Original Research Article

Season of Birth and Subsequent Body Size: The Potential Role of Prenatal Vitamin D

MARTA KRENZ-NIEDBAŁA,1,3 ELZBIETA A. PUCH,1 and KRZYSZTOF KOŚCINSKI2
1Department of Human Evolutionary Biology, Adam Mickiewicz University, Umultowska 89, Poznań, 61-614, Poland
2Department of Human Population Ecology, Adam Mickiewicz University, Umultowska 89, Poznań, 61-614, Poland

ABSTRACT Objectsives: The relationship between season of birth and various physical and psychological outcomes was reported in many studies, although the underlying mechanism still remains unrecognized. The aim of this study was to explore the season-of-birth effect on body size in the sample of 1,148 eight-year-old Polish urban children and propose the mechanism responsible for this effect. Methods: The children were examined three times at their birthdays and at two cross-sectional surveys. Effects of the season of birth were checked by fitting the cosine function to empirical values and by comparison between two groups born in different periods of the year. Results: Data gathered at three examinations led to the same results: season-of-birth effect occurred only in boys and only in those relatively shortly breastfed and/or descended from the families of low-socioeconomic status. Specifically, the individuals born in October–April were taller (by 2–3 cm), heavier (by 2–3 kg), and fatter than those born in May–September. Conclusions: The following explanatory mechanism has been formulated: insolation in Poland is minimal in November–February (winter period), and so ultraviolet absorption and vitamin D production is then the lowest. Vitamin D regulates embryo’s cellular differentiation, and its deficiency triggers permanent developmental changes. Therefore, individuals conceived in autumn (i) are at the greatest risk of early vitamin D deficiency, (ii) are born in summer, and (iii) are relatively small in their further lives. The contribution of low-socioeconomic status, short breastfeeding, and being a male to the occurrence of the season-of-birth effect is also discussed. Am. J. Hum. Biol. 23:190–200, 2011. © 2010 Wiley-Liss, Inc.

Many seasonal changes of environment cause physiological and developmental seasonality in organisms (Benefice et al., 1996; Maleta et al., 2003). Short-term environmental impacts, especially during prenatal period, may exert long-lasting phenotypic changes (Cameron and Demerath, 2002). For example, the risk of many diseases in adulthood is increased by fetal undernutrition (Barker, 1995) or hormonal imbalance (Manning and Bundred, 2000). This phenomenon is called fetal programming and its mechanisms range from DNA and histone methylation, through membrane receptors organization, to an organ’s growth retardation (Waterland and Michels, 2007). If a factor responsible for programming early in life changes seasonally, then individuals born in various seasons would be programmed differently, and therefore the season of birth would be related to the later-life phenotype. Indeed, many characteristics have been revealed to correlate with the birth season; in humans, these are, for example, reproductive potential (Cagnacci et al., 2005; Lummaa and Tremblay, 2003; Smits et al., 1999), longevity (Doblhammer and Vaupel, 2001; Flouris et al., 2009; Lerchl, 2004), and psychological status (Chotai et al., 2003; Joinson and Nettle, 2005; Torrey et al., 1997).

Human body size (height and weight) was also repeatedly shown to depend on the season of birth (Banegas et al., 2001; Henneberg and Louw, 1990, 1993; Kihlbom and Johansson, 2004; Kościński et al., 2004; McGrath et al., 2006; Puch et al., 2008; Puch and Kozłowska-Rajewicz, 2004; Shephard et al., 1979; Waldie et al., 2000; Weber et al., 1998). Various birth seasons were reported to be beneficial for further growth, however, most studies pointed to the winter period [see Table 3 in Puch et al. (2008)]. The seasonal factor exerting long-term developmental changes is unrecognized, although malnutrition (Doblhammer and Vaupel, 2001), ambient temperature (Murray et al., 2000), ultraviolet B (UVB)-dependent production of vitamin D (McGrath et al. 2006), photoperiod-dependent melatonin production that inhibits growth hormone secretion (Waldie et al., 2000; Weber et al., 1998), electromagnetic field or gravity (Henneberg and Louw, 1993), and family planning (Kościński et al., 2004) were suggested.

Our study examines the relation between season of birth and body size and proportions in 8-year-old children from a Polish well-developed city. In comparison with previous research, this study has several advantages. First, children were measured close to their birthdays, so that they were in the same age irrespective of their month of birth (in cross-sectional surveys, children born in some months are larger than others just because of being older). Second, we collected data on many biosocial characteristics to check their role in the development of season-of-birth effect. Finally, a comparison was made between the results of this study and those from our previous investigation of Polish rural children (Kościński et al., 2004), which proved helpful to elucidate the mechanism of the effect.
MATERIALS AND METHODS

Participants

The study embraced 1,322 children at the age of 8 years (born in 1999 and examined in 2007) with parental informed consent. They were before the adolescent growth spurt, so that many growth factors (e.g., sex hormones) that turn on at puberty (Bogin, 1988) and possibly obscure the season of birth effect were avoided. Participants were gathered from 31 elementary schools in Poznan, a relatively well-developed city in Western Poland. We took this site for a contrast to our previous study conducted in a poor village in Eastern Poland (Kościński et al., 2004) to compare the season-of-birth effect in two culturally different populations living in the same climate.

Anthropometric data

Several anthropometric traits were measured: stature (with a stadiometer, 1 mm precision), body weight (bathroom balance, 0.1 kg), and thickness of triceps, subscapular, and abdominal skinfolds (Harpenden skinfold caliper, 0.1 mm) with CVs for 4.6%, 6.7% and 3.4%, respectively. Except random losses, all children were examined three times in April and October (two cross-sectional surveys) and at their eighth birthdays. Furthermore, body mass index (BMI) was calculated as body weight in kilograms divided by squared height in meters, and body fat percentage (FAT) was estimated from skinfold measurements with formulas established for prepubescent children (Slaughter et al., 1988).

In the studies of the effect of birth season on later body size, there is a potential threat of confounding individual chronological age in the results obtained. In the case of cross-sectional examination (all subjects measured within a short period), individuals born in different months also differ in their exact age. Thus, the ones born in some months would be bigger than others just because of being older (Kościński et al., 2004, 2009). For this reason, all height and weight values in the present sample were age-corrected with the adjusted linear regression function (determined for each sex separately). BMI and FAT values were not corrected as they did not depend on age.

To eliminate the effect of calendar age, we also conducted the birthdate examination, which ensures identical age of all participants at measurement. Most children were not measured exactly on their birthdays (the median time-shift was 5 days), and so their height and weight were also age-corrected. Because of summer holidays, children born in July and August could not be examined at their birthdays. So they were measured both in June and September, and their birthday’s size was then linearly interpolated. Further analysis was carried out on the data coming from each of those three examinations, the birthday and two cross-sectional ones.

Questionnaire data

The participants’ parents filled in two anonymous questionnaires. The first one gathered biosocial data: pregnancy length (in weeks), birth weight, breastfeeding duration, and the number of siblings of the child, as well as current height, weight, and age of each parent. Several items concerned the socioeconomic status of the family: place of birth (further coded from 1 (village) to 4 (city above 100,000 inhabitants)), education level (further coded from 1 (elementary) to 6 (academic)), and the occupation of each parent as well as declared total monthly income and number of books at home. Occupation names were transformed into the profitability index and prestige index, according to the Polish sociological classification system (Domański et al., 2007). All these variables are known correlates of child body size (Johnston, 2002) and simultaneously some of them (e.g., birth weight) are related to birth season (Chodick et al., 2007; McGrath et al., 2005; Tustin et al., 2004). In further analysis, they were therefore checked for mediating or moderating the possible relation between season of birth and later body size.

We also applied a questionnaire developed within the International Study of Asthma and Allergy in Childhood (ISAAC, 2010), which screens for allergic diseases in childhood (asthma, allergic rhinitis, and atopic eczema) and inquires into diet and physical activity (Asher et al., 1995; The International Study of Asthma and Allergies in Childhood http://isaac.auckland.ac.nz/phases/phase5wo/phase5wo.html). An allergist coded the data as symptomatic or not of each of these diseases. The parents returned 949 biosocial and 918 ISAAC questionnaires.

Analysis

Some children were excluded from the analysis for the following reasons: born not in 1999 (17 children), posture defect (3), mental impairment (1), gross measurement error (5), pregnancy length beyond 37–42 weeks or birth weight beyond 2,500–4,200 g range (126). Same-sex twins are potentially monozygotic and as such may lead to data pseudoreplication; thus, we excluded one twin from each of six same-sex pairs. Finally, we excluded all (16) individuals whose height, weight, BMI, or FAT value deviated more than three SDs from the sex-specific average, as potentially reflecting a developmental abnormality. This reduced the sample from 1,322 to 1,148 children.

Body weight, BMI, and FAT were not normally distributed; thus, nonparametric tests were applied: Spearman’s rank correlation to test relationships between two variables and Mann–Whitney test to check the equality of two means. When comparing two groups of children born in different year periods, effect sizes were calculated as the raw difference between these groups and also as the Cohen’s $d$, which is the difference between means divided by the pooled standard deviation (Cohen, 1988).

For the purposes of this study, the day of birth in the year was treated as a cyclic variable with the period of 1 year. To check the relation between a trait and the season of birth, we first fitted the cosine function of the birth month to the trait’s values: Trait = $a \times \cos(2 \times \pi \times (\text{month of birth} - b)/12) + c$. Next, Spearman’s rank correlation was used to check the relationship between the trait and the values of the fitted function. The statistical analysis was carried out in Statistica StatSoft 8.

RESULTS

Initial calculations

Descriptive statistics of anthropometric and biosocial variables are presented in Table 1. Before the main analysis, we checked for possible confounders of body size and season of birth. Multiple regression analysis proved height and weight of each parent, and individual’s birth
weight to be the only biosocial variables that affected body size and proportions of the examined boys and girls (raw correlations ranged from 0.2 to 0.4). ISAAC measures of physical activity, TV watching, fast food consumption, and diet diversity (calculated as the number of 14 diet components being consumed at least once a week) were not related to boys’ body size and fattiness (all |R|s < 0.11, NS). In girls, only the frequency of TV watching was related to BMI (R = 0.12, P = 0.043). Although lifestyle and diet have been proved to influence body mass and fat (D’Addesa et al., 2010; Kopelman, 2000; Malina, 2002), the crude method of their diagnosing in the ISAAC questionnaire was presumably responsible for such weak correlations in our sample. Anyway, we decided to correct each individual’s height, weight, BMI, and FAT at the age of 8 years for height and weight of each parent, own birth weight, physical activity, TV watching, fast food consumption, and diet diversity. For this purpose, we established eight (two sexes × four traits) multiple regression equations of anthropometric variables on these potential confounders. The regression residuals were then added to the appropriate sample mean so to obtain the corrected values of height, weight, BMI, and FAT.

On the other hand, height and weight of each parent, own birth weight, physical activity, TV watching, fast food consumption, diet diversity, the pregnancy length, breastfeeding duration, and all socioeconomic indicators were not related to season of birth of any sex (all Ps > 0.05 for correlations with fitted cosine functions). Birth frequency was also independent of birth month ($\chi^2 = 12.68, P = 0.31$). We may thus reject all above-mentioned variables as possible mediators between season of birth and further growth. In all subsequent analysis, we then checked for associations between season of birth and the corrected height, weight, BMI, and FAT.

In this sample, no relationship was found between season of birth and body size, BMI, and fattiness at the age of 8 years, for any sex or both sexes altogether, and for any of three examinations. This null result was independent of the statistical method applied: nonparametric ANOVA with 12 months or four quarters as independent variables or correlation analysis with the fitted cosine function (all Ps > 0.05).

Allergic diseases as confounders

The presence of some allergic diseases is related to both season of birth (Gazala et al., 2006; Graf et al., 2007; Guerra et al., 2002) and body size in childhood (Ellison et al., 2006; Scholtens et al., 2009; Taylor et al., 2008). Allergy occurrence could thus confound the season-of-birth effect on further body size. In the present sample, symptoms of asthma were recognized in 142 individuals, allergic rhinitis in 258, and atopic eczema in 332 children. The increased frequency of asthma in boys born in the mid-year may reflect a prenatal impairment of lungs development caused by seasonal vitamin D deficiency (Litonjua and Weiss, 2007). Higher body weight of asthmatic boys ($\alpha$ = 0.041) and atopic eczema in 332 children. The increased frequency of asthma in boys born in the mid-year may reflect a prenatal impairment of lungs development caused by seasonal vitamin D deficiency (Litonjua and Weiss, 2007). Higher body weight of asthmatic boys ($\alpha$ = 0.041)
matic boys is likely caused by lifestyle factors, as diet and restricted physical activity (Corbo et al., 2008; Glazebrook et al., 2006), but it can also partly result from chronic inflammation and corticosteroid treatment (Brand, 2001; Iles et al., 2008). Because asthma is a pathologic condition and its relation to body size may be partly of the pharmacological origin, we excluded from the sample all children with asthma symptoms (N = 149) as well as those lacking relevant data (ISAAC questionnaire, N = 388). This limited the sample to 330 girls and 290 boys.

Season-of-birth effect appeared in the nonasthmatic boys. Although the fitted cosine function of the birth month was not related to anthropometric traits, the Mann–Whitney test revealed that the boys born in October–April had higher FAT and nonsignificantly higher BMI than those born in May–September (Table 2). These and below presented results refer only to the birthday examination; nonetheless, two cross-sectional examinations brought very similar results (not presented here). No evidence was found for the season-of-birth effect in girls (all P > 0.05).

**Social factors as moderators**

Several social factors appeared to moderate the season-of-birth effect in boys. Specifically, breastfeeding duration below 7 months, having no or one sibling, low declared income, lowly profitable job of mother, and low education level of father defined groups in which boys born in December–May and June–November. When groups born in October–April and May–September were compared, the effects dropped to marginally significant.

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in the complementary groups (that is, breastfeeding duration of at least 7 months etc.), nor in any group of girls.

To reduce the number of variables, we conducted a factorial analysis on all 12 social variables and obtained a three-factor structure. The first factor explained 36% of variance and was highly loaded by declared income, number of books, parents’ education, and their job’s profitability and prestige. The second factor explained 11% of variance and was loaded by the mother’s and father’s place of descent. The third factor explained 10% of variance and was loaded by breastfeeding duration and the number of siblings (Table 3). Hereafter, we refer to these factors as socioeconomic status (SES), descent (DESC), and traditionalism (TRAD), respectively. The use of the term “traditionalism” corresponds to the reproductive behavior in traditional societies that are characterized by longer breastfeeding (Dettwyler, 1995) and higher number of offspring (Henry, 1961) than modern populations. Then, DESC and TRAD values were calculated for each individual for whom the relevant questionnaire data were available (DESC: 261 boys, 304 girls; TRAD: 270 boys, 314 girls). Because of many missing data on parental job, individual SES values were computed from declared income, number of books, and parents’ education only (240 boys and 264 girls).

Among boys with SES index below the average, those born in December–May were taller (by 2.0 cm), heavier (by 2.6 kg), and fattier (by 3.0%) than those born in June–November (Table 2, Fig. 1). In boys having below-average TRAD index, those born in October–April were heavier (by 2.7 kg), fattier (by 4.2%), and had higher BMI (by 1.1 kg/m²) than those born in May–September (Table 2, Fig. 2). Even stronger season-of-birth effect, exceeding 3 cm of height and 3 kg of weight, was observed in boys from families of both low SES and low TRAD (Table 2). The results for thickness of triceps, subscapular, and abdominal skinfolds analyzed separately were similar to those for the estimated body fat percentage (data not shown). Results for high-DESC and low-DESC boys (not presented here) followed those for all boys analyzed altogether. No season effects were found among high-SES or high-TRAD boys or in any girls group (all $P_s > 0.05$).

We also checked whether the season-of-birth effect was present already at birth, that is whether birth weight was associated with the season of birth. The analysis was performed for the total sample, separately for boys and girls and for the groups of children distinguished by the SES and TRAD values. The only significant relationship was observed in boys deriving from the families of low traditionalism: male newborns delivered at the turn of the year were heavier than the ones from the mid of the year ($N = 124$, the fitted cosine function had the peak at December, and the Spearman’s correlation between birth weight and the cosine function was $R = 0.24, P = 0.008$). However, it should be noted that the power of analyses involving birth weight was relatively lower in this study on account of often imprecise data on the trait value: in as many as 31% of all cases, parents gave birth weight of the child with the precision to 100 g only.

**DISCUSSION**

**Sex difference in occurrence of the season-of-birth effect**

No evidence for the season-of-birth effect in girls was found in this study. On the other hand, the boys born at the turn of the year were bigger and fatter at the age of 8 years than those born in the mid-year. The effect was, however, revealed only after exclusion of asthmatic children from the analysis. Asthma occurrence correlated with both season of birth and body size at the age of 8 years, and so it seems to obscure this effect.

Greater season-of-birth effect in boys than in girls was also reported in several previous studies (Banegas et al., 2001; Henneberg and Louw, 1990, 1993; Kościnski et al., 2004). Girls appear therefore more resistant to the factor responsible for the season-of-birth effect, irrespective of its character. Indeed, many studies showed that males respond stronger than females to both adverse and beneficial environmental factors (reviewed in Stinson (1985), see also Jantz and Jantz (1999), Lamp et al. (2010), and Padez et al. (2009)). The former is reflected in prenatal and childhood mortality, incidence of childhood illnesses, stress-induced effects on prenatal, and postnatal growth as well as skeletal and fat development, and the latter in response to environmental improvements, for example, in the magnitudes of catch-up growth following nutritional supplementation and secular trends in body height. Remarkably, the most convincing evidence for greater male than female vulnerability comes from the studies of prenatal period (Stinson, 1985).

Several mechanisms may underlie relative developmental instability in males. Unlike females, males possess only one $X$ chromosome, so that phenotypic effects of its mutations are not masked with a homologous chromosome (Benenson, 2005; Harrison et al., 1989). Also, male conceptions grow faster than female ones at early pregnancy (de Zegher et al., 1999; Mittwoch, 1993), and it is known that more rapid growth implies higher susceptibility to environmental influences (Ulijaszek, 1998). Another mechanism may involve reactive oxygen species. Testosterone, a hormone produced by testes in the male conceptus, was shown to increase the production of these species and thereby to enhance oxidative stress and damage (Alonso-Alvarez et al., 2007; Mougeot et al., 2009). Prenatal oxidative stress, in turn, was suggested to elevate risks of some postnatal diseases, such as diabetes or cancer (Luo et al., 2006; Wan and Winn, 2006).
We are unable to point the precise reason for the season-of-birth effect to be revealed only in boys in this study, but each of above-mentioned mechanisms may be potentially responsible. Whatever the reason, however, our results fit well with empirical evidence, particularly from prenatal period, that males are more sensitive than females to various developmental factors.

The potential role of season-related vitamin D deficiency

Hereewith, we propose the UVB-vitamin D mechanism as responsible for the season-of-birth effect on later body size. Insolation and sun hours per day display substantial seasonal fluctuations in Poland with minimum in November–February and maximum in May–August (Woś, 1999).
Consequently, skin exposure to UVB radiation is season-dependent and so is the vitamin D production, which requires UVB light (Holick, 2005). Relatively low skin production of vitamin D in winter is caused not only by low UVB radiation, but also by winter clothing covering most of the body surface (Holick, 2005). During prenatal development, vitamin D is achieved exclusively via placental transport from the mother’s organism (Salle et al., 2000); therefore, its amount in the fetus’ organism also varies seasonally. Fetal vitamin D deficiency was proved

Fig. 2. Height, weight, BMI, and body fat as related to the month of birth in boys coming from low-degree traditionalism families (means and standard errors are given).
to worsen development and health in childhood (Javaid et al., 2006; Litonjua and Weiss, 2007; Nabulsi et al., 2008; Sayers and Tobias, 2009), and so the season-of-birth effect may originate from seasonally varying accessibility of vitamin D at the early stages of development.

Annual UVB variation causes that if the first trimester of pregnancy falls on a season of relatively high amount of ultraviolet light (summer), then the third trimester occurs in a season of low UVB radiation (winter) and conversely. Therefore, it is crucial to establish the period of pregnancy in which vitamin D-dependent permanent developmental changes originate. The first trimester is a period of rapid tissue differentiation; therefore, developmental disturbances at this stage may exert long-lasting influence on the organism (Armony-Sivan and Eidelman, 2005). For example, the proportion between the levels of sex hormones has then organizational influence on the organism, detectable effects of which may appear as late as in puberty (Neave et al., 2003; Schaeffer et al., 2005). Abnormal ratio between the concentrations of these hormones in the first trimester results in disturbances of many organ systems in later life (Manning and Bundred, 2000). Interestingly, also, Harding (1997) observed retardation of fetal growth in sheep as a result of malnutrition just after the fertilization, irrespective of nutrition in the remaining period of pregnancy.

What is important here is that tissue differentiation is favored by vitamin D (Esteban et al., 2005), which emphasizes the potential role of the vitamin for early fetal development. On the other hand, however, several studies suggested that vitamin D production just in the third trimester of human pregnancy was critical for the development of bone mass after birth [(Goodson et al., 2008; Sayers and Tobias, 2009); see also Namgung et al. (1998)]. Therefore, we checked which period of pregnancy appeared to be crucial for the child subsequent growth in our study. First, meteorological data on sun hours per day in the city of Poznań (Biuletyn Statystyczny, 1999, 2000) were used as a proxy for the relative amounts of vitamin D produced in the skin in each month of the years 1998 and 1999 (the time-frame of fetal development of the examined children). Next, correlations of body size of the boys at the age of 8 years with the assumed production of vitamin D by their mothers during a specific month of the boys' prenatal development were calculated across 12 months of the year. The highest positive correlation was observed for the values supposed for the second month of fetal development (e.g., for body weight: $N = 12, r = 0.76, P = 0.004$). Moreover, most studies on the relationship between body height and birth season showed that bigger were those individuals whose early fetal life fell on the period of high insolation [(Kościnski et al., 2004; McGrath et al., 2006; Puch et al., 2008; Puch and Kozłowska-Raje-wicz, 2004; Shephard et al., 1979; Weber et al., 1998); but compare studies from the southern hemisphere: (Henne-berg and Louw, 1990, 1993; Waldie et al., 2000)].

However, it is possible that one factor differently programs growth depending on the pregnancy stage. For example, Ravelli et al. (1976) showed that famine during the first trimester increases the risk of obesity in adulthood, but the risk decreases when the starvation occurred in the third trimester. In this study, we found a clear relationship between body fat percentage and the estimated accessibility of vitamin D in the first trimester, whereas
early growth falls on the winter period. We then postulate that, in urban populations, the season-of-birth effect is more pronounced in children of lowly educated parents because of relatively low parental knowledge and financial status, whereas, in rural regions, this mechanism is overridden by differential UVB exposition of farmers versus nonfarmers. The opposite moderation of the season-of-birth effect by parental education level in the urban and rural samples therefore fits the hypothesis of vitamin D as a factor underlying this effect.

Alternative explanations

Some other mechanisms of the season-of-birth effect have also been suggested in the literature (see Introduction section). Weber et al. (1998) and Waldie et al. (2000), for example, proposed a sunlight—melatonin—growth hormone pathway to be the mechanism. This is somewhat doubtful as the influence of melatonin on growth hormone secretion is not established yet and both inhibiting and stimulating effects were reported (Ostrowska et al., 2001). Anyway, the production of melatonin is determined by the darkness duration and not by the amount of light during daytime, and so we believe that the melatonin-related mechanism would not lead to the stronger season-of-birth effect in well-educated families in the rural sample. Also, other factors suggested in the literature, as malnutrition, ambient temperature, electromagnetic field, or gravity would interact with parental education in the same way in villages and cities. What is more, modern human populations are largely independent of the seasonality in the ambient temperature (thanks to clothing and heating systems) and night length (due to artificial lighting), and so these factors have very limited opportunity of exerting any seasonal effect on human development. On the contrary, UVB radiation does possess such an opportunity, because, in winter, its availability for the skin is blocked with clothes, and it is not accessible through standard artificial lighting. Finally, the present results challenge the hypothesis that month-of-birth effect derives from parental body size-dependent family planning (Kosiński et al., 2004). Because family planning is rather characteristic of high-SES than low-SES families (Bobak and Gjonca, 2001), it should have produced the strongest season effect in high-SES groups, while we found it in the low-SES one.

CONCLUSIONS

Several methodological refinements of this study allowed us to analyze the season-of-birth effect more thoroughly than previous studies did and to provide further arguments for vitamin D deficiency as a factor underlying this effect. First, apart from two cross-sectional examinations, we also measured children at their birthdays, thereby excluding the possibility of chronological age to be confounded in. All three datasets led to qualitatively the same results, supporting the reliability of both the season-of-birth effect and the age-correcting procedure applied to cross-sectional data. Second, the allergological data enabled us to exclude asthmatic children, whose share obscured the observed effect. Third, thanks to the data on social variables, we were able to identify factors that predispose to the season-of-birth effect. Some previous studies reported season-of-birth effects, which were statistically significant due to huge samples (many thousand), even though their sizes were trivial (e.g., few millimeters of height) (Kihlbom and Johansson, 2004; Sayers and Tobias, 2009; Weber et al., 1998). Here, we demonstrated that even in relatively affluent populations, the size of the season effect in boys was of practical significance in specific social groups (i.e., above 3 cm of height and above 3 kg of weight). Finally, the comparison of two Polish samples, big-city and rural ones, provided further support for the explanation of season-of-birth effect with the prenatal deficiency of vitamin D. We believe that this study is important both theoretically—it elucidates the intriguing relationship between season of birth and later body size—and practically—it points to the importance of prenatal vitamin D supply (through the exposition to sun or supplementation) for further child’s growth.

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LITERATURE CITED


