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In utero undernourishment during WWII: Effects on height and weight of young adult women

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Abstract: Under marginal nutritional conditions, growth in utero is related to subsequent growth and adult height. The aim of this research is to compare the young adult body size of women grouped by estimated duration of pregnancy relative to World War II. Subjects were 620 university students 18-25 years, for whom archival data for date of birth, age, height and weight were available; the BMI was calculated. Based on estimated time of pregnancy and birth relative to WWII, the women were grouped as follows: (1) pregnancy and birth before the war (n=203); (2) pregnancy before the war, birth during the war (n=54); (3) pregnancy and birth during the war (n=173); (4) pregnancy during the war, birth after the war (n=16); and (5) pregnancy and birth after the war (n=174). Heights of women born before and after WWII were significantly taller than heights of women born during the war. Though not significant, the height of women who were conceived before but born during the war was intermediate between those of women born before and during the war. The height of women conceived during the war but born after the war was similar to that of women conceived and born during the war. In contrast, BMIs and the distributions of women by weight status did not differ among the five pregnancy groups. The results suggested that heights of young adult women exposed *in utero* to the conditions of WWII (marginal nutritional status, maternal stress, among other factors) were shorter than women who were not exposed *in utero* to wartime conditions.

Key words: prenatal stress, maternal nutritional status, foetal malnutrition, growth restriction, body size

Introduction

The long-term consequences of the conditions of war (stress, famine, food shortage) are generally negative for health, well-being and human capital. For example, adults who experienced starvation in childhood and adolescence during World Wars I and II and The Spanish Civil War had poorer physical and mental health compared to those not exposed to the war time conditions (Havari and Peracchi, 2017). They also had poorer cognitive skills and subjective assessments

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of well-being in adult life. It is also well documented that maternal and child undernutrition has long-term effects on adult size, intellectual ability, economic productivity, reproductive performance, metabolic disease and cardiovascular disease (Black et al. 2008). The link between prenatal conditions at specific periods of gestation and size and proportions at birth, and on obesity, metabolic disorders and chronic diseases later in life is also well-documented (Entringer et al. 2012; Lumey et al. 1993; Lumey and Stein, 1997; Roseboom et al. 2011b; Scholte et al. 2015; Smith 1947; Stein et al. 2004a; Ylihärsilä et al. 2007).

The long-term effects of *in utero* exposure to famine and stress during conditions of war on pregnancy outcome (Smith 1947; Stein et al. 2004b) and subsequent health including later age at menarche and earlier menopause, and increased risk for obesity, diabetes, coronary heart disease, hypertension, glucose intolerance and mental health problems (e.g. Alastalo et al. 2013; Jovanović et al., 2003; Kalichman et al. 2007; Perälä et al. 2012; Prebeg and Bralić 2000; Stanner et al. 1997; Yehuda et al. 2005; 2007, 2016) are reasonably well documented. It also has been suggested that foetal malnutrition associated with a poor maternal diet during pregnancy impacts birth weight which in turn may impact subsequent growth in height and weight (Barker 1992, 1997). The latter is evident in reduced adult heights associated with famine and undernutrition during fetal development (Victoria et al., 2008; Meng and Qian, 2009). Similarly, girls exposed to the Dutch Famine associated with WWII were shorted than peers not unexposed to the famine conditions (Portrait et al. 2017).

The purpose of this research is to compare the body size of young adult women grouped by estimated duration of their respective gestations relative to World War II. It specifically attempts to evaluate the long-term effects of in utero undernourishment during WWII on the final height and weight status of young adult women.

Material and Methods

Archival records spanning 1955–1972 from the Institute of Anthropology of Adam Mickiewicz University in Poznań, Poland, were the source of data for this analysis. Individual data for birth date (day, month, year), chronological age, height and weight were available for 625 young adult women who were students attending Adam Mickiewicz University in Poznań (n=523) between 1955 and 1972 and Nicolaus Copernicus University in Toruń (n=102) between 1958 and 1963. The material was collected by prof. Franciszek Wokroj and his research team from the then Department of Anthropology of Adam Mickiewicz University. Height was measured to the nearest 0.1 cm with an anthropometer after Martin (1928). Weight was measured to the nearest 0.1 kg. The research was performed in accordance with the ethical standards of the University (AMU).

Complete records including day, month and year of birth, chronological age, height and weight were available for 620 women. The body mass index (BMI, kg/m^2) was calculated; weight status was classified relative to adult cut-off values of the World Health Organization (1995): severe thinness, BMI<16.0 kg/m^2; moderate thinness; 16.0–16.99 kg/m^2; mild thinness; 17.0–18.49 kg/m^2; normal range, 18.5–24.99 kg/m^2; overweight, 25.0–

29.99 kg/m^2; and obese, ≥30.0 kg/m^2. Father's level of education (primary or none, vocational, secondary, university), a commonly used indicator of socioeconomic status in Poland, was available for only 457 women.

Preliminary analyses indicated no differences in height, weight and BMI between women from Poznań and Toruń, respectively, 161.7±5.9 cm and 161.8±5.5 cm (t=−0.20), 54.5±6.4 kg and 54.9±5.7 kg (t=−0.49), and 20.8±2.0 kg/m^2 and 20.9±1.7 kg/m^2 (t=−0.42). Age, however, differed significantly between the groups, Poznań, 21.0±1.5 yrs and Toruń, 21.4±1.2 yrs ($F=8.79$; $p<0.01$). The distribution of father's level of education between women from Poznań (n=358) and Toruń (n=99) also did not differ ($\chi^2=1.44$).The samples were thus combined for analysis and age was used as a covariate in the analysis.

The women were grouped by estimated time of pregnancy relative to WWII. It was assumed that WWII lasted from September 1, 1939 to May 9, 1945. The time of pregnancy for each woman was estimated by subtracting the clinically accepted duration of a full-term pregnancy, 280 days (Chazan 2007; Bhat and Kushtagi 2006) from date of birth (day, month, year) for each woman, assuming that the women were born after full term pregnancies. Birth dates of the 620 women ranged from 1931 and 1959. Information about pre-term or post-term births, the course of pregnancy or type of delivery was not recorded.

Taking into account the assumed dates for the beginning and the end of the war, the date of birth of each woman and the estimated time of pregnancy, the following categories were defined relative to WWII: (1) pregnancy and birth before the war (n=203, entire pregnancy before the war); (2) pregnancy before the war, born during the war (n=54); (3) pregnancy and birth during the war (n=173, entire pregnancy during the war); (4) pregnancy during the war, born after the war (n=16); and (5) pregnancy and birth after the war (n=174, entire pregnancy after the war).

The height, weight and BMI of the women in the five categories of pregnancies relative to WWII were compared with ANCOVA with age and age squared as covariates. Distributions of weight status among the five pregnancy groups were compared with the Chi square statistic. Calculations were performed using the STATISTICA package (STATISTICA version 12.0) and the Statistical Package of SPSS, version 19.0. Significance was set at $p<0.05$.

Personal data used for this study were processed in accordance with Recitals 27, 158 and 150 and Article 89 of Regulation 2016/679 (GDPR), by which the processing of personal data of deceased persons is not covered by data protection provisions; while in the case of living individuals, appropriate technical and organizational precautions were used to respect their rights.

Results

Descriptive statistics (means and standard deviations) for women in the five pregnancy groups are summarized in Table 1 along with age-adjusted means and standard errors for height, weight and the BMI.

With age and age-squared as covariates, height differed significantly among women in the five pregnancy groups ($F=4.47$, $p=0.001$). Post hoc comparisons, adjusted for multiple comparisons (Bonferroni), indicated that women born of pregnancies

Table 1. Means and standard deviations for age, height, weight and BMI of young adult women grouped by estimated timing of pregnancy and birth relative to WWII, and age-adjusted means and standard errors controlling for age (ANCOVA)

Estimated timing of pregnancy-birth		Age (years)		Height (cm)		Weight (kg)		BMI (kg/m²)		Age-adjusted values: Height (cm)		Weight (kg)		BMI (kg/m²)	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SE	Mean	SE	Mean	SE
Before-before	203	21.8	1.4	162.4	6.0	54.6	6.3	20.7	1.9	162.6	0.4	54.7	0.5	20.7	0.1
Before-during	54	21.4	1.3	161.4	6.1	53.6	6.2	20.5	2.0	161.6	0.8	53.7	0.9	20.5	0.3
During-during	173	21.1	1.2	160.3	5.1	54.2	6.1	21.1	2.2	160.3	0.4	54.2	0.5	21.1	0.2
During-after	16	20.4	1.0	160.0	7.2	52.3	3.6	20.5	1.4	159.9	1.4	52.6	1.6	20.5	0.5
After-after	174	20.1	1.2	162.5	5.7	55.5	6.5	21.0	1.9	162.2	0.5	55.3	0.5	21.0	0.2
F										4.47***		1.41		1.73	
Significant post hoc pairwise comparison	Before-before = After-after > During-during for height														

*$p<0.05$, ***$p \le 0.001$.

before (162.6±0.4 cm, $p<0.001$) and after (162.2±0.5 cm, $p<0.05$) WWII were significantly taller than those born of pregnancies during the war (160.3±0.4 cm). Although not significant, the age-adjusted height of the small sample of women conceived before the war but born during the war (161.6±0.8 cm) was intermediate between the age-adjusted heights of women born of pregnancies before the war and of pregnancies during the war, while the height of the small sample of women conceived during the war and born after the war (159.9±1.4 cm) was similar to that of women born of pregnancies during the war (160.3±0.4 cm). In contrast, weight (F=1.41, $p=0.23$) and the BMI (F=1.73, $p=0.14$) did not differ among the pregnancy groups, and there was no clear gradient in mean weights across groups. However, the BMI was, on average, highest in women born of pregnancies during the war.

Only one woman was classified as severely thin (BMI 15.98 kg/m², pregnancy before, born during WWII) and only two women were classified as obese (31.64 kg/m², pregnancy during the war; 31.71 kg/m², pregnancy after the war). The three women were combined with the moderately thin and overweight groups, respectively, for comparison. Results are summarized in Table 2.

The distribution of women by weight status did not differ among pregnancy groups relative to WWII (Chi square =13.63, $p=0.33$). There also was no clear pattern in the distributions of weight status within each group. The overwhelming majority of young adult women had BMIs within the normal range (88%), while small numbers had BMIs classified as severely/moderately thin (2%), mildly thin (7%) or overweight/obese (3%).

Young adult heights, but not weights and BMIs, of women born of pregnancies

Table 2. Distribution of women by weight status within each of the pregnancy-birth groups relative to WWII

Estimated timing of pregnancy-birth	N	Severe + moderate thinness n	Severe + moderate thinness %	Mild thinness n	Mild thinness %	Normal n	Normal %	Overweight + obese n	Overweight + obese %
Before-before	203	4	2.0	19	9.4	176	86.7	4	2.0
Before-during	54	3	5.5	5	9.3	46	85.2	0	
During-during	173	2	1.1	14	8.1	150	86.7	7	4.0
During-after	16	0		1	6.3	15	93.7	0	
After-after	174	2	1.1	7	4.0	160	92.0	5	2.9

during WWII were significantly shorter than women born of pregnancies before and after WWII. Young adult heights of women born of pregnancies that spanned only part of WWII were slightly taller (though not significantly) than women born of pregnancies during WWII, but were significantly shorter than women born of pregnancies before and after WWII. By inference, conditions of WWII likely influenced the prenatal growth of women born of pregnancies during the war and also of women born of pregnancies that spanned part of the war. Conditions of WWII apparently had a long-term effect in the form of shorter young adult height compared to women born of pregnancies before and after the war.

On average, young adult women born of pregnancies before and after WWII were identical in height, and were more than 2 cm taller than young adult women born of pregnancies during the war and more than 1 cm taller than women born of pregnancies that spanned part of the war (Table 1).

Discussion

The results were consistent with a previous analysis which showed that young adult heights of Polish women born during the war were about 2 cm shorter and attained menarche later than those born before and after the WWII (Liczbińska et al. 2017, 2018, 2019). This study, however, focused on dates of birth and did not take into consideration the potential influence of pregnancies that spanned only part of the war. Note, however, lack of information about women born of pre-term and post-term pregnancies, regardless of the duration of pregnancy in relation to WWII is a limitation that must be considered in the interpretation of the observations. Nevertheless, the observations for young adult Polish women were consistent with those for heights of Dutch adults who were in utero or 1–2 years of age during the "Hunger Winter" (1944/1945) in the Netherlands (Portrait et al. 2017). Adults exposed to the "Hunger Winter" prenatally and during infancy were shorter by more than 4 cm compared to peers who were not exposed to the food shortages.

Available historical literature addressing nutritional conditions during WWII emphasize the adverse effects of in utero malnutrition on foetal growth of Polish infants. Polish women were undoubtedly exposed to such conditions during WWII specifically nutritional deprivation associated with food shortages and associated severe psycho-emotional stresses, among others. Official food allocations in Poznań, for example, were twice as high for Germans than for Poles in 1941 (Łuczak 1989). Weekly food rations for Germans included 250 g of butter and

500 g of sugar per individual, while allocations for Poles were only one-half, 125 g of butter and 250 g of sugar per individual. Germans also received 100 g of pasta/macaroni, 62 g of cheese, 2 eggs and 100 g of peas per individual weekly, while these foods were not allocated for Poles (Łuczak 1989). Rations of meat for "hard-working" individuals were 400 g for Germans but only 200 g for Poles, while weekly rations for those working "very hard" were 600 g for Germans but only 200 g for Poles. The weekly ration of bread for the latter group was 2400 g for Germans compared to 1200 g for Poles (Łuczak 1989).

The "hunger food rations" were significantly lower than rations recommended by dieticians to pregnant women (Szostak-Węgierek and Cichocka 2012). Daily recommendation for a woman in the 1st and 2nd trimesters was 8 portions of cereal products (one portion is equivalent to one slice of bread and 3 tablespoons of rice or crushed grains), while that for a woman in the 3rd trimester was 9 portions per day. Recommended daily portions of poultry, fish and meat products, depending on trimester, were 150 g to more than 200 g; the latter were about equivalent to weekly portions during the war. Recommended daily portions of vegetables or potatoes were 400 g (1st trimester) to 600 g (2nd and 3rd trimester), while those for fruit were 300 to 400 g (authors' calculation based on Szostak-Węgierek and Cichocka 2012).

Relationships between food deficiencies in mid- and late-gestation and low birth weight have been confirmed in many studies (Roseboom et al. 2006; Schulz 2010). Birth weights of those exposed to the Dutch famine in mid- and late-gestation were about 200 g less than those not exposed in utero to food shortages (Ravelli et al. 1999). Also of note, birth weight is positively associated adult height (Ylihärsilä et al. 2007). Unfortunately, information on birth weight was not available for the women in the present analysis. Earlier analyses (Liczbińska et al. 2017, 2018, 2019) have shown that heights of young adult women born before, during and after WWII were related to father's level of education.

Secular trends in the heights of the Polish population from the 19th century to modern times have been widely discussed (Bielicki and Szklarska 1999; Czapla and Liczbińska 2014; Czapla et al. 2019; Kołodziej et al. 2015; Łopuszańska-Dawid et al. 2019). The positive secular trend in height was interrupted during conditions associated with WWI and WWII, but was re-established after WWII: 1955/1956=156.45 cm; 1967/1968=158.20 cm; 1975=160.39 cm (Górny and Dobrzańska 1981).

Similar results were noted during the Dutch Famine; adult females who were exposed to famine of WWII in infancy and early childhood were shorter than those not exposed to the famine conditions (Portrait et al. 2017). Unfortunately, corresponding information for young adult women born before, during and immediately after WWII in other areas of Poland are lacking and thus limits potential inferences.

A potential biological mechanism that may explain the observations of the present and other studies is the foetal programming hypothesis (Barker, 2004). Accordingly, during periods of nutritional deficiencies and hunger, the foetus invests in the development of the nervous system and body composition to the neglect of other somatic features, specifically linear bone growth. By inference, the fetal phenotype consistently tries to accumulate as much energy as possible to ward off further nutritional deficiencies, which can lead to nutrition-related metabolic diseases. "Programming" is a label commonly used to describe the adverse effects of factors which may influence early human development, specifically during the so-called critical periods – pregnancy, infancy and early childhood. The effects of programming are commonly described in the context of permanent changes in the structure, composition and functions of the body in later periods of life and increased risk of several diseases in adulthood (Fall et al. 1998; Barker 1998; Gluckman and Hanson 2004; Jansson and Powell 2007). Foetal programming is often defined as a process whereby adverse experiences and exposures in utero contribute to changes in gene expression (Roseboom et al. 2011a).

Although foetal programming has a primarily molecular background, maternal nutritional status during pregnancy can lead to epigenetic changes in the fetal genome which may influence expression of the genotype (Jaenisch and Bird 2003; Waterland and Jirtle 2004; Wu et al. 2004). In this context, environmental factors during prenatal development may alter gene expression and programme structures, composition and functions throughout life (Hales and Barker 2001, 2013; Barker 2004; Barker et al. 2012). For example, adverse environmental factors (e.g., major food shortages) during foetal life, can influence bodily structure and function, and impose "a new development schedule", i.e., modify the foetal program of the developing organism (Barker 1992, 1998; Lucas, 1991; Wells 2003).

Limitations

The present study is not free of limitations. First, information on birth weight and duration of pregnancy was not available. Specific information on hunger conditions and specific food shortages to which the mother and in turn foetus were exposed was also lacking. Although malnutrition in pregnancy has a direct impact on foetal growth, the relationship between maternal malnutrition and foetal growth is a complex process and other factors are likely involved, e.g., maternal genotype and body size, maternal stress, and behavioral and social factors (lifestyle, crowded living conditions, smoking, alcohol consumption, among others). In addition, the impact of environmental factors on growth during the postnatal years should not be overlooked – socio-economic status, family size (number of children in the family), area of residence, environmental pollution, and psychological/emotional factors.

In addition, information is lacking on the potential influence of the conditions during WWII (dietary restrictions, emotional stress) on early childhood morbidity and mortality of the women born before, during and immediately after the war. Nevertheless, the selective mortality of children during WWII in European countries who were most vulnerable to war conditions and hunger (e.g., Poland, Belgium, Greece, Italy and the Netherlands) remained relatively low (Havari and Peracchi, 2017).

Conclusions

Allowing for the preceding, the results were generally consistent with available studies of the impact of war time conditions on pregnancy outcomes, perinatal state and potential long term consequences. Women exposed in utero to conditions of WWII in Poland were shorter as young adults compared to women born before and after the war. In contrast, young adult body weight and the BMI did not differ among women born before, during and after WWII. The results contribute to our understanding of the long-term effects and consequences of modern wars and armed conflicts on the biological and health status of the population. Nevertheless, it should be noted that the "state-of the art" in this field of research in Central and Eastern Europe is relatively limited, due largely to the lack of data during and immediately after WWII.

Author's contributions

ZC study conception and design, contributed to acquisition of data, performed statistical analyses and interpreted results, wrote the manuscript; GL contributed to acquisition of data, edited the manuscript for important intellectual content and provided critical revision of the first version of manuscript; JP contributed to acquisition of data and provided critical revision of the first version of manuscript; RM contributed to the analysis, edited the manuscript for intellectual content and provided critical revision of manuscript. All authors read and approved the final version of the manuscript

Conflict of interest

The authors declare that there is no conflict of interest regarding this publication.

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