Young Adult	36	34	16	28	2	12
Middle Adult	55	53	29	52	0	0
Older Adult	3	3	6	11	1	6
Undetermined Adult	11	10	5	9	14	82

Middle Adult range, 65% are males and 35% are females. However, in the Older Adult range, 30% are males and 60% are females. Since the cemetery excavation remains incomplete, it is unknown if the Giecz Collection is truly representative of the living population in medieval Giecz. However, all ages and both sexes are well represented across the sample, suggesting that the cemetery site Gz4 contains those comprising a normal population and not one restricted to only certain sectors (e.g., military troops, clergymen, etc.). It should be noted that the method chosen for age categorization is similar to that outlined in Buikstra and Ubelaker (1994), but was modified slightly to ensure sample sizes were adequate for statistically valid comparisons to be made. This approach, while useful for this study, does limit the comparability of the data to other studies.

Bone preservation is an obstacle to overcome in any study of skeletal remains and can potentially bias results. Child bones, especially, are at a significant risk of taphonomic changes affecting the presence of elements (see Lewis 2007) as well as the ability to accurately take measurements. Although common, taphonomic changes are not likely to have preferentially destroyed the youngest individuals in this cemetery, since even possible fetal remains have been recovered.

Trauma

While it is known that Giecz functioned as a political and religious center utilizing the massive fort constructed there (Barford 2001), it is unknown how extensive of a military effort was undertaken at Giecz during the 11th and 12th centuries, or where war victims were buried. The specific objective of the investigation into trauma is to identify sex and age-differentiated patterns in traumatic injuries in the Giecz Collection. If a military movement were present, we would expect to find a great amount of clearly violent trauma, presumably restricted to males (which should substantially outnumber all other sectors of the population).

Only adults were included in this analysis of trauma, and the available sample was divided by sex and age. All ante- and peri-mortem evidence of trauma was recorded. Skeletal elements and anatomical regions were examined and only included if the majority of the element or the body region was present. Chi-squared analysis was employed to compare trauma frequencies between sex and age categories. Additionally, a simple Correspondence Analysis was performed to determine if relationships existed between individuals in demographic cohorts (i.e., Young Male, Young Female, Middle Male, Middle Female, Older Male, Older Female) and the skeletal elements affected by trauma (Upper Limb, Scapula, Clavicle, Radius, Ulna, Wrist/Hand, Lower Limb, Femur, Tibia, Fibula, Ankle/Foot, Trunk, Sternum, Ribs, Vertebrae, Thoracic Vertebrae, Lumbar Vertebrae, or Cranium). All frequencies and results are reported for individuals.

Results indicate that the overall frequency of trauma in Giecz adults was high at 49%. Only 3.4% of all individuals with trauma (3/88) had injuries clearly intentionally violent in nature. Peri-mortem injuries associated with interpersonal violence account for only two of those cases (Justus and Agnew 2009), suggesting most individuals did not engage in frequent battles.

Each age cohort revealed a high incidence of trauma, with no statistically significant difference between them ($\chi2=0.81$, $p> 0.05$). Trauma sustained by Young Adults was 50% (27/54), and the Middle and Older Adult cohorts had slightly higher frequencies with 60% each (50/84 and 6/10, respectively) as shown in Figure 1a. Giecz males have a higher incidence of trauma than females at 56% (59/105) and 43% (24/56) respectively (Fig. 1b), although this comparison was also not statistically significant ($\chi2=1.35$, $p>0.05$). This sex-specific pattern remained consistent when the body was divided into regions (Fig. 2a). Trauma divided by body region shows a general increase with age, specifically for the upper limb and trunk (Fig. 2b). This trend is not surprising since a longer life generally allows for more chances for sustaining injuries.

Figure 2 is most notable for displaying the frequency of trunk fractures relative to other body regions. The trunk, when divided by age cohort and sex, consistently exhibits more trauma than any other body region. Fractures in the trunk region affected 82% (72/88) of all individuals with trauma, and individuals with vertebral fractures account for 87.5% (63/72) of those with trunk trauma. Vertebral trauma in this analysis included only compression fractures of the vertebral body and spondylolysis (fractures at the pars interarticularis). Spondylolysis was only observed in 10

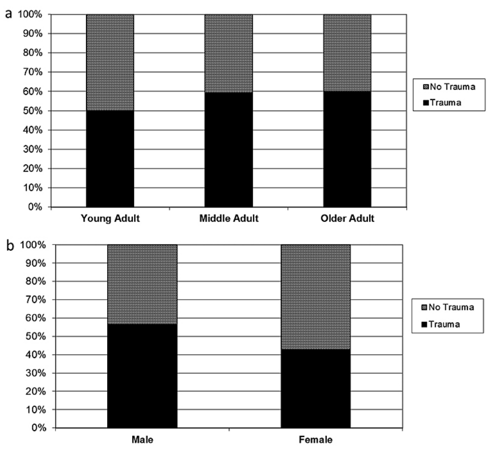

Fig. 1. Frequencies of trauma (%) in Giecz adults according to: a) age categories and b) sex

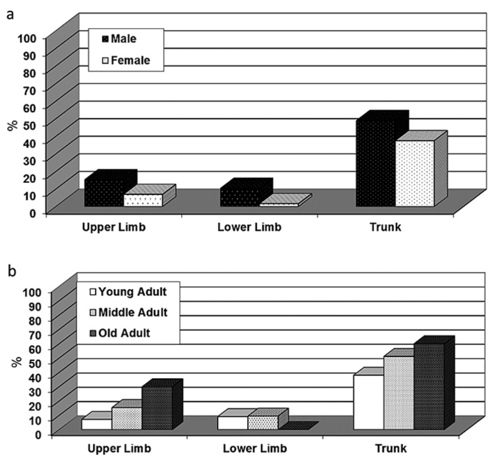

Fig. 2. Frequencies of trauma (%) in Giecz adults divided by anatomical region according to: a) sex and b) age categories

Fig. 3. Representative examples of common vertebral trauma in Giecz: bilateral unhealed spondylolysis in L4 of a 35–45 year-old female (left) and compression fracture of T12 with severe anterior wedging in a 45–55 year-old female (right). Scales are in cm

individuals, so the majority of spinal trauma included here was classified as compression fractures (diagnosed as moderate to severe wedging). Overall, males have a higher frequency of vertebral trauma than females with 44% (46/104) and 32% (18/56), respectively. Although this sex-difference is not statistically significant ($\chi 2=1.33$, $p> 0.05$), it is possible that males participated in more physically demanding labor than females. Vertebral trauma is particularly indicative of chronic heavy compressive loads and is common in the thoracolumbar spine by this mechanism (Myers and Wilson 1997). This suggests the Giecz population was partaking in labor intensive activities. Figure 3 shows examples of vertebral trauma found in the Giecz Collection.

Correspondence analysis revealed no significant relationships between demographic cohorts and any combination of skeletal elements ($p>0.05$). The model accounts for only 12% of the variance (total inertia), and of that, two dimensions accounted for the majority of the proportion of inertia (58% and 33%). Figure 4 displays an example symmetric plot showing a lack of defined groups ($\chi 2=17.22$, $df=20$, $p> 0.05$). This further supports the results above, suggesting that a similar risk of fracture existed

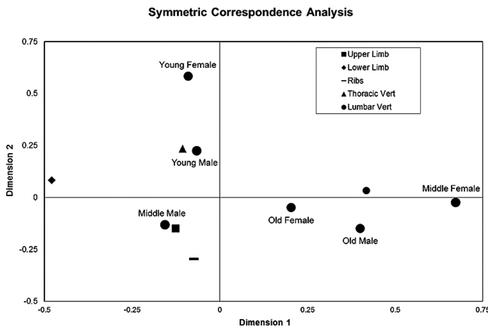

Fig. 4. Representative symmetric correspondence analysis plot showing no relationships between any demographic group or body region

for all age groups and both sexes across body regions.

Of those affected by trauma in Giecz (49%), 97% were categorized as having non-violent injuries (i.e., stress-related or accidental injuries). For many skeletal elements, a significantly higher rate of such injuries (Fisher's exact test, $p<0.05$) was found in Giecz adults than in a contemporaneous and geographically similar adult population (Poznań-Śródka) (Agnew et al. 2010). This suggests the Giecz population's lifestyle was relatively physically demanding, even for this time period in Poland.

The trauma analysis described above has been limited to adult skeletons, however some subadults in the Giecz Collection also exhibit evidence of non-violent trauma. For example, one late adolescent individual (16–18 years old) exhibits vertebral compression fractures in thoracic vertebrae 10–12 with notable wedging of T11. It is unusual for such a young individual to suffer this type of stress fracture and it is considered traumatic in nature. Further evidence for subadult trauma is found with the occurrence of osteochondritis dissecans in the Giecz Collection.

Osteochondritis dissecans (OCD) is characterized by an osteochondritic defect on an articular surface. The etiology of OCD is incompletely understood. Although it is thought to have a genetic component (Kenniston et al. 2008), the etiology currently favored by clinicians is repetitive traumatic events that cause microfractures, osteonecrosis, and eventual separation of a loose body (Gangley et al. 2006). Overuse of a joint puts physically active, skeletally immature individuals at high risk of developing OCD (Jones and Miller 2001). In skeletal remains, active OCD is identified by a clearly defined circular lesion in subchondral cortical bone with exposure of underlying trabeculae. Rounded borders or a smoothed depression can indicate healing. The presence of OCD in some archaeological populations is suggested to be related to stress from occupational trauma and agricultural activities (Wells 1974).

Five skeletons recovered from site Gz4 exhibit osseous defects consistent with OCD (see Fig. 5 for examples). Sex could only be determined in one case (17–22 year old male), since the others were too young to exhibit sexually dimorphic traits (all adolescents).

Fig. 5. Examples of osteochondritis dissecans in Giecz with no evidence of healing: bilateral lesions on each capitulum of humerii in a 12–13 year old of unknown sex (left) and a lesion on the medial condyle of the left femur in a 12–14 year old of unknown sex (right). Scales are in cm

While it is recognized that other factors, such as genetics, play a role in the development of OCD, trauma from overuse and repetitive, high-stress activity is implicated as a causal factor in the Giecz adolescents described here. Since osteochondritis dissecans in adolescence can accelerate degenerative processes in adults (Twyman et al. 1991), future research will incorporate severity of degenerative joint disease (DJD) into detailed hypotheses concerning physical activity levels and lifestyle of the Giecz population.

It is unlikely that the majority of people buried at Giecz were involved in military battles, as evidence of intentional violence in the population is rare (Justus and Agnew 2009). However, stress-related traumatic injuries are common in medieval populations because of a severely laborious lifestyle, often associated with agricultural activities (Judd and Roberts 1999). This is supported by the trauma analysis of the population from Giecz, suggesting that rigorous activity contributed to high risk for trauma. These activities are consistent with the labor intensive lifestyle typical of rural medieval populations.

The tradition of military service likely continued in Giecz through the 13th century despite a lack of skeletal trauma resulting from intentional violence. It is possible that battles were not fought frequently by this population, or at least not by those interred at Gz4. However, to maintain a fortification of the magnitude of the Giecz stronghold would have required extensive labor by troops and the general population, putting them at high risk for traumatic injury. We cannot assume this activity was restricted to males, given the non-significant differences in trauma between the sexes. Since females and individuals of all ages are almost equally affected, an overall physically demanding lifestyle for the entire population is suggested as the cause for the elevated rates of trauma, specifically vertebral fractures. It is likely that subadults represented part of the labor-force in Giecz and were considered adults in many activities.

Stress

Stress can be defined by a physiologic disruption in normal biological processes (Goodman et al. 1988). The effect of stress on the body can oftentimes be observed on the skeleton, indicating the adaptive response to the stressor (Larsen 1997). This type of analysis allows us insight into the general health of a population. Subadult remains are likely to reflect immediate environmental conditions and are less likely to have experienced catch-up growth yet (Bogin 1999), so are ideal for stress studies. The specific objective of this investigation into stress is to assess differences in femoral diaphyseal length between Giecz subadults and a modern standard. The results should increase our knowledge of the level of physiological stress endured by the Giecz population and their ability to adapt during growth.

Long-bone growth

Longitudinal skeletal growth is a complex interaction between genetics and nutritional status as a function of the environment (Hoppa 1992). Individual diaphyseal lengths are commonly used to represent a growth profile for past populations. The femur is most commonly compared, perhaps because it is often present, but also as a component of an appendage is also more likely to reflect environmental stress (Bogin et al. 2002). It is reported that long-bone growth retardation was particularly common in past agricultural populations and attributed to an increase in nutritional deficiency and physiological stress (Cook 1984; Goodman et al. 1984; Larsen 1997).

Ninety-six subadult burials from the Giecz Collection (see Table 1) were available for analysis. Some were eliminated from the study because dental remains were not present for age estimation, leaving a total sample size of 74 individuals between the ages of birth and 14 years. Specific subadult age categories and individuals present within them are shown in Table 3. Absence or damage of the femur could further reduce the sample size

Table 3. Frequencies per dental age for subadults in the Giecz Collection

Age category[1]	Femur	
	N	n
0	4	1
1	13	10
2	10	9
3	10	10
4	6	4
5	2	1
6	7	6
7	7	6
8	1	1
9	3	3
10	2	1
11	3	1
12	0	–
13	6	5
14	0	–
Total	74	58

[1]Age categories include 6 months prior and 6 months after the year indicated. Category "0" includes only those individual less than 6 months. N=total number of individuals present, n=number of individuals with femur present (i.e., number of elements included).

available for study, which is reflected in the total row. Femur measurements are maximum diaphyseal lengths, and only long bones with unfused proximal and distal epiphyses were included in the study. For repeatability, all measurements were taken by A. Agnew. If present, bilateral femur pairs were measured and the larger of the two measurements was used. Femur lengths of the Giecz sample were compared to a modern sample of European descent, in presumably good health, as shown in Figure 6 (Maresh 1955; Maresh 1970).

Femoral length in Giecz appears to lag behind that of the modern comparative sample throughout all phases of skeletal growth (Fig. 6). It has been suggested that the best comparison of growth differences between samples should be made on those less than five years of age because of increased caloric demands at this stage (Eveleth and Tanner 1990). Since the younger age ranges are better represented in this sample, this is potentially an even more useful comparison. The differences between femoral length in Giecz and the modern sample are less variable under the age of five years, but still consistently show that Giecz subadults have shorter lower limbs than the modern sample.

Differences in genetic growth potential could contribute to differences in femoral length, however this is not suggested as the cause in this case because Giecz adults are relatively taller than other European counterparts from the medieval period (Vercellotti et al. 2009; Vercellotti et al. 2011). Additionally, Giecz adults are close in stature to a modern American population, suggesting that the genetic growth potentials of the two

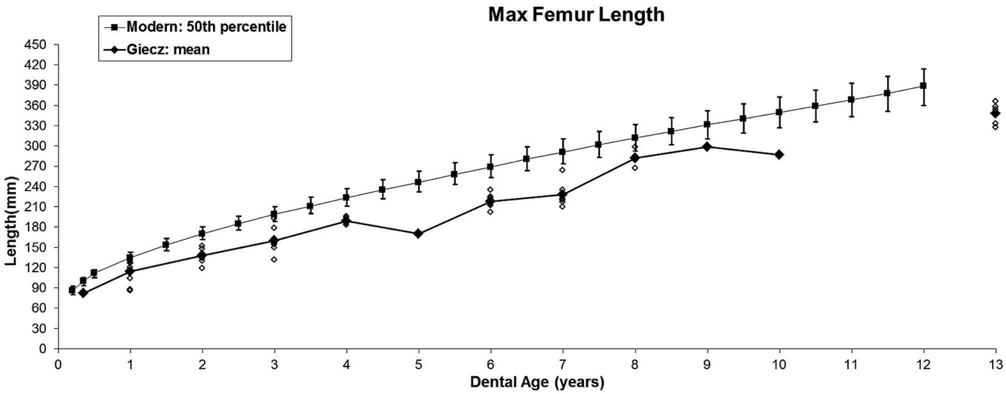

Fig. 6. Femoral lengths for a modern population of European descent (Maresh 1955, 1970) and Giecz. The modern population values (squares) represent the 50th percentile at each dental age with bars extending to the 10th and 90th percentiles. The Giecz values (diamonds) represent the mean (solid) and individual (hollow) values at each dental age

populations compared here are similar[1]. However, this comparison should be approached with extreme caution as there are many biases present that are outside the scope of the current discussion.

Shorter femoral lengths for subadults in the Giecz Collection are probably the result of differences in nutritional and disease stressors influencing long-bone growth. The subadult femoral growth rate of Giecz subadults lags behind a comparative population, suggesting they were stressed. However, tall adult stature suggests otherwise. It is possible that during adolescence, for which our sample is underrepresented here, catch-up growth is occurring. This needs to be explored further in future research.

As is the case in any skeletal assemblage, the sample is cross-sectional in nature. The subadults do not represent the healthy children living in Giecz, but rather those who died before reaching maturity. It is possible that some suffered from chronic conditions that would affect their dental and skeletal development and therefore skew results, so results should be approached with caution. However, it is more likely that the subadults are comparable with those who survived until adulthood as is argued by others (e.g., Lovejoy 1990; Sundick 1978). An additional limitation is that all age categories are not equally represented across the sample. Since the excavation of site Gz4 is incomplete, it is unknown if the demographic of the study sample is representative of the true population. Lower mortality rates in children and adolescents probably play a role in the sample, as infants under four years are greater in numbers, creating an intrinsic bias in the sample.

Future manuscripts will include comparisons of long-bone lengths to similar geographic and temporal populations, as well as relationships with non-specific indicators of stress.

[1] A survey of adult stature in the US during this same time period (~1960) reports mean adult statures for males and females of 173 cm and 160 cm, respectively (Ogden et al. 2004), while those estimated for Giecz are 172 cm and 157 cm, respectively (Vercellotti et al. 2009).

Conclusions

Trauma results suggest a rigorous lifestyle that likely involved heavy lifting and repetitive, strenuous activities for the Giecz population. The heavy workload was not restricted to males, but also extended to females and adolescents. Growth-data allow us to infer that selection influenced mortality (i.e., those with stunted growth did not survive into adulthood) and that the population at Giecz endured generally stressful environmental conditions (e.g., poor nutrition, infection, etc.).

The Giecz Collection offers a unique opportunity to study life and death and the circumstances surrounding each in early Medieval Poland. This geographical area is generally limited in anthropological publications, so it is our goal to continue research in Giecz and make interesting and meaningful comparisons with other Medieval Polish and European samples.

Ongoing and future research includes investigations into other non-specific indicators of stress (linear enamel hypoplasia's, porotic hyperostosis, cribra orbitalis), infectious disease prevalence, degenerative joint disease and cases of diffuse idiopathic skeletal hyperostosis, in addition to explorations of social inequality, population structure, cranial variation, kinship, and post-marital residence patterns.

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Authors' contributions

AMA and HMJ excavated much of the skeletal material in the Giecz Collection and both collected data used in this study. AMA analyzed and interpreted the data presented here, and primarily wrote the manuscript. HMJ supported data analysis and interpretation and edited the manuscript.

Conflict of interest

The Authors declare that there is no conflict of interests regarding the publication of this article.

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