A Bioarchaeological Analysis of Spinal Trauma in an Early Medieval Skeletal Population from Giecz, Poland: The Osteological Evidence for an Agricultural Lifestyle

Thesis

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By

Kelila Bridget Thomsen, B.S.

Graduate Program in Slavic and East European Studies

The Ohio State University

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Thesis Committee:

Amanda Agnew, Advisor

Clark Spencer Larsen

Abstract

The present study evaluated spinal trauma present in a skeletal assemblage from medieval Giecz, Poland. Degenerative Joint Disease (DJD), vertebral compression fractures, Schmorl's Nodes, and spondylolysis were analyzed and documented in individuals with vertebral columns that were partially or fully complete. Males in this sample presented with a higher frequency of DJD, Schmorl's Nodes, and wedge vertebral compression fractures. This supports the hypothesis that there was a sexual division of labor in the population at Giecz. When placed in a broader historical context, and in concert with findings from biomechanical research, it is clear that the population at Giecz, especially the males, experienced significant physiological pressure associated with agricultural production during the beginnings of feudalism. The members of this population lived a physically demanding lifestyle, as can be seen in the increasing prevalence of DJD and wedge compression fractures with age.

Dedication

I dedicate this work to the individuals belonging to the Gz4 skeletal assemblage, whose lives and deaths offer the opportunity for me and so many others to learn.

I also wish to dedicate this thesis to my parents, who always encourage and support me, regardless of the path I choose. And to my brothers, who never cease to challenge me and push me to be better.

Acknowledgements

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Vita

2013……………………………………………………Springboro High School

2019……………………………………………………B.S. Anthropological Sciences, The Ohio State University

2020-present ..………………………………………Graduate Student, The Ohio State University

Fields of Study

Major Field: Slavic and East European Studies

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Chapter 1: Introduction

Bioarchaeology involves the study of human skeletal remains in an archaeological context. This scientific field is useful in recreating past lifestyles by analyzing different pathological changes to the skeleton in order to make observations about an individual's life. By studying these biological phenomena in the context of cultural changes, bioarchaeology enables researchers to fully reconstruct past societies in a well-rounded manner. In doing so, bioarchaeology can provide specific, scientific evidence to support theories about lifestyles of past populations.

Degenerative changes and trauma to archaeological human remains can be useful in reconstructing past lifestyle patterns since different lifestyle patterns or habitual activities affect the skeleton in different ways (Larsen 2015). For example, an individual who performs strenuous physical labor on a daily basis will show more degenerative changes to the skeleton than someone who does little physical labor in their lifetime (Larsen 2015).

An element of the human skeleton that is especially sensitive to these degenerative changes is the human spine. Past bioarchaeological studies have found an increased prevalence and severity of degenerative changes to the spine among populations with physically demanding lifestyles (Larsen 2015). These forms of spinal trauma include Schmorl's Nodes (SN), osteoarthritis or Degenerative Joint Disease (DJD), vertebral compression fractures, and spondylolysis. In past scholarship, researchers have found that increased prevalence of these degenerative spinal changes, especially when found together, is associated with more physically demanding lifestyles (Curate et al. 2016; Dabbs et al. 2015; Dabbs 2019; Novak and Slaus 2011; Novak et al. 2012).

The aim of this paper is to analyze and report the presence of traumatic and degenerative spinal changes in a skeletal population from medieval Giecz, Poland and evaluate the implications that these findings have on recreating the lifestyle of this population, while looking at Giecz in the broader historical context of medieval Poland.

It is hypothesized that males will present more evidence of spinal trauma than females, supporting the idea that there was a sexual division of labor in Giecz which relied on men to perform the heavy labor. In addition to this, it is also expected that DJD and wedge vertebral compression fracture prevalence will increase with age in the members of this sample. Moreover, it is hypothesized that vertebral compression fractures will more often affect vertebrae proven to be associated with strenuous manual labor, such as agricultural tasks.

Chapter 2: History of Site and Region

History and Development of Early Medieval Poland

The early medieval period in Poland was characterized by an incredible growth in population. The population increased from less than one person per square kilometer in the 6^{th} century AD to 7 people per square kilometer in 1200 AD (Barford 2001). As a result of this population increase, cultural and organizational changes spread throughout Poland (Barford 2001). At the end of the 7^{th} century and with increasing frequency through the 9^{th} and 10^{th} centuries, the process of social consolidation spread throughout Poland, leading to new societal and economic conditions. Correspondingly, in the 8^{th} and 9^{th} centuries, there was an increase in stronghold production throughout western Slavdom due to this increased social organization. By the late 9^{th} century, strongholds were a common occurrence throughout Slavdom and became characteristic of the early Middle Ages (Barford 2001). Some strongholds reflect a central place in settlement hierarchy, supporting the idea that these societies were becoming more stratified. Even in the 8^{th} century, the hierarchical nature of Slavic societies can be seen within the structure of the settlements, caused by the increase in population density (Barford 2001). Moreover, in the 9^{th} century there was a growth in material wealth, evidenced by increased variety in types of artifacts, as well as in evidence of trade centers established on the Baltic coast (Barford 2001). The centralization of power and wealth in these strongholds led to the development of a tribute economy. Elites in these societies would collect tribute from those belonging to lower classes, usually in the form of agricultural goods and other products (Barford 2001).

In 9th century Pomerania, the eastern portion of which would soon become integrated with Poland, there was also increasing centralization of power. Because of growing settlement density, there was a transition towards building more strongholds throughout these areas. By the late 9th century and early 10th century, regional differences in settlement patterns began to fade, being replaced by small, circular strongholds following a regular pattern (Barford 2001). This change was related to the formation of a more centralized socio-political structure throughout the region, which was a precursor to the formation of a Polish state (Barford 2001). The economic growth in the 9th century was supported by densely built-up trade and production centers located on the Baltic coast, which encouraged long-distance exchange. Evidence supports the increase in the number of strongholds that were built during the 9th century across Pomerania, as well as throughout Central and Southern Poland (Barford 2001).

Even before the formation of a distinct Polish state, when the region was instead divided into ‘chiefdoms’, there is clear evidence of a tribute economy. However, instead of the tribute serving as payment for the ability to use a section of land (as is the case in a feudal society), this tribute was instead seen as an acknowledgement of belonging to a cohort with protection from a specific leader (Barford 2001). This centralization of power present in these chiefdoms was further increased, as can be seen with the formation of strongholds. Reflecting the central role and focus of strongholds in this period, open settlements were often constructed in concentric circles surrounding the fortification (Barford 2001). These major sites often further developed and transformed into the estate centers of the princes of Poland. There is clear evidence that these strongholds played a central role in the formation of states (Barford 2001).

Strongholds, along with playing a role in the formation of states, were also the precursors to town formation (Barford 2001). However, not all early medieval Polish strongholds grew into medieval towns; some simply remained strongholds with surrounding settlements devoted to production (Barford 2005). Regardless, some strongholds were command posts, therefore functioning in an elite, military, and administrative capacity. There is also archaeological evidence in some strongholds of imports and craft production. In addition, evidence shows that the internal inhabitants of the stronghold – often elites – were the main focus of the settlement (Barford 2001). In the late 10th and early 11th centuries, there was a rise of a regional economy in Poland. As a result, some strongholds developed into towns (i.e., Poznań, Gniezno, Wrocław, Opole, Cracow, and Lublin). Strongholds were the centers where tribute was exacted in early medieval Poland, therefore there was increasing demand on local production (Barford 2001). The settlements surrounding strongholds became increasingly important, eventually becoming the focal point of economic development and production in the latter portion of the 11th century (Barford 2005). During this time there was also a continued increase in population, leading to distinct social stratification. This led to a new social system in which material culture became more diverse. Strongholds were the basis of local administration, placing power in the hands of the elite. The early Polish state social structure loosely resembled feudalism (Barford 2001).

Dating back to the reign of King Bolesław the Brave (late 10^{th}-early 11^{th} century), rural communities paid tribute to the elites and/or rulers. In the 10^{th} and 11^{th} centuries, King Bolesław would travel through the Polish countryside, demanding tribute and labor services from the peoples of these rural communities (Gorecki 1983). Local officials in these rural centers were expected to gather a great deal of food and supplies from the local workers in order to ensure a comfortable stay when the King would stop in their town. Peasants provided the labor force, as well as anything else the King required during his visit (Gorecki 1983). When examining Poland under King Bolesław I's rule, scholars identify it "as a classic example of the earliest type of medieval economy" (Gorecki 1983, p. 17), with harsh, exceedingly demanding extortions required of the peasant class.

Moving to the 12^{th} century, Poland became divided into small feudal statelets, each presided over by a minor prince belonging to the Piast Dynasty from 1138 to 1333 AD (Barford 2001). Each fortress or stronghold was appointed a local official by the prince. These officials held the responsibility of managing the military and judicial administration of their district. These administrators were also in charge of the royal estate, including overseeing customary service and collection of tribute (Davies 2005). These strongholds and their respective administrators served various functions in the centralized Polish state, including central administrative and economic roles as well as concentrations of political and military power. Strongholds often also served as nodal points in trade networks (Barford 2005). The demand for consumer goods continued to grow in these strongholds as they "were inhabited and frequented by an elite and by sizable military garrisons" (Barford 2005, p. 85). This increasing demand stimulated local production in addition to encouraging luxury trade (Barford 2005).

In the latter half of the 12^{th} century, the Polish peasantry became even more focused on economic production of agriculture and crafts. Landless rural laborers also came about in increasing frequency (Gorecki 1983). In the 12^{th} and early 13^{th} centuries in Poland, the economy shifted from a force and warfare-based economy to one focusing on intense agriculture production and craft specialization (Gorecki 1983). As a result, from the 12^{th} century on, peasants were not required to fight, and instead worked to support the monetary needs of the elite in their settlement, including the equipment and training of the knights belonging to their fortress (Davies 2005).

The Polish peasant in the 12^{th} and 13^{th} centuries lived a mobile lifestyle, moving from place to place semi-frequently. When these peasants did settle, it was often in familial settlements. Each familial settlement or household would perform a variety of different specialized agricultural as well as nonagricultural tasks in service to the royal household (Gorecki 1983).

In the 13^{th} century, slavery began to fade. Free or semi-free peasants became more common, making up an increasing portion of rural workers. Towns also attracted administrators, merchants, and craftsmen (Davies 2005). In the 13^{th} century in Poland, colonization became more common, leading to the creation of incorporated towns, as well as rural villages, which again spurred social change. Foreign immigrants entered

Poland and recognized existing settlements along with their locals (Davies 2005). Polish princes offered conditions of tenure better than those present in Germany, enticing people to settle on their lands, which led to increasing populations (Davies 2005). Henryk the Bearded, the Prince of Silesia, attracted more than 10,000 peasant families, creating around 400 new villages, with a campaign beginning in 1205 (Davies 2005). In 1227, Henryk signed an agreement with the Bishop of Wrocław which became the model for future rural communities in Poland. The rest of Poland's rural population was still subject to mandatory tributes as well as the "*ius ducale*" or "Polish Law" under the princes. Wrocław, Poznań and Kraków became "German" cities according to the agreement signed by Henryk in 1242, 1253 and 1257 respectively (Davies 2005). This process of incorporating cities and making them "German" by the standards of the signed agreement increased in pace beginning in the 14th century (Davies 2005).

Economic life advanced quickly in 13th century Poland. A revolution of farm management occurred, encouraging the concentration and maximized efficiency of land holdings, creating compact units. Elites also began to compete to maximize outputs of land holdings, raising demands on the peasantry. Cities became incorporated with increasing frequency. Colonization in Poland also led to the growth of a cash economy, along with an increase in internal trade (Davies 2005).

Figure 1: Map of Poland circa 990 AD, showing the location of Giecz and two other major Polish cities. Image adapted from Betsinger et al. (2020).

History of the Stronghold at Giecz

Giecz, located in Western Central Poland in the *Wielkopolska* or Greater Poland region, was a significant city in early medieval Poland (Fig. 1). In the 9th century there was a minor expansion to the stronghold at Giecz, and later in the 10th century the stronghold at Giecz underwent a larger expansion (Agnew 2014). Giecz was a special stronghold during the first Piast monarchy, since it held a favorable location near an intersection of long-distance trade routes, which afforded the town good fortune (Krysztofiak 2000). These roads connected Giecz to other important cities such as Gniezno, Ląd, Poznań, and Śrem. In addition to its location along these two major roads, the stronghold at Giecz held a favorable geographic location due to waterways and swampy lands which formed natural defensive barriers to the north and east (Kostrzewski 1964). Giecz was a strategic defensive center in Poland, holding great military significance. In addition, Giecz was a castellan's seat in the 11th century, dating to the reign of Bolesław the Brave (Kostrzewski 1964). By the 11th century, Giecz was an urban center with a market economy as well as a strong complex. This settlement was likely a hereditary property belonging to Poland's first rulers judging by its large surface, strong fortifications, and dense grouping of surrounding settlements. These features are characteristics of the important chieftains' boroughs (i.e., Gniezno, Poznań and Kruszwica) (Kostrzewski 1964).

The makeup of the Giecz stronghold indicates that it had varied functions. Strongholds such as the one in Giecz were the basis of local administration. These strongholds were also the locations where tribute from the surrounding population would be exacted (Barford 2005). In early medieval Giecz, the social system was organized in a manner called 'early feudalism' – a precursor to classic feudalism, which would not come about in Poland until the High and Late Middle Ages. In this model of 'early feudalism', the whole society was involved in the economic system. During this time there was also the differentiation and integration of social classes, along with the creation of new identities (Barford 2005). Class delineations remained fluid during this time period, only solidifying once classic feudalism emerged. These changes to the societal and economic makeup of early medieval Polish strongholds such as Giecz led to changes in production, including increased craft specialization (Barford 2005).

The sample under study in the present paper is one dating to this early Medieval period from Giecz, Poland. This skeletal population was excavated from a cemetery outside the fortifications of the stronghold at Giecz, meaning it is likely made up of those who belonged to the lower classes (Agnew 2015). Given the historical context laid out above, this sample population likely experienced significant pressure on agricultural production to fulfill tribute requirements and provide for the elites living in the stronghold walls, in addition to providing for themselves.

Chapter 3: Materials and Methods

The skeletal remains used in this study are from a population excavated from Giecz, a town located in Western Central Poland in the *Wielkopolska* or Greater Poland region (Agnew 2014). This population (named Gz4) represents a group of individuals dating to the 11^{th}-12^{th} centuries A.D. The cemetery from which these remains were excavated is located just outside the stronghold in Giecz (Agnew 2015). Excavations at this site began in the mid-20^{th} century, although most of the work completed at this site was undertaken in the years 1999-2008 (Agnew 2014). Evidence suggests that the population interred in the Gz4 site is not that of the social elite, evidenced by the fact that there is no church located nearby, in addition to the fact that these burials are located outside of the Giecz stronghold walls (Agnew 2015).

The focus of the present paper is on the evaluation of spinal trauma present in this skeletal assemblage from Giecz, Poland. As such, only individuals from the population who presented partial or fully preserved spinal columns were included in the analyses, numbering 123 individuals. All individuals examined and analyzed were adults. These individuals were broken up into age groups constituting 'Young Adult' (13-34 years), ‘Middle Adult’ (35-49 years), and ‘Older Adults’ (50+ years). The demographic distribution of the sample used in the present analyses are included in Table 1.

Sex determinations for each individual were made using the os coxae and sexually dimorphic traits of the skull. Femoral and humeral heads were also measured to help confirm individual sex in some cases (Agnew 2015). Age-at-death estimations for young adults were made by observing secondary ossification centers, including fusion of rib ends, sternal bodies, and the medial clavicle. For all individuals, established, general changes to skeletal morphology related to aging were also analyzed (Agnew 2015). Pubic symphysis morphology was most often used. Changes to sternal rib ends and the auricular surface of the os coxae were not heavily relied upon for age-at-death determination in this study (Agnew 2015).

The types of spinal trauma analyzed for the present study are Degenerative Joint Disease (DJD), vertebral compression fractures, Schmorl’s Nodes (SN), and spondylolysis. The vertebral compression fractures observed in this population can be divided into three categories: wedge, biconcave, and crush fractures (Grigoryan et al. 2003). Wedge compression fractures affect the anterior portion of the vertebral body; biconcave compression fractures affect the middle of the vertebral body; and crush fractures affect the posterior portion of the vertebral body. These compression fractures were observed and scored (when possible) using a standard method called the Genant method, proven reliable in scoring vertebral compression fractures (Fig. 2) (Curate et al. 2016; Grigoryan et al. 2003). When analyzing the Gz4 population, measurements of the anterior and posterior aspects of the vertebral bodies were taken for each vertebra. Using these measurements, the author scored the identified vertebral compression fractures based on the ratio of posterior to anterior height, or P/A. Using these P/A values, the wedge compression fractures were graded as such: Grade 1 = P/A value of 1.20-1.25; Grade 2 = P/A value of 1.26-1.40; Grade 3 = P/A value >1.41. The crush compression fractures were graded using these P/A values as follows: Grade 1 = P/A value of 0.75-0.80; Grade 2 = P/A value of 0.60-0.74; Grade 3 = P/A value <0.59 (Fig. 2). Biconcave compression fractures were not scored, as P/A values do not indicate the effect on the middle of the vertebral body.

For the specific analysis of wedge compression fractures to the vertebrae, certain individuals were excluded. These individuals were excluded because they presented no observable thoracic vertebrae, for thoracic vertebrae were the only ones effected by wedge compression fractures in all cases. There were 116 individuals who did present observable thoracic vertebrae capable of being analyzed. The demographic breakdown of these individuals can be seen in Table 1.

Table 1: Demographic breakdown of the individuals from Gz4; Numbers and percentages on the left pertain to sample with observable vertebrae (N = 123), numbers and percentages on the right pertain to only those individuals with observable thoracic vertebrae (N = 116).

SEX	**N**	**% of total pop**	**N**	**% of total pop**
Males	77	62.6	71	61.2
Females	46	37.4	45	38.8
AGE				
Young Adults	36	29.3	33	28.4
Middle Adults	69	56.1	65	56.0

Older Adults	18	14.6	18	15.5
BOTH				
Young Males	21	17.1	18	15.5
Young Females	15	12.2	15	12.9
Middle Males	48	39.0	45	38.8
Middle Females	21	17.1	20	17.2
Older Males	8	6.5	8	6.9
Older Females	10	8.1	10	8.6
TOTAL	**123**	**100**	**116**	**100**

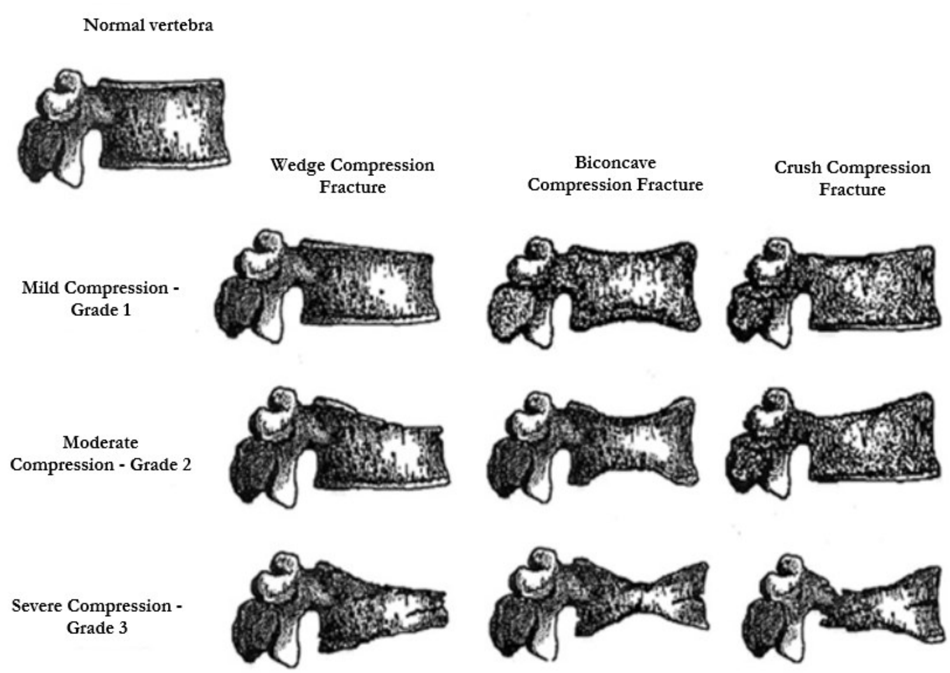

Figure 2: Visual graphic displaying Genant grading scale for vertebral compression fractures (adapted from Grigoryan et al. 2003)

Chapter 4: Results

The Gz4 sample is predominately male (62.3% of the sample). In addition, the majority of this sample falls in to the ‘Middle Adult’ categoy of 35-49 years old at death (56.1%). The demographic breakdown of the Gz4 sample is seen in Table 1 along with their respective percentages. The composition of the sample is visually represented in Figure 3.

Of the 123 individuals with partially or completely preserved vertebral columns from the medieval Giecz population under study in the present article, 108 of them (87.8% of the population) presented with one or more forms of spinal trauma. The most common form of vertebral trauma observed was DJD, present in 84 individuals (68.3% of the population). Over half of the sample with preserved thoracic vertebrae presented with wedge compression fractures affecting the anterior portion of the vertebral body (Table 2). Crush fractures, affecting the posterior portion of the vertebral body, were present in 39% of the sample. Biconcave fractures, affecting the center of the vertebral body, were observed in 11.4% of the sample (14 individuals). Only 7 individuals in this sample (5.7%) presented observable spondylolysis, while 20 individuals (16.3%) showed evidence of Schmorl’s Nodes (Table 2).

Males in this sample were significantly more affected by vertebral wedge compression fractures (71.8% of males) as opposed to females (20% of females). Schmorl's Nodes also occurred more frequently in the males of Gz4, affecting 20.8% of males as opposed to 8.7% of females (Table 3). Males also showed more evidence of DJD – 74% of males, compared to 58.7% of females. Females showed slightly more evidence of biconcave vertebral compression fractures, on the other hand (15.2% of females and only 9.1% of males). Presence of spondylolysis and vertebral crush fractures were fairly similar in both males and females (Table 3).

Incidence of DJD increased with age, with 100% of the 'Older Adult' individuals showing evidence of degenerative osteoarthritic changes to the vertebrae. The prevalence of DJD increases drastically between the 'Young Adult' (19.4% of young adults) and 'Middle Adult' (85.5% of middle adults) groups (Table 4). Within the 'Middle Adult' population, middle-aged males had a higher pprevalence of DJD (93.8% of middle males) than middle-aged females (66.7% of middle females) (Table 5). Wedge vertebral compression fractures also increased with age, rising from 42.4% in young adults to 53.8% in middle adults, and even more to 61.1% in older adults (Table 4).

The incidence of vertebral crush fractures decreased with age, on the other hand. 44.4% of young adults presented evidence of crush fractures, whereas only 27.8% of older adults were observed with crush fractures (Table 4).

The difference in prevalence of DJD, wedge vertebral compression fractures, and Schmorl's Nodes between males and females carries throughout age groups. As is seen in Table 5, young males present higher frequencies of these vertebral trauma than young females, and this remains true as these frequencies increase in middle males and again in older males. The only slight exception is that 100% of both older males and older females show evidence of DJD, so males do not technically have a higher incidence of this type of trauma.

Moreover, in Table 6 we can see that far more males experience moderate DJD (33 individuals) and severe DJD (21 individuals) than do females (11 individuals and 2 individuals, respectively). As wedge compression fractures get more severe, however, the distribution of males versus females with observable fractures begins to even out. 39 males and only 5 females present with grade 1 wedge compression fractures, whereas only 6 males and 4 females present with grade 3 wedge compression fractures (Table 6).

Table 7 shows the percentage distribution of different trauma in demographic groups, meaning that these are percentages of people with a certain trait that belong to each category. This gives a better sense of how these vertebral trauma are broken down between categories.

Some vertebrae had more incidences of vertebral compression fractures than others. Table 8 shows the number of each vertebra that showed observable compression fractures. The highest concentration of wedge compression fractures occurred on T11 (N = 37). There is an interesting trend wherein wedge compression fractures increase around T7 and T8 (N = 11 and N = 9, respectively), and then again around T11-L1 (N = 37, N = 17, and N = 11, respectively). Both biconcave and crush fractures increased in incidence inferiorly in the vertebral column. Biconcave fractures to L5 numbered 7 and crush fractures to L5 numbered 48 (Table 8).

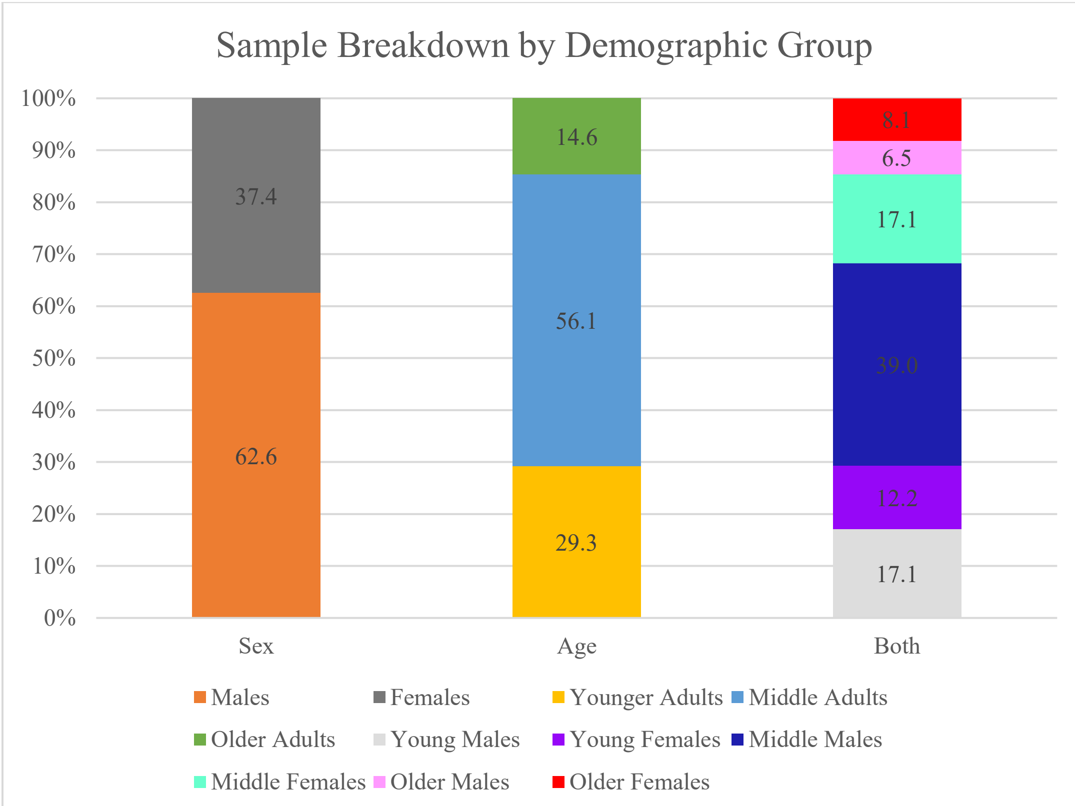

Figure 3: Demographic breakdown of Gz4 sample in percentages

Table 2: Percentage of Gz4 sample with specific observable trauma present; N = number of individuals with observed trauma (fx = fracture).

	N	% of sample
DJD	84	68.3
Wedge Compression fx	60	51.7
Crush fx	48	39.0
Biconcave fx	14	11.4
Spondylolysis	7	5.7
Schmorl's Nodes	20	16.3

Table 3: Numbers and percentages of males and females in Gz4 sample who present specific forms of trauma.

	Males			**Females**		
	N	% of males	% of sample	N	% of females	% of sample
DJD	57	74.0	46.3	27	58.7	22.0
Wedge Compression fx	51	71.8	44.0	9	20.0	7.8
Crush fx	30	39.0	24.4	18	39.1	14.6
Biconcave fx	7	9.1	5.7	7	15.2	5.7
Spondylolysis	4	5.2	3.3	3	6.5	2.4
Schmorl's Nodes	16	20.8	13.0	4	8.7	3.3

Table 4: Numbers and percentages of age groups in Gz4 sample who present specific forms of trauma.

	Young Adults			Middle Adults			Older Adults		
	N	% of young adults	% of sample	N	% of middle adults	% of sample	N	% of older adults	% of sample
DJD	7	19.4	5.7	59	85.5	48.0	18	100.0	14.6
Wedge Compression fx	14	42.4	12.1	35	53.8	30.2	11	61.1	9.5
Crush fx	16	44.4	13.0	27	39.1	22.0	5	27.8	4.1
Biconcave fx	0	0.0	0.0	12	17.4	9.8	2	11.1	1.6
Spondylolysis	1	2.8	0.8	6	8.7	4.9	0	0.0	0.0
Schmorl's Nodes	7	19.4	5.7	9	13.0	7.3	4	22.2	3.3

Table 5: Number and percentages of trait present in each specific demographic group.

	Young Males			Young Females		
	N	% of young males	% of sample	N	% of young females	% of sample
DJD	4	19.0	3.3	3	20.0	2.4
Wedge compress fx	12	66.7	10.3	2	13.3	1.7
Crush fx	11	52.4	8.9	5	33.3	4.1
Biconcave fx	0	0.0	0.0	0	0.0	0.0
Spondylolysis	1	4.8	0.8	0	0.0	0.0
Schmorl's Nodes	5	23.8	4.1	2	13.3	1.6
	Middle Males			**Middle Females**		
	N	% of middle males	% of sample	N	% of middle females	% of sample
DJD	45	93.8	36.6	14	66.7	11.4
Wedge compress fx	33	73.3	28.4	2	10.0	1.7
Crush fx	17	35.4	13.8	10	47.6	8.1
Biconcave fx	7	14.6	5.7	5	23.8	4.1
Spondylolysis	3	6.3	2.4	3	14.3	2.4
Schmorl's Nodes	8	16.7	6.5	1	4.8	0.8
	Older Males			**Older Females**		
	N	% of older males	% of sample	N	% of older females	% of sample
DJD	8	100.0	6.5	10	100.0	8.1
Wedge compress fx	6	75.0	5.2	5	50.0	4.3
Crush fx	2	25.0	1.6	3	30.0	2.4
Biconcave fx	0	0.0	0.0	2	20.0	1.6
Spondylolysis	0	0.0	0.0	0	0.0	0.0
Schmorl's Nodes	3	37.5	2.4	1	10.0	0.8

Table 6: Number of individuals belonging to each demographic group with different DJD, compression fracture and crush fracture divided into grade levels.

Numbers of Individuals with Trait Present									
SEX	**Mild DJD**	**Moderate DJD**	**Severe DJD**	**Grade 1 wedge compress fx**	**Grade 2 wedge compress fx**	**Grade 3 wedge compress fx**	**Grade 1 crush fx**	**Grade 2 crush fx**	**Grade 3 crush fx**
Male	31	33	21	39	25	6	27	3	0
Female	17	11	2	5	5	4	12	6	0
AGE	**Mild DJD**	**Moderate DJD**	**Severe DJD**	**Grade 1 wedge compress fx**	**Grade 2 wedge compress fx**	**Grade 3 wedge compress fx**	**Grade 1 crush fx**	**Grade 2 crush fx**	**Grade 3 crush fx**
Young	6	2	2	10	5	3	14	2	0
Middle	36	30	14	27	17	4	21	6	0
Older	6	12	7	7	8	3	4	1	0
	Mild DJD	**Moderate DJD**	**Severe DJD**	**Grade 1 wedge compress fx**	**Grade 2 wedge compress fx**	**Grade 3 wedge compress fx**	**Grade 1 crush fx**	**Grade 2 crush fx**	**Grade 3 crush fx**
Young Male	3	2	2	8	5	3	11	0	0
Young Female	3	0	0	2	0	0	3	2	0
Middle Male	26	25	14	26	16	3	14	3	0
Middle Female	10	5	0	1	1	1	7	3	0
Older Male	2	6	5	5	4	0	2	0	0
Older Female	4	6	2	2	4	3	2	1	0
TOTAL # OF PPL	48	44	23	44	30	10	39	9	0

Table 7: Percentage of trait occurrence WITHIN individuals with observable trauma (i.e., (# of males with DJD / Total # of people with DJD)*100).

Percentages WITHIN trait groups									
SEX	**DJD**	**Wedge compression fx**	**Crush fx**	**Biconcave fx**	**Spondylolysis**	**Schmorl's Nodes**	**Mild DJD**	**Moderate DJD**	**Severe DJD**
Male	67.9	85.0	62.5	50.0	57.1	80.0	64.6	75.0	91.3
Female	32.1	15.0	37.5	50.0	42.9	20.0	35.4	25.0	8.7
AGE	**DJD**	**Wedge compression fx**	**Crush fx**	**Biconcave fx**	**Spondylolysis**	**Schmorl's Nodes**	**Mild DJD**	**Moderate DJD**	**Severe DJD**
Young	8.3	23.3	33.3	0.0	14.3	35.0	12.5	4.5	8.7
Middle	70.2	58.3	56.3	85.7	85.7	45.0	75.0	68.2	60.9
Older	21.4	18.3	10.4	14.3	0.0	20.0	12.5	27.3	30.4
	DJD	**Wedge compression fx**	**Crush fx**	**Biconcave fx**	**Spondylolysis**	**Schmorl's Nodes**	**Mild DJD**	**Moderate DJD**	**Severe DJD**
Young Male	4.8	20.0	22.9	0.0	14.3	25.0	6.3	4.5	8.7
Young Female	3.6	3.3	10.4	0.0	0.0	10.0	6.3	0.0	0.0
Middle Male	53.6	55.0	35.4	50.0	42.9	40.0	54.2	56.8	60.9
Middle Female	16.7	3.3	20.8	35.7	42.9	5.0	20.8	11.4	0.0
Older Male	9.5	10.0	4.2	0.0	0.0	15.0	4.2	4.5	21.7
Older Female	11.9	8.3	6.3	14.3	0.0	5.0	8.3	13.6	8.7

SEX	Grade 1 wedge compress fx	Grade 2 wedge compress fx	Grade 3 wedge compress fx	Grade 1 crush fx	Grade 2 crush fx	Grade 3 crush fx
Male	88.6	83.3	60.0	69.2	33.3	0.0
Female	11.4	16.7	40.0	30.8	66.7	0.0

AGE	Grade 1 wedge compress fx	Grade 2 wedge compress fx	Grade 3 wedge compress fx	Grade 1 crush fx	Grade 2 crush fx	Grade 3 crush fx
Young	22.7	16.7	30.0	35.9	22.2	0.0
Middle	61.4	56.7	40.0	53.8	66.7	0.0
Older	15.9	26.7	30.0	10.3	11.1	0.0

	Grade 1 compress fx	Grade 2 compress fx	Grade 3 compress fx	Grade 1 crush fx	Grade 2 crush fx	Grade 3 crush fx
Young Male	18.2	16.7	30.0	28.2	0.0	0.0
Young Female	4.5	0.0	0.0	7.7	22.2	0.0
Middle Male	59.1	53.3	30.0	43.6	33.3	0.0
Middle Female	2.3	3.3	10.0	10.3	33.3	0.0
Older Male	11.4	13.3	0.0	5.1	0.0	0.0
Older Female	4.5	13.3	30.0	5.1	11.1	0.0

Table 8: Number of compression fractures affecting each vertebra divided into type of fracture.

VERTEBRA	# with wedge compression fx	# with biconcave fx	# with crush fx	TOTAL # of fxs per vertebra
T1	7	0	0	7
T2	0	0	0	0
T3	3	0	0	3
T4	4	1	0	5
T5	3	0	0	3
T6	6	0	0	6
T7	11	0	0	11
T8	9	0	0	9
T9	4	0	0	4
T10	6	0	0	6
T11	37	1	0	38
T12	17	1	0	18
L1	11	3	0	14
L2	4	5	0	9
L3	2	6	0	8
L4	0	6	2	8
L5	0	7	48	55
L6	0	1	0	1

Chapter 5: Discussion

The stronghold in Giecz served as a major administrative and agricultural center in medieval Poland (Barford 2001). Beginning in the late 11th century continuing through the 13th century, strongholds and their surrounding settlements became central to the economic development of medieval Poland (Barford 2005; Gorecki 1983). In 12th and early 13th centuries in Poland, the economy shifted from a force and warfare-based economy to one focusing on intense agriculture production and craft specialization (Gorecki 1983). As agriculture was the basis of the entire economy in early Slavic society, the pressure on the production of agriculture in Giecz would have been substantial, especially as the settlement at the stronghold in Giecz was likely seen as an agricultural production center in medieval Poland (Agnew 2015; Barford 2001). Further archaeological evidence recovered from excavations in Giecz suggests that this population practiced agricultural production and intense, heavy labor (Agnew 2015).

In past research, the population from Giecz showed almost no evidence of intentional, violent trauma that would have been caused by interpersonal violence or warfare. Instead, this population shows trauma related to a labor-intensive lifestyle pattern (Agnew 2014). Further elucidating the kind of strenuous lifestyle of those living in medieval Giecz, a contemporaneous population located nearby in Poznań-Śródka presented a significantly lower percentage of non-violent trauma in its adult population, indicating that the lifestyle of those living in Giecz was more demanding even than that of its neighbors (Agnew 2015). This difference is especially telling because the sample from Poznań-Śródka signifies an urban population, meaning there were fewer people practicing difficult agricultural labor (Agnew 2015). Beyond the demands of increased agricultural pressure, the labor required to construct and maintain the fortified stronghold at Giecz would also be intense, further supporting the evidence of a labor-intensive lifestyle related to the population at Gz4 (Agnew 2014).

The population excavated from Gz4 shows extensive osteological evidence supporting the hypothesis that this group of individuals carried out habitual, labor-intensive work, consistent with an agricultural lifestyle. The extremely high incidence of spinal trauma in the adults from the Gz4 population (87.8% of the present sample presented with one or more form of spinal trauma) suggests that these individuals were constantly performing tasks associated with heavy loading. Spinal trauma and degenerative changes to the vertebrae have been repeatedly shown in past bioarchaeological research to correspond to a labor-intensive lifestyle, such as agricultural production (Curate et al. 2016; Dabbs et al. 2015; Dabbs 2019; Larsen 2015; Novak and Slaus 2011; Novak et al. 2012).

Another significant indicator of the structure and function of past populations according to past bioarchaeological research is diet and nutrition. Populations that are agriculture-based typically present less evidence of meat consumption, as well as degenerative osteological changes due to malnutrition, especially in childhood (Larsen 2015). The population from Giecz is consistent with this pattern established in past bioarchaeological research. The skeletal population from Giecz presents a high prevalence of *cribra orbitalia* and porotic hyperostosis – two degenerative osteological conditions associated with malnutrition – especially during childhood (Betsinger 2020). These conditions are evidence of vitamin deficiencies, as well as a lack of meat products in the diet of this population (Betsinger 2020). This evidence supports the findings of the population from Giecz being one that was largely focused on agriculture. Moreover, historically, non-elite working classes had less access to meat products as these were reserved for the elites or those belonging to a higher socioeconomic class (Larsen 2015). Therefore, this data supports the assertion that the population at Giecz was one of lower-class laborers.

Past bioarchaeological studies into populations similar to that from Giecz – physically-demanding, agricultural societies – has yielded similar results to those in this study, reaffirming the finding that Gz4 was an agriculture-based society experiencing a huge emphasis on production. Novak and Slaus (2011) examined two skeletal populations from 16th-19th century Croatia, comparing working-class and non-working-class populations. They found that Schmorl's Nodes were a very reliable indicator of a laborious lifestyle (Novak and Slaus 2011). In fact, in their study, Novak and Slaus (2011) found a sexual division of labor reflected in the SN prevalence as well, with significantly more males than females presenting with Schmorl's Nodes. In the present study, there is a significant prevalence of SN (16.3% of the population), especially among the males (20.8% of males), supporting the finding that the Gz4 population was one practicing heavy labor, especially the males.

Moreover, Dabbs et al. (2015) conducted a similar research study on a skeletal population from Akhetaten in Egypt. In this study, evidence supported finding that combined prevalence of spinal trauma – Schmorl's Nodes, DJD, vertebral compression fractures, etc. – was a very reliable indicator of habitual stress from labor activities (Dabbs et al. 2015). These findings were reaffirmed in another study by Dabbs (2019) focusing on non-elite burials in Amarna. In this population, again, combined prevalence of spinal trauma was found to support repeated stressful labor activities.

In the Gz4 sample under study in the present paper, there is clear evidence for a physically demanding lifestyle. Moreover, it is clear from the data that there was a sexual division of labor, in which the males in this population performed the more stressful, heavy labor. Males in this sample had extremely high prevalence of DJD, Schmorl's Nodes, and wedge vertebral compression fractures, all of which support the hypothesis that these individuals were performing physically stressful labor tasks. This combination of spinal trauma is consistent with previous research – mentioned above – centered on populations performing habitual strenuous labor (Tables 3, 5).

Dietary reconstructions further support this sexual division of labor. Reitsema et al. (2010) reconstructed the diet of those living in Giecz during this time period, finding that males consumed more meat products than females. This allocation of the protein to the men is consistent with a society wherein there is a sexual division of labor (Reitsema et al. 2010).

The sample population from Gz4 also presented increasing prevalence of DJD with increasing age. *All* older adults in this sample – 100% of them – presented with evidence of DJD (Table 4). Age-related degenerative changes can also be seen in the wedge vertebral compression fractures present in the members of this sample. The prevalence of this particular spinal trauma also increases with age in both sexes (Tables 4, 5). This finding strongly supports the idea that the lifestyle of those at Giecz was a physically demanding one that caused degenerative changes regardless of sex with increased time living in this way.

According to Duan et al. (2001), young men and young women are at equal risk for developing wedge vertebral compression fractures. However, this does not hold true throughout the aging process. As males and females age, females become more at risk for developing vertebral compression fractures than males (Duan et al. 2001). When looking at the population from Gz4, these finding support the hypothesis that there was a sexual division of labor in the population. The males in this sample show a higher frequency of wedge compression fractures in all age groups (Table 5). The incidence of wedge compression fractures in both sexes increases with age, however this incidence increases more dramatically in females (Table 5). This increase in wedge compression fractures in females in the older adult age range can be explained by the increased risk females are under as they age as compared to males (Duan et al. 2001). Even so, males with wedge compression fractures in all age ranges far outnumber females, indicating that the males are performing physically stressful activities throughout their lifetimes.

The vast majority of vertebral compression fractures affected the thoracolumbar region of the spine in the sample from Gz4, as can be seen in Table 8. Bruno et al. (2017) conducted a study to attempt to identify what activities cause vertebral compression fractures in this area of the spine. The activities that put the greatest stress on this region, and therefore presented the most risk for causing vertebral compression fractures, were those associated with lifting or carrying heavy loads (Bruno et al. 2017). For example, standing and holding weight in one's hands with elbows bent at 90 degrees, or with arms outstretched, caused significant force to be exerted on the vertebrae. Lifting objects up from the floor and lifting objects above the head also exerted a great deal of stress on the vertebrae. Transferring objects from the chest forward, transferring objects from right to left while twisting, as well as shoveling were also activities that caused a great amount of stress to the vertebrae. Activities such as standing, bending over, or carrying a heavy backpack caused much less stress to the vertebrae (Bruno et al. 2017).

These activities identified by Bruno et al. (2017) are consistent with tasks that would be performed by those living an agricultural lifestyle. This evidence strongly supports the hypothesis that the population from Gz4 was one performing physically demanding labor like that associated with agriculture. Even shoveling, identified by Bruno et al. (2017) to be stressful on the vertebrae, is consistent with activities these individuals would perform either in agriculture, or in the construction of the stronghold at Giecz. Moreover, in this sample, males present with wedge compression fractures far more frequently than females do (71.8% of males as opposed to 20% of females; Table

3), further supporting the finding males were conducting more physically demanding labor activities.

Bruno et al. (2017) also found that the vertebrae that experienced the most compressive stress were T11 and L5, with T11 being the most vulnerable to fracture. In addition, their study found that vertebral compressive strength (i.e., resistance to fracture/ability to support greater loads) increased moving inferiorly along the spine, meaning L5 was the most resistant to fracture (Bruno et al. 2017). These findings are consistent with the data from Gz4. In this sample, T11 showed evidence of a form of vertebral compression fracture 38 times, and L5 showed evidence of a form of vertebral compression fracture 55 times (Table 8).

Mokhtarzadeh et al. (2021) conducted a similar study that found that the thoracolumbar region was put under stress by similar activities, namely bending over with weight in each hand (the peak of stress being at L1 and L2), carrying weight in front with elbows at 90 degrees (the peak of stress being at T12), and moving weight from side to side while twisting (stress for this activity also peaked at T12). Interestingly, these researchers also posited that the boundary regions between upper and lower thoracic (T7-T8), as well as between thoracic and lumbar (T12-L1), are at a higher risk for fracture because of risky or improper loading carried out during activities that put excess pressure on these regions of transition (Mokhtarzadeh et al. 2021). These findings are, again, consistent with those in the present study, where we observed an increase in incidence of wedge vertebral compression fracture at T7-T8 and T11-L1 (Table 8). Future research should explore in more detail what makes these ‘boundary areas’ more susceptible to fracture and if it is, indeed, because of a transfer in stress from one region of the spine to another.

The stronghold at Giecz was an agricultural production hub in medieval Poland, further compounded by the fact that, it was a location where tribute from the local population would be exacted (Barford 2005). Its strategic location and agricultural significance led to Giecz becoming an increasingly exceptional settlement, earning it importance in the economic production and development in early-medieval Poland. The population felt this stress on production and thus maintained an extremely difficult, physically stressful lifestyle. This labor-intensive lifestyle imposed on those living in Giecz is reflected in the skeletal population from Gz4. The degenerative changes to the spinal columns of the individuals in this population, coupled with the other degenerative spinal changes analyzed in past research, paint a clear picture of how physically demanding the lifestyle was in this time period in Giecz. The prevalence and location of vertebral compression fractures in the Gz4 skeletal sample also illustrates what kind of activities these individuals would have been performing on a habitual basis: most of which are associated with lifting, carrying or moving heavy loads.

Chapter 6: Conclusions

During the early medieval period, the Polish state underwent a great deal of change. Most of this change was associated with immense population growth. Continuously increasing population density was associated with increasing centralization of power and early moves towards feudalism. As a result of these societal and economic changes, extreme stress was places on agricultural producers in early medieval Poland.

This would have been especially true in the agricultural settlements surrounding the stronghold at Giecz because this stronghold held great military and economic significance to the Polish rulers. Evidence of this stress can be seen in the skeletal assemblage from Gz4, representing a population performing intense manual labor. In this study, alone, 108 of 123 adult individuals with observable vertebral columns (87.8% of the population) presented with one or more form of vertebral trauma. This is an incredibly large proportion of the population, supporting the hypothesis that these individuals performed strenuous manual labor. Incidence of different vertebral trauma, especially when present together with other forms of vertebral trauma, are very reliable indicators of lifestyle.

When viewed in concert with evidence from past analyses of Gz4 that show degenerative or traumatic changes supporting a physically demanding lifestyle, it becomes highly likely that this population from early medieval Giecz experienced a demanding and stressful agricultural lifestyle.

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