



Research article

Influence of physiological stress on the presence of hypoplasia and fluctuating asymmetry in a medieval population from the village of Sypniewo



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ABSTRACT

This study aims to estimate the levels of physiological stress in the medieval rural population of Sypniewo by evaluating patterns of fluctuating asymmetry (FA) and enamel hypoplasia (EH), and provide information on the influence of physiological stress during the prenatal and perinatal period on early childhood development.

Stress is defined as any external or internal condition that challenges homeostasis of an organism. FA is associated with physiological stress occurring mainly during prenatal development and early childhood. The level of FA is thought to reflect the intensity of the stressor(s). EH is caused by physiological stress such as nutritional instability during the first years of life.

The studied material consisted of 126 skulls from the village of Sypniewo (Poland). Cranial radiographs were taken in postero-anterior (P-A) and basal views. The images were scanned and calibrated. Measurements of the cranium were used to estimate FA. The presence of EH was assessed using standard anthropological methods. The highest levels of FA were observed in the region of the cranial base. EH was observed in 29% of individuals from the rural skeletal series. There was no statistically significant correlation between FA and EH occurrence or between sex and the studied stress indicators.

1. Introduction

Systemic homeostasis is defined as maintenance of fairly stable conditions in the internal environment of living things (Cooper, 2008; Davies, 2016). Any external or internal condition that challenges homeostasis of an organism is called “stress” (Chovatiya and Medzhitov, 2014; Temple and Goodman, 2014). Physiological response to environmental factors interfering with biological development is currently a widely studied problem in relation to contemporary and prehistoric populations (Gawlikowska et al., 2007; Krenz-Niedbała and Kozłowski, 2013; Piontek, 1999; Polak, 2003).

Studies on the health status of archaeological populations have investigated different indicators of stress such as enamel hypoplasia, Harris lines or cribra orbitalia, and analysed the relationship between them (Gawlikowska-Sroka et al., 2013; Gawlikowska et al., 2007; Hoover and Matsumura, 2008; Krenz-Niedbała and Kozłowski, 2013; Özener, 2010; Piontek, 1999; Polak, 2003; Szczurowski, 2002;

Żądzińska, 2004). Stressors can (but do not always) disrupt the buffering mechanisms that contribute to developmental stability and canalization, which may result in increased levels of fluctuating asymmetry (Gonzales, Lotto and Hallgrímsson, 2014; Willmore et al., 2005). The term “fluctuating asymmetry (FA)” was coined by Van Valen (1962). FA is defined as a deviation from typical bilateral body symmetry (Leary and Allendorf, 1989). It is used to assess the stability of development and reflects the presence of processes disturbing development at the stage of ontogenesis (Gonzalez et al., 2014; Polak, 2003; Rossi et al., 2003; Schaefer et al., 2006; Żądzińska, 2004). A high level of FA is associated with many different kinds of environmental stress (pollution, malnutrition, alcohol abuse, or smoking) occurring mainly during pregnancy (DeLeon, 2007; Gawlikowska-Sroka et al., 2013; Klingenberg et al., 2010; Özener, 2010; Żelaźniewicz and Pawłowski, 2015). Some experimental studies have shown the influence of genetic factors on FA (Schaefer et al., 2006; Willmore et al., 2005); however, some authors remain sceptical of this statement (Bjorksten

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and Pomiankowski, 2000; Debat, 2016; Leamy and Klingenberg, 2005).

FA may be used as a good indicator of physiological stress (all stressors that disturb embryonic and early-life development) in both archaeological and contemporary populations (Bigoni et al., 2013; DeLeon, 2007; Mizgirytė et al., 2014; Özener, 2010). Elevated levels of FA have been observed more often in skeletal series representing populations of low socioeconomic status, regardless of its cause (Özener, 2010; Perzigian, 1977). In prehistoric populations, increased levels of asymmetry were observed during the shift from the hunter-gatherer lifestyle to farming and the development of urbanization (Palubeckaitė and Jankauskas, 2001; Perzigian, 1977; Redfern and Dewitte, 2011). In modern populations, the increased level of FA is connected not only with low socioeconomic status (Özener, 2010), but also with a higher incidence of some disorders resulting from disturbances of buffering mechanisms—for example, psychotic disorders (Russak et al., 2016). The study of FA spans several different research areas, including genetic and environmental effects on the development of FA (Fraser and Schadt, 2010; Hill and Mulder, 2010) and the influence of FA on sexual attractiveness and partner selection (Van Dongen, 2011; Zaidel and Hessamian, 2010).

Many clinical and animal research studies discovered a correlation between the level of FA and attractiveness, number of sexual partners, and also age of sexual initiation and sperm quality (Firman, 2003; Gangestad and Thornhill, 2003; Hume and Montgomerie, 2001; Mi et al., 2012; Prieto et al., 2011). Individuals with a low level of FA (which indicates stable development) are characterized by better endurance, fertility, and are more often chosen in sexual selection (Brown et al., 2008; Firman, 2003; Hughes et al., 2002; Pawłowski, 2000; Wells et al., 2006).

However, some researchers questioned the value of FA as a bio-monitoring tool of developmental stress (Cárcamo et al., 2008; Gonzalez et al., 2014; Houle, 1998; Quinto-Sánchez et al., 2017). Bigoni et al. (2013) observed no significant differences between male populations from low and high socioeconomic classes and surprisingly higher values of FA in a group of females characterized by higher socioeconomic status. A study by Quinto-Sánchez et al. (2017) on the relationship between FA of the face of Latin American individuals and age, sex, and genetic ancestry did not find any correlations with the socioeconomic status. FA (and its usefulness) is still the subject of a lively debate.

Enamel hypoplasia (EH) is defined as the defective development of enamel matrix, usually characterized by a deficiency in enamel thickness arranged in a band around the tooth crown (Hillson, 1998; Smith et al., 2016). EH results from physiological perturbations (stress) during the secretory phase of amelogenesis (Alt and Pichler, 1998; Irish and Scott, 2015). It may be used as an indirect indicator of childhood nutritional status (Gawlikowska-Sroka et al., 2013; Hoover and Matsumura, 2008; Krenz-Niedbała and Kozłowski, 2013) mainly due to an association between the peak of hypoplasia incidence and weaning (Hoover and Matsumura, 2008). Because dental enamel is characterised by regular development and is not remodelled after its final formation (Irish and Scott, 2015), EH is a non-specific indicator of physiological stress. For example, populations that are exposed to a high degree of malnutrition and disease, from prehistoric to contemporary times, share high rates of linear EH defects. While these defects seem to relate to bouts of malnutrition and infection, their etiology cannot be exactly determined without additional analyses (Alt and Pichler, 1998; Irish and Scott, 2015).

About 100 various stressful factors may lead to EH (Krenz-Niedbała, 2000). The most important is dietetic deficiency of macro- and micro-nutrients (e.g. Ca, Mg, P, F), proteins, and vitamins (A, C, D); gastrointestinal disorders; disrupted endocrine system; infections and allergies (Correa-Faria et al., 2013; Ford et al., 2009; Guatelli-Steinberg and Lukacs, 1999). The connection between EH and malnutrition and disease is well-documented in anthropological (King et al., 2002; Krenz-Niedbała and Kozłowski, 2013; Miskiewicz, 2015) and medical

publications (Correa-Faria et al., 2013; Goodman et al., 1987; Maunders et al., 1990).

In the permanent dentition, two thirds of EH defects are caused by physiological stress occurring during the first ten months of life, usually affecting the molars, incisors (except for maxillary lateral), and canines (Sarnat and Bradley, 2010; Tomczyk et al., 2012). About one third of EH is formed between the 11th and 34th month of life and it is located on maxillary lateral incisors and premolars. The formation of EH in this period appears to be caused, in many cases, by “weaning stress” (DeWitte, 2010; Staniewski et al., 2008), the result of malnutrition, low protein and/or calcium supply, or immunodeficiency associated with the cessation of breastfeeding.

Later formation of EH is mostly connected with stress in the post-weaning period and occurs between 3.5 and 4.5 years of life and is usually found on permanent second molars (Krenz-Niedbała, 2017; Moggi-Cecchi et al., 1994). Early childhood associated EH usually takes a linear form (Blakey, 1987; Blakey and Armelagos, 1985; DeWitte, 2010; Staniewski et al., 2008).

Time of occurrence of physiological stress episodes may be estimated with Swärdstedt’s method (Swärdstedt, 1966), which is based on half-year time intervals of tooth growth and crown modelling. This method was modified by Goodman and Rose (1990) and Goodman and Song (1999), and later by Reid and Dean (2000). However, the accuracy of these methods is still discussed, and the best method cannot be indicated unanimously (Krenz-Niedbała and Kozłowski, 2013).

Many studies have been conducted on the correlation between these stress indicators and the relationship between them and the overall biological condition of populations and the social status of individuals. For example, Buzon and Judd (2008) investigated the relationship between the occurrence of cribra orbitalia, EH and the status of individuals from the Nubian population in the time of the Egyptian Empire. Temple (2010) evaluated both indicators of stress in Japanese Jomon (Neolithic) and Yayoi populations (Bronze Age). Corruccini et al. (2005) studied the correlation between EH and FA in Australian twins. Kozak and Krenz-Niedbała (2002) compared cribra orbitalia and EH in skeletal remains representing a medieval population from Kolobrzeg. However, none of mentioned papers showed any significant correlation between the studied indicators.

The lack of relationship between these traits is probably due to the fact that these changes reflect different nutritional deficiencies and are formed in different periods. Cribra orbitalia most often forms in children in response to nutrient deficiencies such as iron, folic acid, vitamin B12 and vitamin C, or anemia from chronic bleeding, or parasitic and bacterial infections (Oxenham and Cavill, 2010; Vasalech, 2011; Walker et al., 2009). EH, on the other hand, may be an effect of other disorders (e.g. gastrointestinal and endocrinal) or nutrient deficiencies (most notably of Ca, Mg, P, F, and vitamin D) and occurs only at the stage of enamel formation (Correa-Faria et al., 2013; Ford et al., 2009). No significant correlation was also found between EH and the Harris lines (McHenry and Schulz, 1976). The presence of hypoplasia without Harris lines can be explained by bone resorption and modelling.

Recently published reports on studies carried out worldwide increasingly deal with the analysis of FA as an indicator of stress (Gawlikowska-Sroka et al., 2013; Graham and Özener, 2016; Kirchengast and Christiansen, 2017; Özener, 2010) and investigate its relationship within different populations.

As the FA is formed mostly during prenatal and early postnatal period and LEH forms usually later (during the weaning period and early childhood), studying of both stress indicators could give an answer to the question, whether prenatal stress (which is also the measure of the mother’s health) could negatively affect the health condition of individuals in the first years of life within a population. Such correlation could be found in archaeological populations living under harsh conditions, such as the Polish medieval rural population, which was characterised by high level of stress indicators (i.e. cribra orbitalia, Harris lines, and periostitis (Krenz-Niedbała, 2017)) and high mortality

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