doi:10.17746/1563-0110.2022.50.2.150-156

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Porotic Hyperostosis Observed in the 16th to 19th Century Crania of Native Siberians, Russian Settlers, and Joseon Dynasty Koreans

Porotic hyperostosis (PH) is the skeletal marker used in the estimation of physiological stress suffered in childhood. Despite a conventional hypothesis that mankind's health conditions declined with the advent of agriculture, there are few reports comparing the PH seen on ancient crania of hunters-fishermen-gatherers and agrarian peoples. In this study, we examined the crania of 16th to 19th century Eurasian peoples: Siberian natives (hunters-fishermen-gatherers), Russian settlers, and Joseon Koreans (agriculturalists) to see whether PH could be observed to differ between populations with varying subsistence strategies. The prevalence of PH decreased in the order of Joseon people (18.9 %), Russian settlers (6.3 %), and Siberian natives (3.8 %). In brief, the hunters-fishermen-gatherers' stress level was lower than agriculture-based Joseon people and Russian settlers. In addition, Joseon people might have been exposed to more serious stressful episodes than Russian settlers were. We assume that the former might have lived under much stressful conditions than the latter did, though both people depended on intense agriculture. As for sexual dimorphism of PH: in all groups, males were identified with more PH signs than females were. Our report successfully shows that the detailed pattern of stress markers might have been influenced by complex interactions between various factors that existed under different conditions in history.

Keywords: *Porotic hyperostosis, Korea, Siberia, hunters-fishermen-gatherers, agriculturalists, crania.*

Introduction

Porotic hyperostosis (PH), small perforations on the surface of cranial bones, is regarded as an osteological indicator that is useful for the assessment of physiological stress suffered in childhood (Ortner, Putschar, 1981: 259–260; Goodman et al., 1988; Lewis, Roberts, 1997; Larsen, 1997; Novak, Slaus, 2010; Wheeler, 2012). Although PH is not an indicator of any specific diseases, its prevalence provides valuable information about

the health and nutritional status of different human populations (Huss-Ashmore, Goodman, Armelagos, 1982; Larsen, 1997: 32–33; Salvadei, Ricci, Manzi, 2001; Temple, 2010).

For a long while, researchers have wondered whether stress indicators changed with the transition of various social factors in history (Gleń-Haduch, 1995; Krenz-Niedbała, 2014: 116). For example, Kyle et al. (2020) proved that physiological stress increased with the social turmoil caused by urbanization in Albanian history. In this study, they observed increased osteological manifestations of physiological stress, possibly caused by social unrest spanning between prehistoric and historic periods (Ibid.). Judging from previous anthropological reports, stress markers are revealed to have changed during a transition from foragers to farming societies in history. In brief, hunters-fishermen-gatherers might have been healthier than agriculturalists, because the former were affected only by seasonal or periodic stresses while the latter were plagued by severe, chronic, and perennial stresses (Cohen, Armelagos, 1984: 68; Bocquet-Appel, Bar-Yosef, 2008: 505). That scenario is accepted nowadays by most academia, who presume that people's physiological stress increased rather than decreased with the advent of agriculture in mankind's history.

Nevertheless, some scholars still reported a different story concerning the changes in stress markers around the emergence of agricultural society. For example, Lopez and Godde (2019) identified no evident difference in PH prevalence between the ancient Egyptian crania of foragers and agriculturalists. Furthermore, as for Jomon foragers and Yayoi agriculturalists, stress marker (e.g., cribra orbitalia) prevalence was not remarkably different between them (Temple, 2010). Ancient Southeast Asia also showed similar patterns. Briefly, the prevalences of stress markers in mid-Holocene foragers and Bronze–Iron Age agriculturalists in Vietnam were not different from each other. In historic Thailand, foragers' physiological stress could have been even higher than agriculturalists' (Pietrusewsky, Douglas, 2002: 171–173; Oxenham, 2006). This means that the detailed pattern of PH between foragers and farmers differs depending on various spatiotemporal conditions in which each group existed.

In this regard, our research on historic Eurasian peoples is meaningful. In brief, Siberian natives, Russian settlers, and Joseon Koreans lived in the 16th to 19th century Eurasian continent, as hunters-fishermen-gatherers or agriculturalists with different subsistence strategies. To see whether physiological stress could be observed to differ between each forager and farmer group in history, we tried to examine PH, one of the physiological stress markers, in skeletons from each Eurasian group.

Materials and methods

We examined the skeletons of three different Eurasian populations of the 16th to 19th century. Total number of crania was 222 (103 male, 119 female). For those skeletons, age and sex were estimated using the standard methods of Buikstra and Ubelaker (1994). All individuals were grouped into different age categories: adolescents and young adults (15–34 years), middle adults (35–49 years), and old adults (over 50 years) (Lee et al., 2019). The homogeneities in the proportions of age and sex across each group was tested by Pearson's Chi-squared test (χ^2).

In this study, the Siberian natives were 16th to 19th century hunter-gatherers. Their skeletons (n=53; 23 males, 30 females) had originated from Siberian Tatars (Krasnoyarsk archaeological complex of the Ust-Ishim region, dated to the 9th to 18th centuries, n=34), Khanty (Alym burial ground, belongs to the presumably indigenous (Khanty) population of the second half of the 18th to early 19th centuries, n=7), and Nenets (Vesakoyacha II–IV and Nyamboito I burial grounds, n=12) peoples (Fig. 1). Siberian Tatars were pastoralists, fishermen, and hunters (Slepchenko, 2017). Khanty were hunters and fishermen in tundra and taiga zones

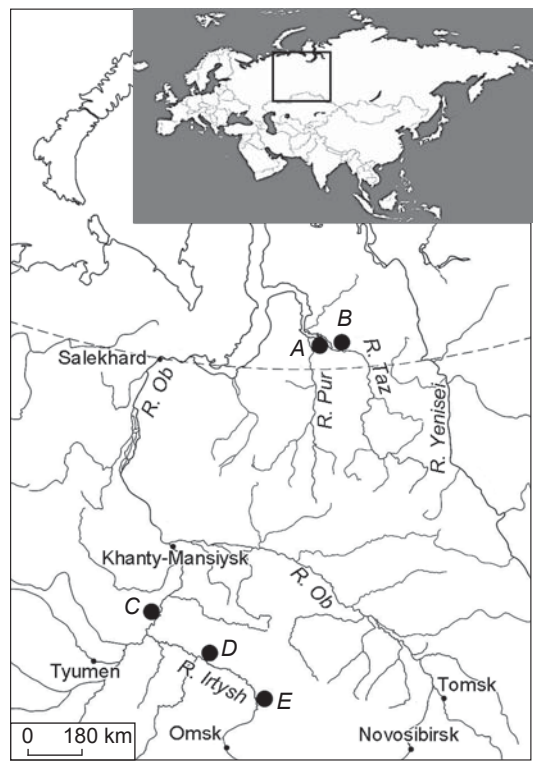

Fig. 1. The locations of archaeological sites in Siberia from which the analyzed series of crania originate: Nenets (A, B), Khanty (C), Siberian Tatars (D), and Russian settlers (E).

(Perevalova, 2004: 252–275). And Nenets were hunters, fishermen, and reindeer-herders who lived in the Arctic Circle (Slepchenko, Tsybankov, Slavinsky, 2016). These osteological collections are currently kept at the Institute of Northern Development SB RAS (Tyumen, Russia) (Lee et al., 2019).

The Russian settlers' crania consist of 79 individuals (32 males and 47 females). They were wheat-cultivation farmers who migrated from Northern or Central Russia, as well as Eastern Europe (Tataurova, 2010: 20). The archaeological excavation around the Irtysh River discovered a Russian settlers' cemetery, next to the Izyuk village built in 1648. Their crania are curated in the Institute of Northern Development SB RAS (Lee et al., 2019).

The Joseon skeletons of the 16th to 18th centuries consist of 90 individuals (48 males and 42 females). We collected the skeletons from Joseon graves of a particular type that were found at archaeological sites in South Korea. This kind of grave was first introduced in Korea in the late 15th century, then rapidly became the prototype favored by the officials and nobles in the 16th century, and was also used by middle-class people in the 17th and 18th century (Shin et al., 2008, 2012, 2021). The buried individuals had evidently been engaged in rice-cultivation. The Joseon skeletal series are currently maintained at Seoul National University College of Medicine (South Korea).

PH on parietal and occipital parts of crania were evaluated macroscopically. Slight or severe pitting forms of PH were observed in the crania, as described by Steckel et al. (2006: 13–14). However, it was recorded as *present* or *absent* categories for statistical analysis. We used package R (R Core Team, 2017) for statistical analysis in this study. PH prevalence of each group was compared by Pearson's Chi-squared test (χ^2). In cases where that sample size was less than 10, Fisher's exact test was applied to compare prevalence. We used the package ggplot2 implemented in R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria) to draw a chart (Wickham, 2009: 20).

Results

The proportions of age in Siberian natives, Russian settlers, and Joseon people were not different (Table 1). The p-values were as follows: 0.3225 for Siberian natives-Russian settlers, 0.217 for Russian settlers-Joseon people (χ^2 test); 0.1507 for Siberian natives-Joseon people (Fisher's test). Likewise, homogeneity in sex proportions could be also confirmed by statistics (χ^2 test): 0.1013 for Siberian Natives-Russian settlers, 0.3297 for Siberian Natives-Joseon people, 0.5157 for Russian Settlers-Joseon people.

In this study, the prevalence of PH decreased in the order of Joseon people (18.9 %), Russian settlers (6.3 %), and Siberian natives (3.8 %) (Table 2; Fig. 2). The difference in PH between Joseon people and Russian settlers (p = 0.02839), as well as between Joseon people and Siberian natives (p = 0.02051), was statistically confirmed. However, the difference between Russian settlers and Siberian natives was not statistically significant (p = 0.7013).

We also compared PH prevalence of each group by sex. Among Siberian natives, PH was found only in two male crania (Fisher's exact test, p = 0.1836). Two other samples showed a similar situation: Russian settlers exhibited 12.5 % of males and 2.1 % of females (Fisher's exact test, p = 0.152). In Joseon people's crania, PH were found in 22.9 % of male skulls and 14.3 % of female skulls (χ^2 test, p = 0.4391). Thus, the PH prevalence of

Table 1. **Proportion of age in the samples under study**

Age group	Siberian natives	Russian settlers	Joseon people	Total
Young adult	33	39	42	114
Middle adult	16	26	37	79
Old adult	4	14	11	29
Total	53	79	90	222

Table 2. **Prevalence of porotic hyperostosis in the samples**

Populations	Male			Female			Male +Female		
	Total (n)	Affected (n)	Frequency (%)	Total (n)	Affected (n)	Frequency (%)	Total (n)	Affected (n)	Frequency (%)
Siberia natives	23	2	8.7	30	0	0.0	53	2	3.8
Russian settler	32	4	12.5	47	1	2.1	79	5	6.3
Joseon people	48	11	22.9	42	6	14.3	90	17	18.9

males was generally higher than that of females in all the groups we examined (Fig. 2), though the differences could not be successfully proven by statistics.

The distribution by age cohorts shows that the PH prevalence generally decreases as age increases (Table 3). This phenomenon is particularly noticeable in old age-groups of Siberian natives and Russian settlers, in whose crania we could not find any signs of PH. However, in the case of the Joseon people, we note that the tendency of the PH to decrease with age was very weak.

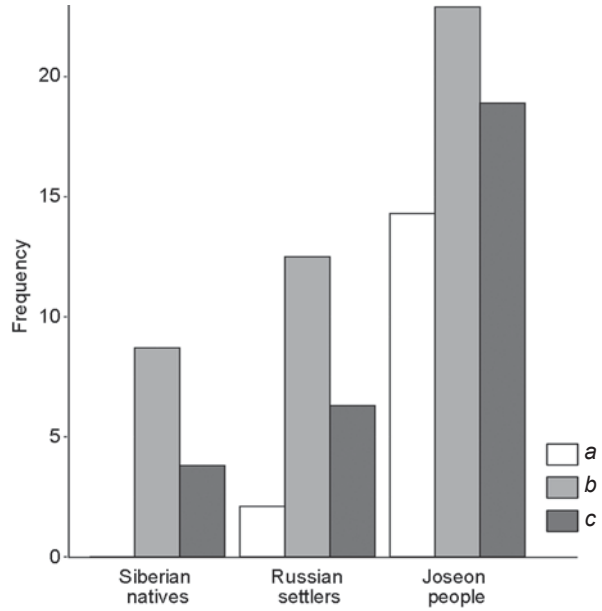

Fig. 2. The analysis of PH rates in the groups under study. *a* – females, *b* – males, *c* – total.

Discussion

Previous studies presumed that the health status of prehistoric hunters-fishermen-gatherers was historically better than that of agriculturalists (Goodman, Armelagos, Rose, 1980; Latham, 2013). On the other hand, many researchers have also presented conflicting views on the same subject. For example, in Ancient Egypt, a population increase induced the Neolithic Revolution, for which nomadic hunters-fishermen-gatherers groups gradually selected agriculture as their main subsistence strategy. When Lopez and Godde (2019) tried to test the PH of ancient Egyptian crania across time, statistical outcomes indicated no difference in prevalence between the pre- and post-agricultural Egyptians in history. In a sense, the historical pattern of stress markers could not be easily expected or interpreted for many of mankind's groups that have existed in history.

In this study on foragers and agriculturalists in 16th to 19th century Eurasia continent, our results were more like those of Goodman et al. (1980) and Latham (2013). Briefly, the prevalence of PH in hunters-fishermen-gatherers (Siberian natives) was lower than that of agriculture-based Joseon people and Russian settlers. Judging from PH, Siberian natives might have been less stressed than agriculturalist Russian settlers or Joseon people. As hypothesized by Cohen and Armelagos (1984: 68) or Bocquet-Appel and Bar-Yosef (2008: 505), agriculture-based peoples in Russia and Korea might have been plagued with more chronic and perennial stresses than foragers were. With sedentism and subsequent growth of population, the agricultural population might have experienced increased risk of infections, as well as a decline in nutritional intake, particularly on their infants or children (Cohen, Armelagos, 1984: 67; Armelagos, Goodman, 1991). This might explain in part why the Russian settlers and Joseon people of the 16th to 19th century showed higher prevalence of PH than Siberian natives.

As for the Joseon people, we also assume that they might have lived under much more stressful conditions than Russian settlers. Unlike Joseon people, Russians at that time did not rely solely on agriculture, but also engaged in more diverse economic activities. By hunting and fishing activities in Siberia, Russians seem to have been able to eat much richer food than Joseon people. Russians could have lived in less stressful conditions, which seems to be due to the abundance of natural products and lower population density in Siberia (Korona, Tataurova, 2011; Bondarev, Tataurova, Tataurov, 2020).

On the other hand, in Korean history, the 16th to 19th century was specifically a turbulent era, during which the Joseon people were involved in major

Table 3. **Prevalence of the individuals with porotic hyperostosis by age**

Age group	Siberian natives			Russian settlers			Joseon people		
	Total (n)	Affected (n)	Frequency (%)	Total (n)	Affected (n)	Frequency (%)	Total (n)	Affected (n)	Frequency (%)
Young adult	33	2	6.1	39	3	7.7	42	8	19.0
Middle adult	16	0	0.0	26	2	7.7	37	7	18.9
Old adult	4	0	0.0	14	0	0.0	11	2	18.2
Total	53	2	3.8	79	5	6.3	90	17	18.9

socioeconomic changes (Shin et al., 2018). In brief, farmers cleared slash-and-burn fields in every corner of the mountains; therefore, there were no lands that had not been utilized for farming. Since the population soared, the Joseon people came to live in highly populated villages and cities, thus more easily suffering from physiological stresses than ever (Ibid.). Those historical incidents may not have been limited only to Joseon Koreans, but have been also the cases for other East Asian countries such as Japan and China (Kim et al., 2014). In a sense, notwithstanding physiological stress-inducing environments, social changes in 16th to 19th century appear to have been a necessary evil for the East Asian peoples (Shin et al., 2018).

The results of PH rates analyzed by age factor is also significant for understanding the detailed status of physiological stress among Joseon people. Different from Siberian natives and Russian settlers, the tendency of PH prevalence to decrease with age was very weakly observed in Joseon people's crania. In fact, while PH was not found in older groups of Siberian natives and Russian settlers, difference in PH incidence according to age-groups was not observed among the Joseon people's group. In previous studies, while higher frequencies of stress markers could be observed in young age group, many of them were also healed after then on; therefore, fewer stress signs could be detected in old age groups (Hengen, 1971; Liebe-Harkort, 2012; Møller-Christensen, Sandison, 1963; Salvadei, Ricci, Manzi, 2001; Stuart-Macadam, 1985; Toso et al., 2019). In a sense, high PH incidence in older group of Joseon people means that the stress situation was not improved to the extent that PH could not be healed even after their youth.

We can also mention about PH from the perspective of sexual dimorphism. In related reports so far, a stress marker like cribra orbitalia was observed more frequently in females than in males, possibly caused by anemia due to menstruation, pregnancy, and childbirth (Armelagos, Goodman, 1991; Cohen, Armelagos, 1984: 31; Cybulski, 1977; Hengen, 1971), or cultural factors such as nutritional care-giving for a baby (Guatelli-Steinberg, Lukacs, 1999; Goodman et al., 1987; May, Goodman, Meindl, 1993). However, the contradictory phenomena were also reported for another stress marker (linear enamel hypoplasia): higher frequency in males than in females (May, Goodman, Meindl, 1993; Palubeckaite, Jankauskas, Boldsen, 2002; Hoyenga K.B., Hoyenga K.T., 1982; Guatelli-Steinberg, Lukacs, 1999). In addition, there were also reports for no significant sexual dimorphism in stress marker prevalence: in skeletons of prehistoric and historic Anasazi Indians (El-Najjar et al., 1976), California Indian population (Walker, 1986), and Neolithic human populations in Poland (Krenz-Niedbała, 2014). Lopez and Godde (2019) also identified no differences of PH prevalence across sex in ancient Egyptian crania.

In this study, when we compared PH prevalence by sex, males' prevalence was higher than females' in all groups we studied. From the perspective of stress markers, our data are similar to the results of Hoyenga and Hoyenga (1982), May et al. (1993), Guatelli-Steinberg and Lukacs (1999), and Palubeckaite et al. (2002). We presume that the detailed pattern of sexual dimorphism for stress markers might have been influenced by complex interactions of various factors under different spatiotemporal conditions in history. However, since statistical analysis of our data could not be obviously significant, such a trend of sexual dimorphism should be confirmed by more forthcoming studies on similar cases in the Eurasian continent.

Conclusions

A hypothesis that the human health condition declined with the advent of agriculture is generally accepted by academia. However, there are not sufficient reports on the physiological stress of hunters-fishermen-gatherers and agrarian people in history, especially by comparing PH visible on their crania. In this study, we can confirm the hypothesis by revealing the PH prevalence of Siberian natives (3.8 %), Russian settlers (6.3 %), and Joseon-period Korean people (18.9 %). We also assume that among agriculturalists, Joseon people of East Asia were exposed to more serious stressful episodes than Russian settlers in Siberia. As for sexual dimorphism of PH, we realized that males were identified with more PH signs than females; but more research is still needed to confirm it.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2020R1A2C1010708) and Korea Ministry of Education (NRF-2019S1A5C2A01083578). Author contributions are as follows. Conceptualization, design of study, and correspondence: Shin Dong Hoon and S.M. Slepchenko; anthropological data analysis and statistical analysis: Lee Hyejin and Hong Jong Ha.

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Received October 27, 2021.
Received in revised form February 2, 2022.