AN INSIGHT INTO THE BIOARCHAEOLOGY OF THE MEDIEVAL INHABITANTS OF VESELAVA

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Abstract

In the course of archaeological excavation in 2004, 2006 and 2007 at the 13th–17th century cemetery of Veselava, in Cēsis District, Latvia, 941 burials were excavated. The osteological material permitted an insight into the palaeodemography and palaeodiet of the medieval inhabitants of Veselava. Demographic research shows that the population was characterised by high mortality among juveniles, aged 15–20, and among women aged 15–35. Among males, the highest mortality was observed at age 30–40, mortality remaining high in the age range of 40–50. As a result, adult life expectancy, e^0_{20}, is 5.1 years shorter for females than for males.

Palaeodietary analysis, utilising inductively coupled plasma atomic mass spectrometry (ICP-MS), was undertaken on 40 individuals, determining the concentration of seven elements in the bone. In order to assess the natural background level of these elements, 20 soil analyses were also undertaken.

The elemental content of male and female bone is similar, although the mean level of Zn and Cu in bone is slightly higher for males, which might indicate higher meat consumption. On the other hand, Sr and Mn values are higher for females, indicating a high proportion of plant foods in the diet.

It is thought that the 13th–17th century inhabitants of Veselava often had a meagre diet, and that plant food consumption was higher among women.

Keywords: Latvia, medieval, rural population, palaeodemography, palaeodiet.

Introduction

Bone is a complex tissue consisting of inorganic calcium phosphates precipitated in an organic collagen matrix. Its composition varies considerably with age and type of bone. Whole cortical bone is approximately 69% inorganic, 22% organic and 9% water (Triffitt 1980). The highly insoluble hydroxyapatite is the dominant calcium phosphate phase in bone mineral.

Bone is one of the few materials that are consistently recovered from archaeological and palaeontological sites; its chemical composition has the potential to provide invaluable information about ancient human and faunal diet and health status. Diet is the key to understanding many aspects of the development of human culture. Changes in dietary regimes came together with the change in the manner of food procurement. Gathering, hunting and, after domestication, cattle breeding and finally agriculture: each stage of the development of the dietary process also brought social stratification that led to a preferred diet for certain individuals. The improvement of analytical methods has made it possible to employ trace elements found in bone remains for the reconstruction of diet. Human diet is converted into the language of elements; not the separate components of diet, but the sources of elements are determined (Smrčka 2005). Gilbert (1985) used Zn, Cu, Mg, Mn and Sr to reconstruct the palaeodiet. He expected zinc and copper to be related to the supply of animal protein, whilst Sr, Mg and Mn could indicate the supply of vegetal food.

The influence of changes in the environment on the degradation of archaeological material needs to be established. Laboratory experiments addressing ionic exchange between soil solution and bone tissue should be tailored for each archaeological or palaeontological site. Solutions prepared with equivalent concentrations of each ion present in the soil solution can then be equilibrated with various bone tissues (Pate *et al.* 1989).

Measurement of trace element mass concentrations in soils is the first step in evaluating their potential health or ecological hazard. Various digestion methods are used to determine the mass concentration of trace elements in solid matrices, including different combinations of concentrated acids (Gaudino *et al.* 2007).

ICP-MS allows rapid multi-element determination of samples. Despite the excellent detection limits obtained with ICP-MS, limitations and problems in the determination of many trace elements in bone might be expected due to potential spectral interferences, mostly from major elements in bones (Ca and P) (Djingova *et al.* 2003). Analysis of these specimens is difficult due to the low concentration of the elements of interest, compared with the high concentration of the matrix elements. Sample preparation is an important step in the analysis of bone. Microwave digestion in sealed containers followed by ICP-MS is, nowadays, one of the most versatile methods for the analysis of samples. Microwave digestion provides a rapid and efficient method, and it also possesses the advantage of reducing volatilisation loss and contamination. The disadvantage of the microwave digestion method is that it is more expensive and requires some experience. Procedures using a low volume of acids or dilute acid solutions generally require H_2O_2 as an auxiliary oxidant agent to decrease solid residue and residual carbon content (Georgia *et al.* 2002). Compared to other studies (Florian *et al.* 1998) the small reagent volume (4 mL) reduced the risk of contamination and allowed less dilution after the digestion, resulting in better detection limits.

Therefore, the aim of the present paper is to determinate the trace elements in archaeological bones for reconstruction of palaeodiet using ICP-MS.

Study site

The medieval cemetery of Veselava is located in Veselava Parish of Cēsis District, Latvia, about 300 m north of Veselava Manor. The cemetery was registered by the Board of Monuments already in 1928. At that time, human bone and bronze ornaments were found in the course of agricultural work. Information was obtained that an oak tree had once grown on the hill here, with a bell in the tree and an icon of the Mother of God in a hollow in the tree. The human bone had been found mainly in the vicinity of the oak.

The monument was registered anew by Vladislavs Urtāns in 1958. The only written evidence of the cemetery is to be found in a 1688 church inspection report for the Livland region. The report states that the dead were being buried at a site where a chapel of Ignatius had once stood.

The excavation of Veselava medieval cemetery, undertaken by the National History Museum of Latvia, was connected with road improvement work, and lasted three seasons. In 2004, the excavation was directed by Jānis Ciglis. A total of 30 burials were excavated and the approximate limits of the cemetery determined. In 2006, excavation work continued under the direction of Ilze Melne, uncovering 235 burials. After removal of the old road surface, it turned out that the archive information and the archaeologists' calculations were misleading, since there were more burials under the road to be rebuilt. In 2007, the work was continued and completed, excavating a further 676 burials.

All the burials in the zone affected by the roadwork were excavated: under the road and in the proposed areas of the roadsides, ditches and bus stop. A total area of about 1244 m² was excavated, corresponding to almost half the area of the cemetery. At the eastern and western ends, the limits of the cemetery were reached, so we know that it was 75 m long. The width, in a north-south direction, was about 50 m.

A total of 941 burials have been excavated. Most were in supine position in accordance with Christian tradition, with heads to the west, but there were exceptions as well, oriented to the east or south. Most commonly, the arms had been placed by the sides, on the hips or across the middle, with the legs extended. There were exceptional cases, where the dead had been buried with legs crossed, in flexed position on the side, or even on the stomach. Most individuals were buried singly, although there were cases of two, three and even as many as six individuals in a single grave. The presence of iron nails and traces of wood in the cemetery indicate that the dead had been buried in plank coffins. Two disturbed cremations with no grave goods were also found in the cemetery.

A total of 524 burials, or 56%, had grave goods. These are mainly items of iron or bronze, with fewer objects of glass, stone or tin, as well as cowrie shells, and fragments of textiles and leather goods. Characteristic medieval objects were found: bead necklaces, brooches, finger-rings, pendants, knives, belt buckles and coins.

The coins found on the burials and in the grave fill have helped to date individual burials and determine the overall period of use of the cemetery. The oldest coin is a coin pendant: a silver coin of Dietrich, Archbishop of Paderborn, Westphalia (1208–1212). Also important among the earliest coins is a pfennig of Nicholas, Bishop of Riga (1229–1253). More common are hohlpfennigs of Hamburg, Mecklenburg, Lübeck, Tallinn and Tartu – bracteates dated to the period from the second half of the 13th to the first half of the 15th century. A second major group of coins, indicating a later period of use of the cemetery, consists of shillings minted by John II Casimir in Poland or Lithuania in the 1650s–60s (1648–1668). Thus, the cemetery was in use for a period of almost 500 years: from the mid-13th to the late 17th century.

The osteological material recovered in the course of the excavation (Plate II:1) provided an insight into the palaeodemography and palaeodiet of the inhabitants of Veselava.

Palaeodemography

Age and sex were determined for 877 individuals, using conventional morphological methods (Ferembach *et al.* 1980, Buikstra and Ubelaker 1994, Scheuer *et al.* 2004). The methodology allowed age determination up to 60 years. Sex was determined for individuals over the age of 15. Demographic analysis was performed using standard life tables (Acsádi and Nemeskéri 1970). Under-representation of children below the age of four was compensated according to methods proposed by Rösing and Jankauskas (1997): increasing their proportion to 45 % of the total sample. Population reproductive indices – potential gross reproductive rate (R_{pot}), net reproductive rate (R_0) and mean potential number of children per female (C) – have been calculated according to Hennenberg (1976), assuming a total fertility value of 7.45. Total mortality is calculated after the formula of Acsádi and Nemeskéri (1970).

Population structure is reconstructed after the scheme of Siven (1991).

Of the individuals buried at Veselava, 30 % were children aged up to 14: children up to the age of 1 year comprised 1.2 %, and children aged 1–4 made up only 7.8 % (Table 1). The number of children aged 5–14 is high in proportion to the number of adults (0.4). In most populations this figure is in the range of 0.2–0.3 (Bocquet-Appel, Masset 1977). According to historical demography data, child mortality up to the age of 1 year constitutes up to 25 % of total annual mortality, with 40–55% of mortality in the age group up to 4 years. In order to compensate for children not represented, the number of children aged 0–4 was increased to 45 % of the total number of individuals. This allows the errors in palaeodemographic calculations resulting from non-represented children to be reduced. Thus, average newborn life expectancy is reduced after compensation from 25.0 years to 18.7 years, which is a more objective figure (Table 1). Total mortality in the population was high: 53.5 per thousand.

Three mortality maxima can be distinguished for the inhabitants of Veselava:

1) the first consists of mortality among the children aged 0–4 years, for which compensation has been made in the calculations,

2) the second appears in the age range of 15–19, and is not characteristic of a balanced population. Increased mortality in this period may indicate epidemics or harsh social conditions,

3) the third maximum appears in the age range of 30–40, the period that sees the highest mortality among females and males (Fig. 1). The proportion of individuals surviving longer than 50 years is small: 5.4%.

Table 1. Summarised demographic data on the Veselava burials

Index	
Number of burials	877
Proportion of subadults $d_{0\text{-}19}$, %	46.0
Proportion of subadults $d_{0\text{-}19}$, % after correction of $D_{0\text{-}4}$ to 45 %	60.6
Juvenitility index ($D_{5\text{-}14}$/ D_{20+})	0.40
Index of masculinisation (Males/ Females)	0.87
Average newborn life expectancy (e^0_0), years	25.0
Average newborn life expectancy (e^0_0), years*	18.7
Average male life expectancy (e^0_{20}), years	19.0
Average female life expectancy (e^0_{20}), years	13.9
Potential gross reproductive rate, R_{pot}	0.550
Number of children per female (C)	4.1
Net reproduction rate, R_0	1.05
Total mortality M $\%_0$	53.5

* After correction of $D_{0\text{-}4}$ to 45 %

As regards the adult burials, it should first be mentioned that, based on the osteological material that could be sexed, the number of female burials is slightly in excess of the number of males (the ratio of males to females is 0.87). This may be connected with high mortality among young women, in the age group 15–35 (Fig. 2). This age group constitutes 67.8% of all female burials in the cemetery, which testifies to particularly high mortality during the most active reproductive period. Because of the high mortality among young women, the mean number of children per woman (including those who had no children) is 4.1, and female life expectancy at age 20, e^0_{20}, was only 13.9 years. Among males, the highest mortality is in the age group 30–40, with mortality remaining high in the age group 40–50 (Fig. 2).

In contrast to females, males do not show increased mortality in the age groups 15–30, and 13.6 % of males survive longer than age 50. Life expectancy among males at age 20, e^0_{20}, is 19.0 years. Accordingly, survivorship among males aged 25–50 is 18.8 % higher than among females (Fig. 3).

Comparing adult life expectancy among the inhabitants of Veselava with the figures for Latvia and Lithuania in the 14th–18th century, we see that the figures for Veselava are low (Fig. 4). Total mortality was high: 53.5 per thousand.

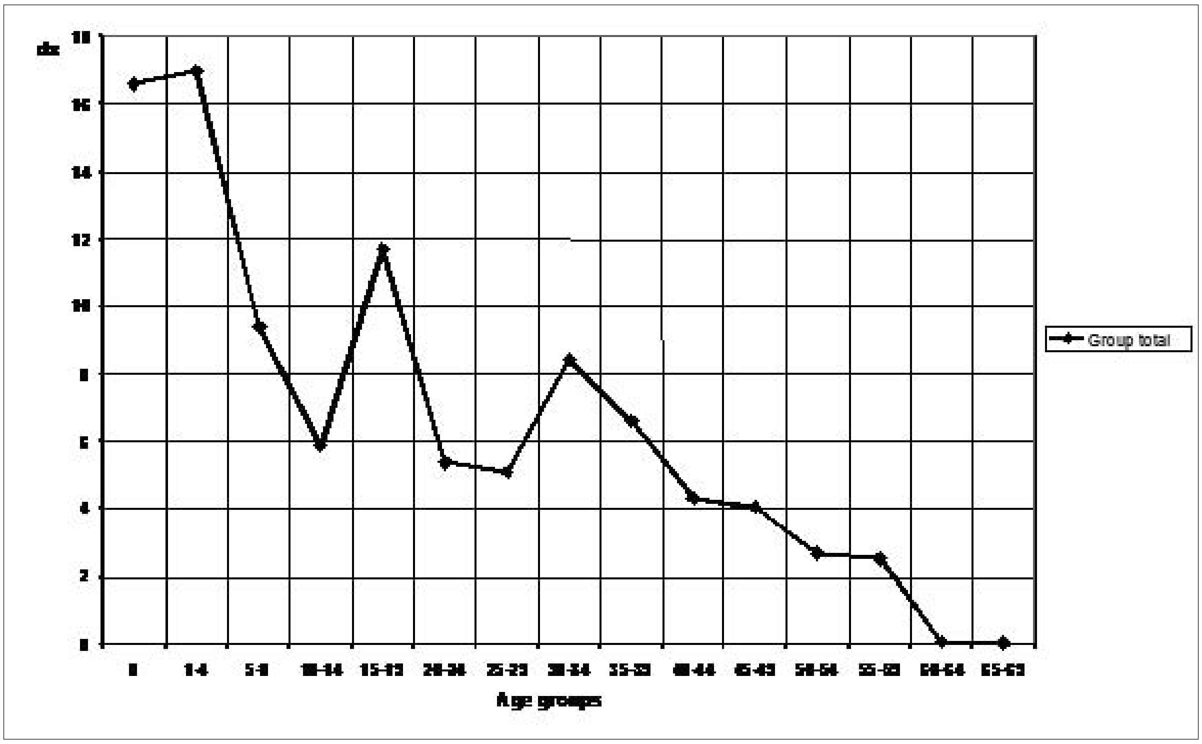

Fig. 1. Age structure of total mortality among the individuals subject to study, after compensation for children aged 0–4 years.

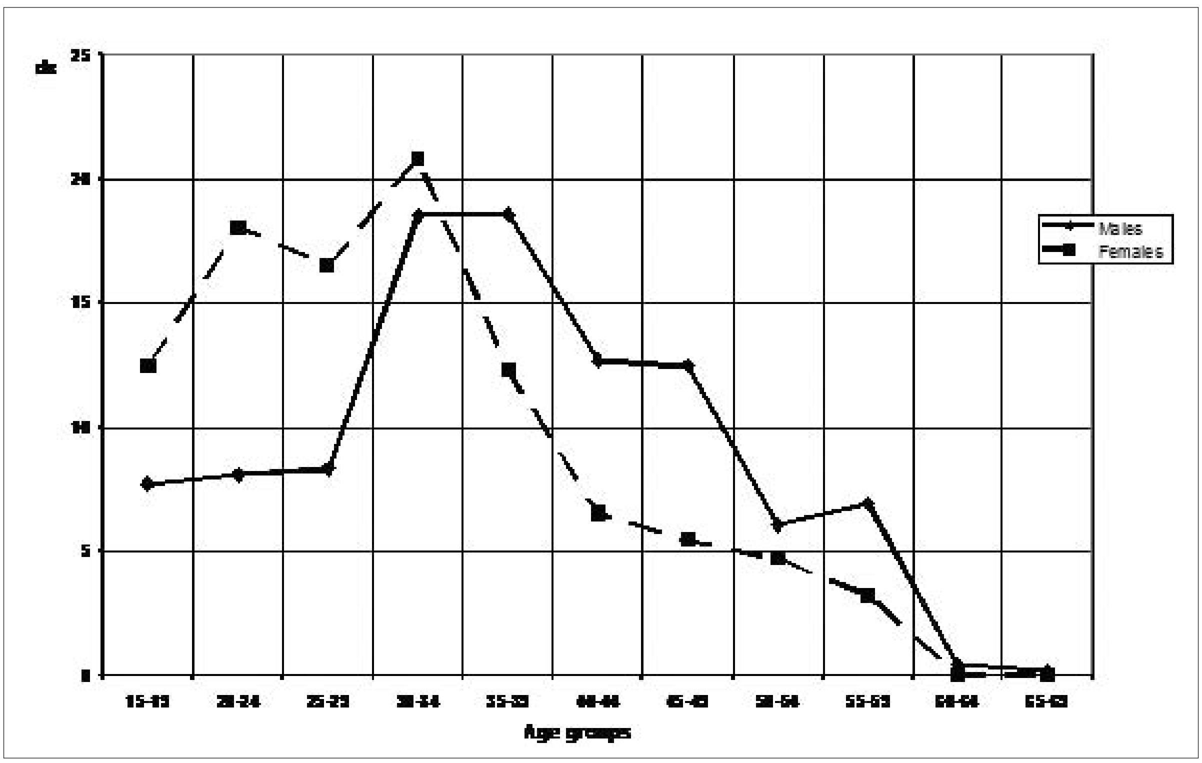

Fig. 2. Age structure of male and female mortality.

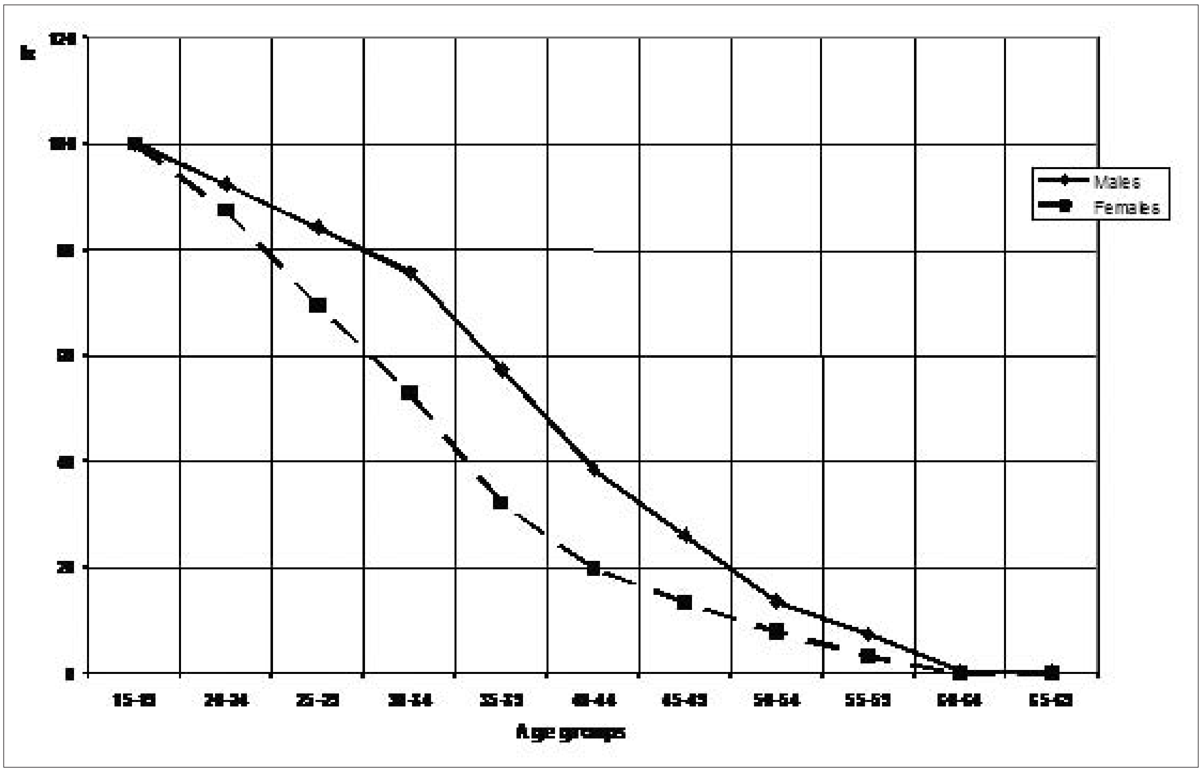

Fig. 3. Male and female survivorship in particular age ranges.

Calculation of the population structure for the inhabitants of Veselava indicates that 21% were children up to the age of 4; 31 % were children aged 5–14; 12% were juveniles aged 15–19; 34.3% were in the age range of 20–50, and only 1.5% were older than 50. Overall, the population was young, since children and juveniles up to the age of 20 made up 64% of the total population (Fig. 5). At the age of 25, there is a predominance of females in the population, but because of high female mortality, males predominate from age 30 upwards (Fig. 6).

The palaeodemographic statistics for the inhabitants of Veselava indicate that socio-economic and epidemiological conditions were adverse, something that significantly influenced mortality among young juveniles and young women.

Experimental

Instrumentation

Measurements were performed using a Perkin Elmer ELAN DRC-e ICP-MS spectrometer with cross-flow nebulizer. External calibration was performed using Merck multi-element stock solutions. Four calibration standard solutions (5; 15; 50 100 ppb) were used for calibration of the instrument. The calibration curve was linear over the whole range of the measured concentrations ($r \geq 0.9999$). The optimum conditions of spectrometer are presented in Table 2.

Table 2. ICP-MS spectrometer optimal measurement conditions

Measurement conditions	
Argon plasma gas flow	15 L min^{-1}
Auxiliary gas flow	1.2 L min^{-1}
Nebulizer gas flow	0.99 L min^{-1}
ICP – RF power	1270 W
Pulse stage voltage	750 W
Lens voltage	8.1 V
Integration time	2000 ms
Dwell time	50 ms
Number of runs	5

An Anton Paar 300 microwave oven digestion system was used. The control temperature was programmed to 125 °C and maximum microwave power (600 W) was applied from the beginning, decreasing later till 350 W. If the temperature of one of the eight vessels exceeded the programmed value, the power was regulated automatically and the temperature held constant for the remaining digestion time (approx. 20 minutes). Each digestion run included seven samples and one blank. The volume of acids in the vessels varied from 6 to 50 mL.

Samples and sample preparation

This study represents an attempt to analyse the paleodiet of the 14th–17th century population of Latvia, using as an example 28 male and 12 female inhuma-

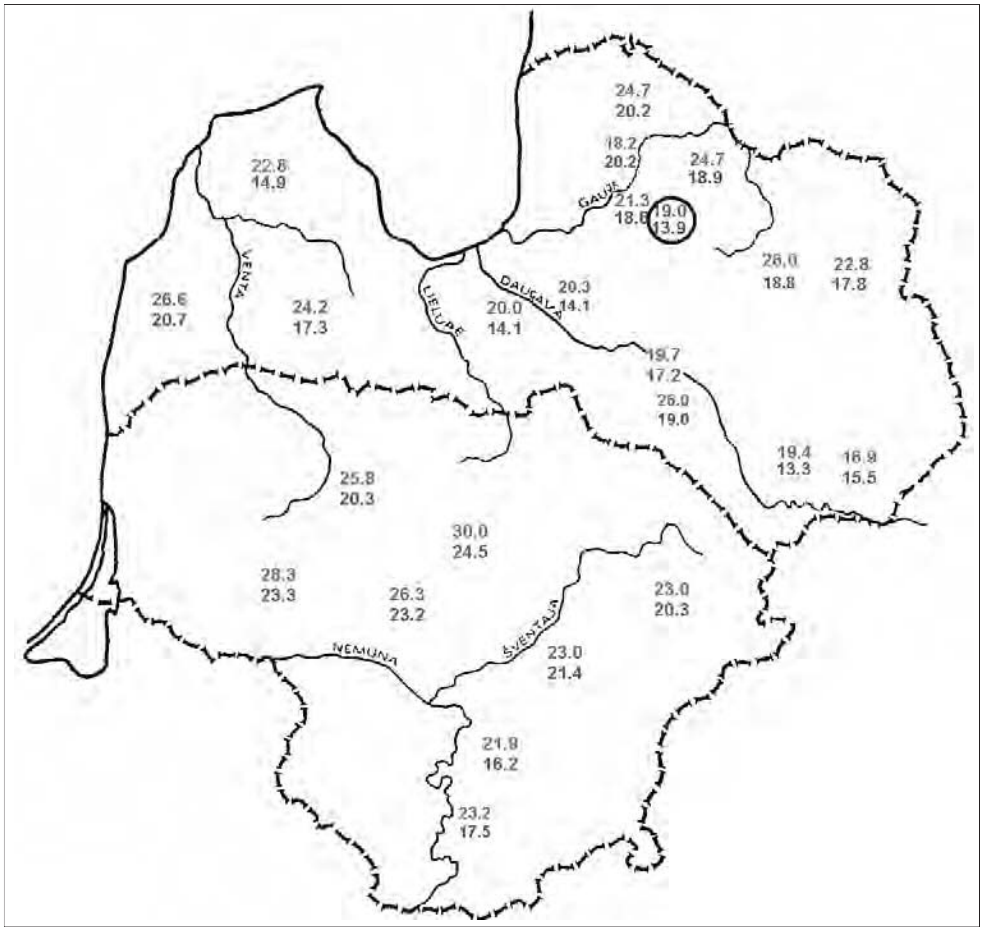

Fig. 4. Life expectancy at age 20, e^0_{20}, among males (upper figure) and females (lower figure) in Latvia and Lithuania in the 14th–18th century (incorporating data from *Česnys, Balčiūniene 1988, Jankauskas 1995*).

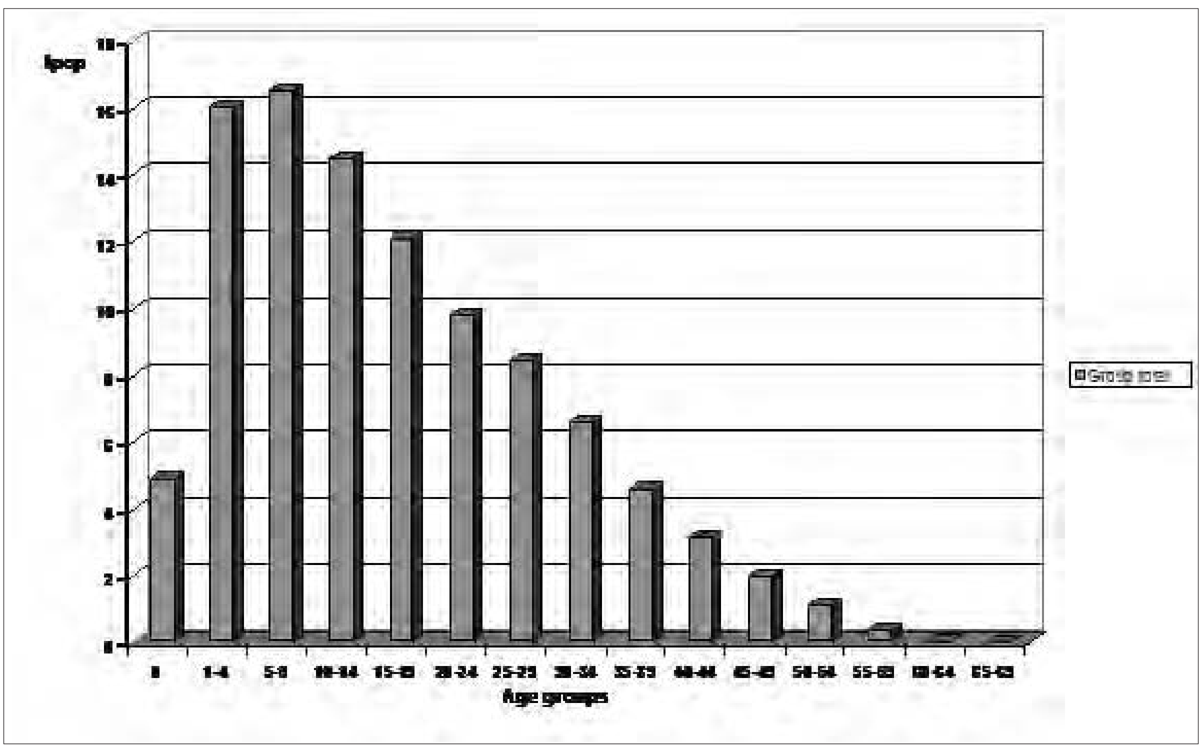

Fig. 5. Hypothetical overall population structure of the individuals buried at Veselava after compensation for children aged 0–4.

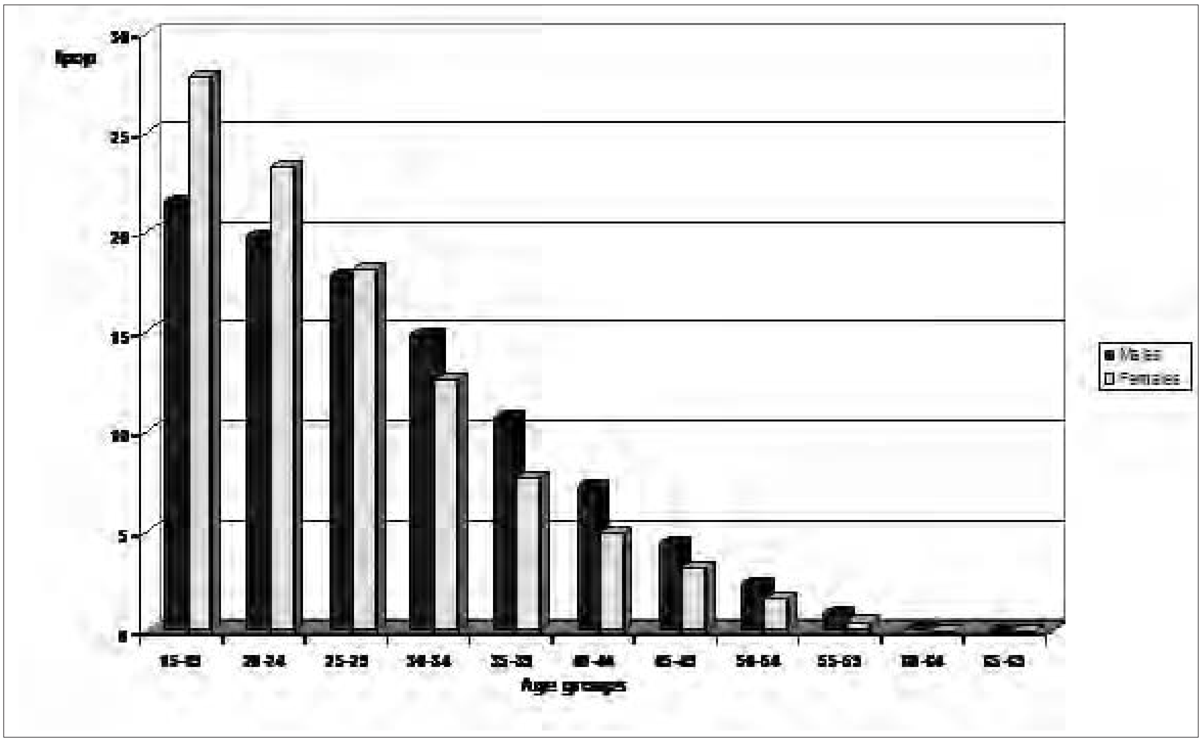

Fig. 6. Hypothetical population structure of the adult individuals buried at Veselava.

tions from Veselava cemetery. Additionally, soil samples were analysed.

The bones were rinsed with deionised water. Samples were taken from the major part of the cancellous bone from the femoral head using a drill. Homogenisation and grinding was performed using a Retsch ball miles MM 301. A 6-minute grinding mill program was used, at 30 Hz frequency. The samples were dried in an oven at 105 ^{0}C for 2 hours. When preparing the samples for chemical analysis, 0.3 g of dried bone powder with precision 0.0001 g was weighed. The samples were placed in a PTFE pressure vessel and a mixture of 4mL HNO_3 (Merck, suprapur) and 2mL H_2O_2 (Merck, suprapur) was added. The closed vessels were placed in the microwave oven-assisted sample digestion system and heated for 40 min (maximum temperature: T = 125 ^{0}C, maximum pressure: 35–40 bar). After cooling, the digested samples were diluted to 25.0 mL with deionised water. The obtained solutions were diluted 10 and 50 times with deionised water before the analysis by ICP-MS instrument.

Quality control and method validation were performed by analysis of NIST-SRM 1486 (animal meal) standard reference material.

Twenty soil samples were collected at the cemetery site. Sampling was performed in June 2007. The soil samples were weighed and stored in cardboard boxes, and then dried in an oven with a fan at 50 ^{0}C until constant weight was reached, after which they were sieved through a 1 mm mesh.

10.00 g of the air-dried soil was transferred into a 50 mL beaker, and 50 mL of water added. The pH was measured after equilibration in an end-over-end 16 h.

20.00 g of dried soil was transferred into an Erlenmeyer flask and 100 mL 0.5 M HNO_3 added. The extract was shaken for 30 minutes with shaker and later filtered into a polyethylene flask (Ranst *et al.* 1999).

After digestion, the metal content (Al, Cr, Mn, Fe, Ni, Cu, Zn, Cd and Pb) in the soil samples was determined with ICP-AES.

Results and discussion

Soil acidification, the presence of soot and soluble salts, the medium-grained sandy soil, and 'open' structures seem to be the main factors accelerating deterioration. The degree of metal mobility was related to soil pH and soil texture. The soil type in the study area was mainly sandy, and the cemetery constitutes an open structure. Most of the bone samples from the excavated area were very poorly preserved.

On the site as a whole, soil pH values ranged from 7.15 to 8.12. Table 3 presents element availability to the soil solution. Al, Fe and Mn are relative abundant elements in the sands, but are highly insoluble. Cation exchange capacity is very low. The sandy soil is low in organic matter.

Table 3. The mean concentration values ($\mu g\ g^{-1}$) of elements available to the soil solution in the analysed soil samples; n=20.

Element	Mean	SD
Al	1186	335
Cr	0.55	0.14
Mn	34	12
Fe	706	284
Ni	0.33	0.18
Cu	2.4	1.7
Zn	4.4	1.9
Cd	0.03	0.01
Pb	1.2	0.8

The small percentage of each element available to the soil solution indicates that it would have had a small influence on the archaeological bone mineral and can be related as background level.

The high content of Ca and P can effect the determination of elements using ICP-MS. The sample preparation method and analysis method with ICP-MS was validated by SRM. The results from the analyses of NIST-SRM-1486 (animal bone) are presented in Table 4. The obtained results illustrate the applicability of the proposed method for determination of Mn, Cu, Zn, Sr, Cd and Pb in bone samples. All analysed results are in a good agreement with certified results.

Table 4. ICP-MS analysis results of the bone powder standard reference material (NIST SRM -1486) after acid microwave digestion; n = 6.

Element	Concentration $\mu g\ g^{-1}$	
	Analysed	Certified
Mn	1.16±0.03	1
Cu	0.72±0.11	0.8
Zn	138±16	147±16
Sr	266±7	264±7
Cd	0.0029±0.0004	0.003
Pb	1.34±0.14	1.34±0.01

The elemental content was analysed in 40 archaeological human bone samples to find any significant differences between the sexes in terms of elemental content. The obtained results are shown in Table 5.

Table 5. The content of elements in archaeological bone samples analysed by ICP-MS ($\mu g\ g^{-1}$); n=40.

Elements	Female		Male	
	Mean	SD	Mean	SD
Mn	149	75	120	64
Cu	1.70	0.47	1.79	0.51
Zn	106	21	119	24
Sr	85	19	79	13
Ba	28.2	9.6	25.9	9.7
Cd	0.1	0.05	0.1	0.04
Pb	2.3	1.4	2.4	1.2

Strontium, manganese, and calcium are usually found in higher quantities in plant resources. Zinc and copper show higher concentrations in animal foods. Other elements, such as Cd and Pb, describe anthropogenic activities and environmental pollution.

Strontium enters the food chain at the level of plants. Higher strontium levels reflect a higher portion of vegetal food in the diet. It is found that strontium content effect lactation period in female life (Mays 2003), but in the current research, the variation of strontium content was not significant in female and male bone samples.

Manganese ions can be accumulated from the soil solution and enrich the bones. The comparison of the results of analysed soil and bone samples shows that the level of manganese content is approximately 4 times higher in the inhabitant bones than in the soil solution. In our opinion, this could not affect the manganese content in bones. The strontium and manganese content was slightly higher in female than male bones.

Barium has a strong affinity to PO_4^{3-} and is bound in the bones more strongly than Ca. The content of Ba also characterises the quantity of plant foods in diet.

The Zn content in the bones does not change so rapidly over time, and it is not affected by the soil solution. So, Zn and Sr can serve as approximate indicators of the proportional presence of vegetal and animal albumens in the diet. A slightly higher mean level of zinc was found in male bones.

There is more Cu in the bones of carnivores than in those of herbivores. The analysis of Cu content showed an increased level in male bone samples.

Looking at all of the elements mentioned (Sr, Mn, Ba, Cu and Zn) we can see that the content of Sr and Mn is higher in the analysed female bone samples, while the content of Zn and Cu is slightly higher in male bone samples.

Cadmium and lead are toxic elements. Sources of Cd include industrial fertilizers, fly ash from fossil fuels and metal processing plants. Lead sources are non-natural: lead may derive from vessels made of hard tin, pottery with lead glaze or lead tubes. The mean lead and cadmium contents in bone and soil samples showed the same levels. In the studied area, the Pb and Cd are at background level.

Conclusions

Rekonstruojant Veselavos The content of Sr, Mn, Ba, Cu, Zn, Pb and Cd in archaeological bones has been investigated, using inductively coupled plasma atomic mass spectrometry, and evaluated in order to reconstruct the palaeodiet. The method of preparing archaeological bone samples allows the accurate determination of studied elements. Digestion with a small amount of HNO_3 acid decreases the possibility of spectral overlap, and added H_2O_2 completely destroys organic matter.

Soil solution analyses will provide essential data to test various models concerning the chemical composition of secondary minerals and ionic substitution phases in fossil bone. Soil samples should be taken from various positions around each skeleton during excavation.

Analysed 40 archaeological human bone samples did not show significant differences between the sexes in terms of elemental content, but still some small tendencies were observed. It is thought that the 13th–17th century inhabitants of Veselava often had a meagre diet.

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VIDURAMŽIŲ VESALAVOS GYVENTOJŲ SAMPRATA BIOARCHEOLOGINIU POŽIŪRIU

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Santrauka

Veselavos viduramžių kapinynas yra Cėsio rajone Latvijoje, apie 300 m į šiaurę nuo Veselavos dvarvietės. Šis kapinynas buvo aptiktas 1928 m. Veselavos kapinyną tyrinėjo Latvijos nacionalinio istorijos muziejaus archeologai Jānis Ciglis (2004 m.), Ilze Melne (2006–2007 m.). Iš viso buvo ištirti 676 palaidojimai. Rekonstruojant Veselavos kapinyne palaidotų gyventojų vartotą maisto racioną, buvo naudotas induktyvusis jungtinis plazminis atomus tiriantis spektrometras. Juo mirusiųjų kauluose buvo aptikta Sr, Mn, Ba, Cu, Zn, Pb ir Cd. Archeologinės medžiagos (kaulų) pavyzdžių paruošimas sudarė sąlygas tiksliai nustatyti nagrinėjamus elementus. Maisto virškinimas su mažu azoto rūgšties kiekiu sumažino spektrinių užsidengimų galimybę, o naudotas vandenilio peroksidas visai sunaikino organinę medžiagą.

Dirvos tirpdymo analizės suteikė pagrindinius bandinių duomenis skirtingų modelių rūpimai cheminei sudėčiai nustatyti, atmetant šalutinius mineralus ir jonizacijos kaitos fazes fosiliniuose kauluose. Dirvožemio mėginiai kasinėjimų metu buvo imami iš įvairių vietų šalia kiekvieno skeleto. Ištyrus 40-ies žmonių skeletų pavyzdžius, nepastebėta ženklaus cheminių elementų skirtumų lyčių požiūriu, tačiau visgi keletas smulkių nukrypimų užfiksuota. Tyrimų metu nustatyta, kad Veselavos gyventojai XIII–XVII a. dažnai maitinosi skurdžiai.

Vertė Algirdas Girininkas