







Birth Size of Neonates and Its Association with Seasonality

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ABSTRACT: The aim of the study is to evaluate the relationship between the season of birth and the birth weight and length of Bulgarian newborns.

The weight and length data of 6517 (6098 full-term and 419 preterm) live births in 2000–2001 were collected from the birth registry of II Hospital of Obstetrics and Gynaecology “Sheynovo”, Sofia, Bulgaria. Statistical analyses were done using the SPSS 16 software for Windows: descriptive statistics; the t-test ($p < 0.05$); One-Way ANOVA, (Tukey, HSD-test, $p < 0.05$) and the Pearson’s correlation. The sunshine duration data for 2000 and 2001 were collected at the Sofia Meteorological Station.

The mean weight of Bulgarian neonates born in 2000–2001 was 3389.8 g in boys and 3261.8 g in girls. The average newborn’s length was 51.0 cm and 50.3 cm in boys and girls, respectively. In all seasons, significant gender differences were observed with a priority for boys ($p \leq 0.001$). The winter period was identified with a peak in birth length for both sexes, and spring and summer were the seasons with the lowest values for boys and girls, respectively. A significant positive correlation between birth length and the daily amount of sunshine during the prenatal period was found ($p < 0.001$).

Seasonal fluctuations influenced weight and length in Bulgarian neonates. The results obtained in this study can be useful in prenatal diagnostics, neonatal care, and health prevention of pregnant women and neonates.

KEY WORDS: birth weight, birth length, seasonality.



Original article

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Introduction

Birth weight and length are the most important determinants of infant health status. Fetal development and newborn anthropometric dimensions depend on a mix of genetic, socio-economic and environmental factors, including the meteorological parameters of the surrounding environment (e.g., solar radiation, air pressure, temperature and humidity, wind speed, air pollution) mediated by the mothers (Wells and Cole 2002; Vershubskaya et al. 2016). In last centuries, the climate is constantly changing (Global Climate Change, NASA). This was especially true in the last decades of the 20th century and continues today, when climate change follows steady one-way trends rather than fluctuations around a certain average (Ways the Climate Changed Over the Past Decade). The upward trend in global temperature from 1880 to the present is 0.08°C per decade. However, in the last 40 years, the average global temperature has risen twice as fast and has a trend of 0.18°C per decade (Annual 2021 Global Climate Report, NOAA). Locally, global climate change is often undergoing transformation. This is due to the influence of local natural and anthropogenic factors, which determine specific features in the nature of climate change. This is especially true in urban areas, where a large part of the population is concentrated. In urban areas climate change is becoming even more noticeable as a result of the highly transformed surface and considerable air pollution. Currently registered climate change has a significant impact on people's working, living and recovery conditions. This affects all areas of human activity – agriculture, biodiversity and the forestry sector, wa-

ter, energy, transport, tourism, as well as human health (Climate risk and response: Physical hazards and socioeconomic impacts, Report, January 2020). The question is no longer whether the change of climate exists, but to what extent it affects nature, man, human activity and health as well as how to mitigate and adapt to it.

Climate change has both direct and indirect impact on prenatal, neonatal, and postneonatal infant health (The Impact of Climate Change on Maternal and Newborn Health Outcomes). For temperate-continental latitudes, the meteorological elements have a well-expressed intra-annual course, which has a corresponding impact on the sizes of the newborns, as well as on some negative birth outcomes, such as low birth weight, malnutrition, and respiratory diseases (McGrath et al. 2005; Chersich et al. 2020). Sunshine duration, as an indicator of solar radiation, is one of the most important climate factors influencing the bio status of man. It affects the human body in two main ways: as a factor in heat exchange between the human body and the environment, and as a source of sunlight, including of ultraviolet (UV) radiation. UV rays are the most biologically active part of the light spectrum affecting blood and lymph circulation, erythropoiesis, neuro-reflex mechanisms, calcium-phosphorus exchange, metabolism, the formation of vitamin D (DeLuca 1986; Kumar 1986; Ross et al. 2011). Seasonal changes in maternal circulating 25-hydroxyvitamin D levels (25(OH)D), directly influence the levels of fetal vitamin D. Neonates born during the summer have almost two-fold higher levels of circulating 25-hydroxyvitamin D₃ compared to those born in the winter (McGrath

et al. 2005). Therefore, sunshine is a vital climate factor affecting health, especially in newborns, where mother's exposure conditions during pregnancy and the first stages of direct contact of the newborn with the environment are important.

We suppose that sunlight is one of the climate factors that influence prenatal development, which is manifested in the variability in birth sizes related to the birth season. The aim of the present study is to evaluate the relationship between the season of birth and the birth weight and length of Bulgarian newborns. For this purpose, we tracked the intra-annual course of the size of newborns in the capital city of Bulgaria – Sofia, as well as the intra-annual course of sunshine, as one of the most significant factors in bio-climatic terms.

Materials and Methods

The data of 6517 (6098 (93.6%) full-term and 419 (6.4%) preterm) live births in 2000–2001 were collected from the birth registry of II Hospital of Obstetrics and Gynaecology “Sheynovo”, Sofia, Bulgaria. In the study, only data from full-term newborns (body weight of more than 2500 g) were analyzed. The babies were distributed according to the seasons of birth, defined as follows: winter (January-February-March), spring (April-May-June), summer (July-August-September), and autumn (October-November-December). The raw data sources we use in this study are organized according to a calendar pattern of the seasons, taking into account the influence of the specific latitude and the specific microclimate of Sofia. Climatic changes, which are well expressed at the geographical latitudes

of Sofia, cause a certain transformation of the seasons, reflecting their onset, duration and typical characteristics. In recent decades, we have witnessed a very diverse manifestation of the seasons, dotted with significant deviations from the norm, which, to a certain extent, veiled their characteristic, astronomically determined features. The climate of Sofia is particularly strongly influenced by a number of local factors, such as morphography, orography and underlying surface. The basin-like character of the relief, the orographic closure of the Horizon from the south, as well as the highly anthropogenic underlying surface, generate highly expressed local modifications of the climate, reflecting, to some extent, the astronomical pre-determination of the local climate in this area.

The conception date and accordingly the three trimesters of pregnancy were determined by the date of birth.

Statistical analysis of anthropometric data was performed using the Statistical package for social science (SPSS 16). The descriptive statistics, the t-test ($p < 0.05$) and One-Way ANOVA, as well as the post hoc procedures for multiple comparisons (Tukey HSD test; $p < 0.05$) were implemented. The Pearson correlation analysis ($p < 0.05/0.001$) was used to assess the relationship between the anthropometric features of neonates and sunshine duration in the three trimesters of pregnancy by the season of birth. Children born before October 2000 were excluded from the analysis because we do not have data about the sunshine duration for 1999.

Data on the duration of sunshine in the years 2000 and 2001 were collected at the Sofia Meteorological Station. The data were generated through direct in-situ ground observations, with standard,

calibrated instruments, in the system of the National Meteorological Network, and were obtained from the meteorological archive of the National Institute of Meteorology and Hydrology (NIMH). For the purposes of the present study, a database of daily sums of sunshine duration (in hours) was created for the period 2000–2001 (corresponding to the data on newborns in the capital city in 2000 and 2001, the same period).

Results

The average annual duration of sunshine in Sofia is about 2200 hours (Mateeva 1999). This is slightly over 50% of its astronomically possible average annual duration (Fig. 1). Compared to most stations from the southern part of the country and many other stations located in Northern Bulgaria, Sofia has a shorter duration of sunshine (Mateeva 1989). The reason for this might be

a significant orographic shadowing of the horizon by the mountains located to the south, southeast and southwest observed in the capital city of Sofia. In addition, its low-lying position, at the bottom of Sofia hollow, causes frequent formation of inversion conditions of the atmosphere during the cold half-year and, accordingly, an increased number of days with fog (Mateeva 2002).

The years 2000 and 2001 were distinguished by higher than average multi-annual values of sunshine. This was especially true for the year 2000, for which the annual sum of sunshine hours reached 2611 h. This is due to a very sunny spring, summer and December-January period in that year. For comparison, in 2001, the annual amount of sunshine hours were normal (2246 h).

The monthly sums of sunshine in the two observed years were characterized by a well-expressed seasonal course with a maximum in July and a minimum in

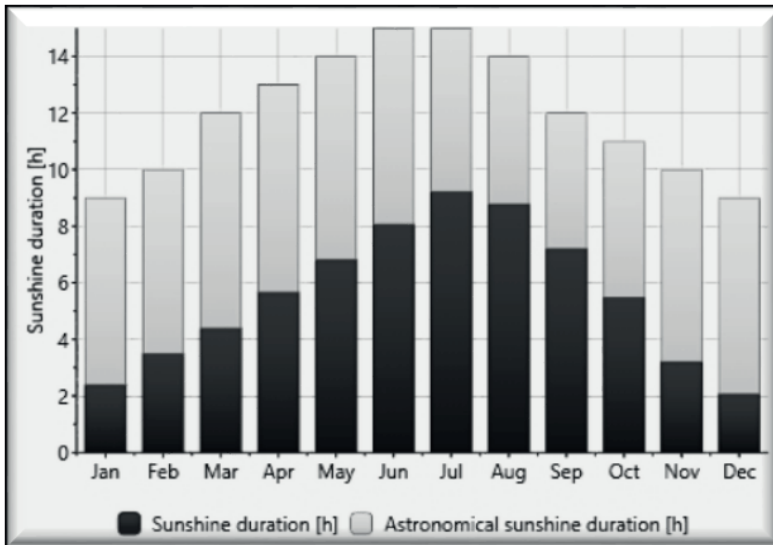


Fig. 1. Intra-annual course of the average daily duration of sunshine compared to its astronomically possible duration in Sofia (Source: Worldwide Irradiation Data). Available online: <https://meteonorm.com/en/>

December. The summer amount of sunshine hours represented about 39–40% of the annual amount, while in winter it was only 10–12%. During the transition seasons, the share of sunny hours

was about 25%. In the year 2000, a certain anomaly is observed – the autumn amount of sunshine hours was less than the spring, and the winter and summer amounts were unusually high (Fig. 2).

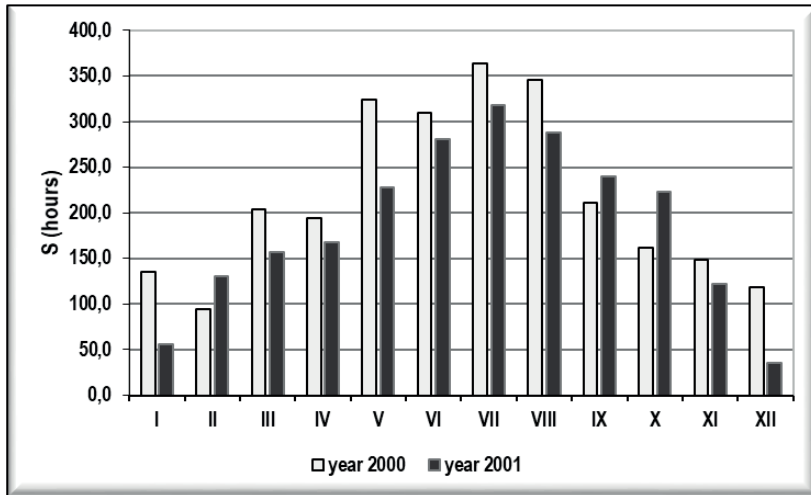


Fig. 2. Intra-annual course of the monthly duration of sunshine (S) in Sofia for 2000 and 2001

Table 1 shows the statistical data in full-term newborns by the season of birth. The number of live births varied considerably by the season, with most births occurring in the summer months, and the lowest in winter (for boys) and autumn (for girls). In all seasons, the number of male newborns exceeded the number of females. The mean values of weight in neonates born in 2000–2001 were 3389.8 g in boys and 3261.8 g in girls. The average newborn's length was 51.0 cm and 50.3 cm in boys and girls, respectively. In all seasons, significant sexual differences according to the newborn sizes with priority for boys were observed ($p \leq 0.001$). Specifically, they were heavier and longer than girls with 128.1 g and 0.74 cm, respectively. Analysis of variance detected sig-

nificant influences of the season of birth on the length of boys ($F=7.49$; $p < 0.001$) and girls ($F=2.78$; $p < 0.05$). The winter period was identified with a peak in birth length in both sexes (Figure 3). The lowest values of birth length were established in spring for boys and in summer for girls. Seasonal variation in the boys' length was expressed with appreciably higher mean values in winter than in spring ($p < 0.001$). The girls born in winter were significantly longer than those born in summer and autumn months ($p \leq 0.001$). Annual variability in birth weight in both sexes was also found, as autumn-born boys, spring-born girls were heavier, and the winter-born boys and summer-born girls were lighter. However, this effect was statistically insignificant.

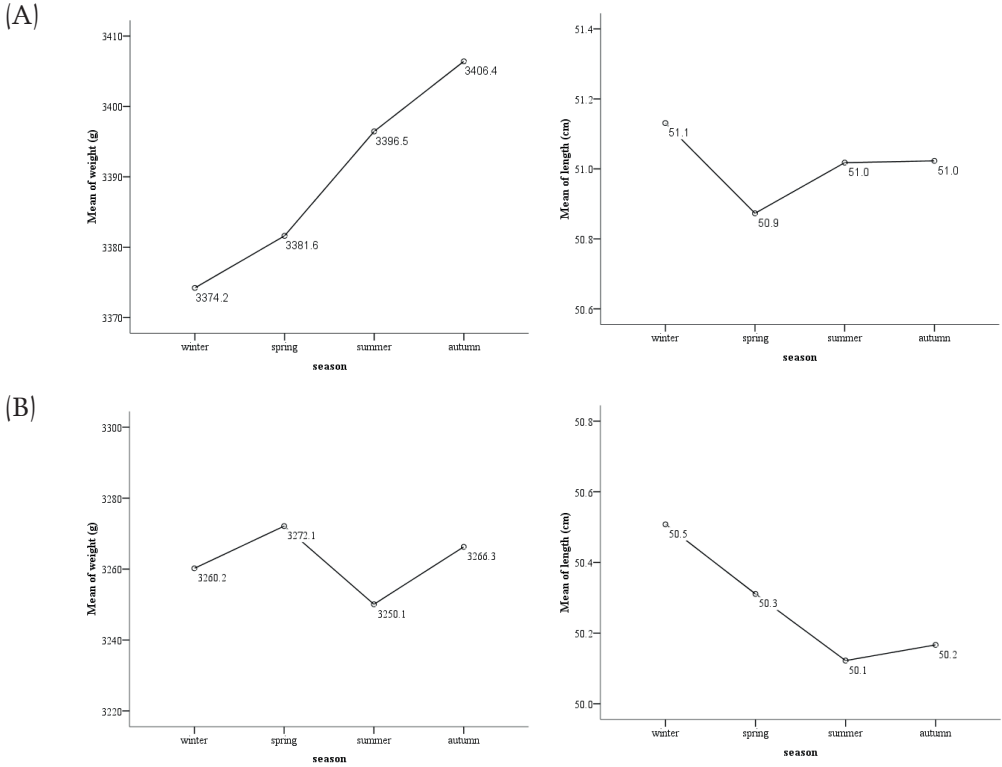


Fig. 3. Average birth weight and length by season in newborn boys (A) and girls (B)

Table 1. The mean values of birth weight and length in full-term neonates, according to the season of birth

Features	2000-2001							p-value (♂/♀)
	Birth year		boys			girls		
	Season of birth	n	mean	SD	n	mean	SD	
Birth weight	winter	774	3374.22	418.99	705	3260.20	390.58	0.001
	spring	780	3381.62	408.51	724	3272.11	384.82	0.001
	summer	838	3396.46	420.16	810	3250.07	382.91	0.001
	autumn	783	3406.41	424.03	684	3266.27	398.74	0.001
	Total	3175	3389.85	417.99	2923	3261.77	388.87	0.001
Birth length	winter	771	51.13 ^b	1.84	705	50.51 ^{c, d}	1.72	0.001
	spring	780	50.87 ^a	1.72	724	50.31	1.67	0.001
	summer	838	51.02	1.74	810	50.12 ^a	1.78	0.001
	autumn	783	51.02	1.77	684	50.17 ^a	1.68	0.001
	Total	3172	51.01	1.77	2923	50.27	1.72	0.001

ANOVA Tukey HSD test: a-significant differences compared with winter newborns; b- significant differences compared with spring newborns; c- significant differences compared with summer newborns; d- significant differences compared with autumn newborns;

Table 2 presents the strength of the relationship between the average sum of sunlight during the three trimesters of prenatal growth and the birth sizes, according to the season of birth. The length of newborn boys correlated significantly with the daily sum of sunshine in the second trimester of pregnancy although this relationship was weaker ($r=0.109$, $p<0.001$). Weak positive ($r=0.120$) and statistically significant ($p=0.019$) correlation was found between the birth weight of boys born in the winter and the sunshine duration in the second trimester of pregnancy. In newborn girls, positive weak correlation between the sunshine

duration in the first ($r=0.130$, $p<0.001$) and second ($r=0.105$, $p<0.001$) trimesters of pregnancy and birth length was also found, especially in those born in spring ($p=0.033$; $p=0.018$) and autumn ($p=0.003$; $p<0.001$). Weak positive correlation was also observed between the birth weight of girls and sunlight exposure during the first trimester of pregnancy ($r=0.109$, $p=0.044$) but only in those born in winter. In addition, in newborn girls, statistically significant negative correlation was observed between their height and weight and sun exposure of the mother during the second and third trimesters of pregnancy.

Table 2. Correlation between newborn birth sizes and sunshine duration across the three trimesters of prenatal growth by seasons of birth.

Trimes- ters Sunshine duration	Boys (n=1946)					Girls (n=1819)				
	Birth weight		Birth length			Birth weight		Birth length		
	n	r	p	r	p	n	r	p	r	p
Winter										
1st	383	-0.075	0.141	-0.025	0.628	345	0.109*	0.044	-0.017	0.758
2nd	383	0.120*	0.019	0.093	0.070	345	-0.118*	0.028	0.021	0.695
3rd	383	0.072	0.160	0.020	0.695	345	-0.107*	0.046	0.016	0.764
Spring										
1st	394	0.002	0.963	-0.004	0.943	386	0.075	0.140	0.108*	0.033
2nd	394	0.001	0.980	-0.016	0.756	386	0.094	0.064	0.121*	0.018
3rd	394	-0.002	0.965	0.005	0.918	386	-0.078	0.125	-0.111*	0.029
Summer										
1st	386	-0.041	0.427	-0.062	0.228	404	0.062	0.216	0.061	0.224
2nd	386	0.039	0.440	0.060	0.239	404	-0.061	0.222	-0.046	0.356
3rd	386	0.041	0.425	0.062	0.225	404	-0.062	0.211	-0.055	0.273
Autumn										
1st	783	-0.036	0.316	0.002	0.965	684	0.043	0.266	0.114**	0.003
2nd	783	-0.050	0.159	0.027	0.450	684	0.062	0.105	0.143**	0.001
3rd	783	0.020	0.577	0.028	0.430	684	-0.014	0.710	-0.055	0.150
Total /October 2000-December 2001/										
1st	1946	-0.039	0.084	0.011	0.632	1819	0.044	0.062	0.130**	0.001
2nd	1946	0.017	0.461	0.109**	0.001	1819	0.006	0.796	0.105**	0.001
3rd	1946	0.037	0.103	0.019	0.405	1819	-0.035	0.140	-0.098**	0.001

*. Statistically significance at $p\leq0.05$; **. Statistically significance at $p\leq0.01$;

Discussion

The present study focuses on the seasonality in weight and length of neonates born at the beginning of the XXIth century in Sofia, as well as on the influence of the sunshine duration during pregnancy on both characteristics.

The meteorological elements and socio-demographic factors have a corresponding impact on the reproductive function of the human and, in particular, on the seasonal variation of birth rates (Kumari and Venkateswar 1982; Bobak and Gjonca 2001). The seasonal tendency of births during the investigated years (2000–2001), which is characterized by a peak in summer and troughs in autumn was observed. The results are close to the overall seasonal birth pattern presented by Darrow et al. (2009). According to the authors, birth rates peaked in late summer–early autumn and declined in April–June and November–January (Darrow et al. 2009). The established tendency in our study differs partially from the results reported by Bobak and Gjonca (2001), who observed most births from March–April while the lowest number of births observed from October to December in the Czech Republic.

Weight and length at birth are important features for the growth and development of infants, for morbidity and mortality during the prenatal and postnatal periods and adulthood. The fetus grows rapidly from the fourth to sixth month (i.e., 2nd trimester) of the intrauterine period, when organs increase in size and mass and differentiate functionally. Following that, the rate of growth slows by the time of birth (Harrison et al. 1977). The study of seasonal variations in birth sizes is a common method used to determine the factors that influence birth weight (Chod-

ick et al. 2009). According to our results, the variation in mean birth weight and length depends on the season of birth and maternal sunlight exposure during pregnancy. There was no significant annual variability in birth weight in both sexes. The highest values for birth length were observed in winter for both sexes. Spring appears to be the season with the lowest birth length in boys and in girls, it is the summer. We suppose that this may be due to the seasonal variability of sunshine duration and intensity of UV radiation, which are closely related to the fetal vitamin D levels. Sunshine is the longest and radiation is most intense during the summer and early autumn months, and opposite during the winter ones. Our results differ from the results reported by other authors (Selvin and Janerich 1971; Siniarska and Koziel 2010; Mladenova 2012). For instance, Selvin and Janerich (1971) studied birth weight in infants born in New York State and reported that those born in winter and spring were slightly heavier and longer compared to those born in summer and autumn. The data for Polish newborns showed that boys exhibited the highest values of weight and length in October and the lowest in March. In newborn girls, the weight and length were the greatest in July and August, respectively, and the lowest in April (Siniarska and Koziel 2010).

Maternal sunshine exposure during pregnancy has a significant positive impact on birth weight, which is different between trimesters. Equally, pregnant women are considered vulnerable to extreme heat waves and cold spells which have been linked to pregnancy complications including preterm birth and low birth weight (Zhang and Wang 2017; Strand et al. 2011; Chersich et al. 2020; Hajdu and Hajdu 2021; Samuels et al.

2022). The second and third trimesters appear to be slightly more sensitive to temperature exposure compared to the first trimester. Infants with low birth weight have a higher incidence of diseases and disabilities, which continues into adulthood. Several studies have reported associations between the month, or season of birth and risks of later life health outcomes (Disanto et al. 2012) such as type 1 diabetes (Kahn et al. 2009) and multiple sclerosis (Willer et al. 2005), cardiovascular disease (Reffellmann et al. 2007), type 2 diabetes (Vaiserman et al. 2009), psychiatric disorders (McGrath et al. 2010; Disanto et al. 2012).

The present results show the impact of seasonal fluctuations and the influence of sunshine duration during pregnancy on newborn body sizes. The two reported years were characterized by a maximum amount of sunlight in summer and a minimum amount in winter. We found some evidence supporting the notion that maternal sunlight exposure during pregnancy is associated with an increment in both weight and length. The sunshine exposure of the pregnant woman influences the maternal 25-hydroxyvitamin D levels (25(OH)D) and reflects on fetal vitamin D levels. An association between seasonal variations in the birth sizes and maternal sunlight exposure during the first and second trimesters of pregnancy is observed, more pronounced in girls. Maternal sunlight exposure during the first and second trimesters of gestation has the greatest impact on the length of spring and autumn-born babies. The exposure to the sun during the third trimester of pregnancy negatively influenced birth sizes, only in girls. This may be related to maximal sunlight in the early months of pregnancy and the levels of vitamin D, which is an important fat-soluble secosteroid for

bone development and affect the growth intensity. The sunshine duration and vitamin D status during pregnancy have a significant effect on fetal skeletal development, tooth formation and birth length (Brooke et al. 1981; Waldie et al. 2000). In boys, the association between birth sizes and maternal sunlight exposure during the three trimesters of gestation is weaker. These results are consistent with the relationship reported by Siniarska and Koziel (2010) regarding the length of boys at birth with the four climatic factors (air temperature, sunlight, humidity, and precipitation) observed during the second trimester of the prenatal period. The authors also found an association between birth weight and the duration of the mother's sun exposure during the second and third trimesters of gestation. The observed relationship between anthropometric features and the variability of sunshine duration during the four seasons is also consistent with data reported by other studies (McGrath et al. 2005, 2010; Chodick et al. 2009; Mladenova 2012). The results presented in this study provide a rather solid evidence of an association between sunshine duration, maternal exposure to sunlight during pregnancy, and newborn sizes. It can be considered indirect evidence for the effect of vitamin D on intrauterine growth and development, which was also documented by other studies (Mannion et al. 2006; Jakubiec-Wisniewska et al. 2022).

Conclusion

In conclusion, our study shows that seasonal fluctuations in the sunshine duration within a year have a significant impact on the length of Bulgarian neonates born in 2000 and 2001. Our results can be helpful in prenatal diagnostics, neonatal care, and

health prevention of pregnant women and neonates. A better understanding of the factors influencing variation in birth sizes (weight and length) may provide a new insight into prenatal growth and development and its effect on individuals' health, longevity, and final height.

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Conflict of interests

No potential conflict of interests was reported by the authors.

Ethical Approval

Ethical approval was given by the Ethics Committee of the Institute of Experimental Morphology, Pathology, and Anthropology with Museum – Bulgarian Academy of Sciences (Protocol 15/01.03.2022) and was conducted in agreement with the principles stated in the Declaration of Helsinki for human studies (2008).

Authors' contributions

AD and IYP design the study; IYP, YZ and BK collected the data; AD, IYP, RG and RS oversaw the statistical analysis/interpretation; AD, IYP, YZ, ZM and AR were the authors of the written content; All authors agree to be accountable for all aspect of the work.

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