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Secular trends in seasonal variation in birth weight

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ABSTRACT

Background: Many environmental factors have been shown to influence birth weight (BW) and one of these are season of birth.
Aim: The aim of the present study was to investigate the seasonal variation in BW in Denmark during 1936–1989, and to see if the variation could be explained by sunshine exposure during pregnancy.
Methods: The study population was selected from the Copenhagen School Health Records Register and included 276 339 children born between 1936 and 1989. Seasonal variation was modeled using a non-stationary sinusoidal model that allowed the underlying trend in BW and the amplitude and phase of the yearly cycles to change.
Results: There was a clear seasonal pattern in BW which, however, changed gradually across the study period. The highest BWs were seen during fall (September – October) from 1936 to 1963, but a new peak gradually grew from the early 1940s during early summer (May – June) and became the highest from 1964 to 1989. The amplitude of the fall peak started at 25.5 (95%CI 24.6; 25.9) grams and gradually disappeared. The amplitude of the early summer peak gradually arose from nothing to a peak of 18.6 (95%CI 17.7; 19.6) grams in the mid 1980s where it started to decrease again. Sunshine did not explain the seasonal variation in BW.
Conclusion: There was a clear seasonal pattern in BW in Denmark 1936–1989, which however changed across the study period. Throughout the study period we observed a peak in BW during the fall, but gradually, starting in the early 1940s, an additional early summer peak emerged and became the highest from 1964 and onwards.

1. Introduction

Both low and high birth weights (BW) are characteristics that besides being the major determinant of fetal mortality and morbidity has been shown to be associated with a wide range of adult traits and health outcomes [1–3].

Both genetic and environmental factors have been shown to influence BW [4]. Gestational age, parity, maternal age, gestational weight gain, maternal smoking, diet and life style during pregnancy, parental body size (BW, adult height and BMI) and occupation has been associated with BW [4]. A better understanding of the determinants may help enabling identification of high-risk groups for both high and low BW.

Season of birth has also been associated with BW, and numerous studies have shown that mean BW varies across seasons [5–12]. Identified seasonal patterns include both 1 and 2 annual peaks, and season of BW peaks and lows (nadirs) is inconsistent between sites [13]. It has been speculated that the heterogeneity in the seasonal patterns is a reflection of the difference in latitudes between the study sites [14]. Also, differences in analytical strategy might be responsible. No obvious interpretation of the seasonal variation in BW has been recognized, but several mechanisms have been proposed [6,10,13].

One of the proposed mechanisms behind seasonal variation in BW is that BW follows the seasonal fluctuations in vitamin D [9]. Vitamin D is synthesized in the skin when exposed to ultraviolet B (UVB) radiation from the sun, and the amount of synthesized vitamin D therefore depends on the season [15]. The hypothesis is that exposure to vitamin D during pregnancy ensures proper fetal development and growth,

Abbreviations: BW, Birth weight; BMI, Body Mass Index; CSHRR, The Copenhagen School Health Records Register; UVB, Ultraviolet B.

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and that vitamin D deficiency during pregnancy may lead to reduced BW as a function of alterations in the fetal development. If the majority of the pregnancy has been experience during the colder months (October to April in Denmark) the synthesis of vitamin D would have been minimal leaving the mother and the child at an increased risk of vitamin D insufficiency (assuming that they did not take vitamin D supplements). If low vitamin D is associated with lower BW, then children born during the early spring would be expected to have the lowest BWs and children born during the fall would have the highest BWs.

Two previous studies have investigated seasonal variation in BW in Danish children [10,16]. None of these have looked at the seasonal pattern before birth year 1973, or across a longer time period (maximum time period 30 years (10)), and they have not investigated the potential determinants of the varying BW.

The aim of the present study was to investigate the seasonal variation in BW in Denmark during a 53 year period (1936–1989). An additional aim was to see if this variation could be explained by the fluctuations in sunshine hours.

2. Methods

Information on BW was collected from the Copenhagen School Health Records Register (CSHRR) which contains information on BW of all children who went to school in the Copenhagen Municipality born from 1936 to 1989. Validation of BW information in CSHRR against medical birth records has shown a high validity of the information (in preparation). At school entry the mother or father reported the BW of the child. The cohort contains 372 636 records and it is described in details elsewhere [17].

Seasonal variation was modeled using a non-stationary sinusoidal model that allowed the underlying trend in BW and the amplitude and phase of the yearly cycles to change. This type of model has previously been employed in similar analyses and is well described elsewhere [6,10,18]. In short the model is a function were BW is predicted by

$$Birthweight = Amplitude(time) \times \text{cosine}(period \times time + phase(time))$$

The phase determines where the BW peaks are during the year and the amplitude determines how big the peak is. The amplitude is the difference in mean BW between the extreme month and the yearly mean BW (mean difference (95% confidence intervals)). The phase is reported in months evaluated from R outputs of date including 95% confidence intervals. The period is set to both 6 and 12 months which allows the model to have either 1 or 2 annual peaks based on results from previous studies [10,16]. The model is non-stationary because all terms are time dependent and therefore are changeable with calendar years.

Individual BWs were used to calculate monthly mean BW for each year, and data were arranged as a continuous time series of 648 consecutive months.

The primary analysis consisted of a model including only BW and month and year of birth. The model was created for boys and girls separately and combined; however only the combined model is reported here since there was no difference between them when divided by gender.

In secondary analyses we wanted to investigate if maternal exposure to sunshine during pregnancy was causally related to the seasonal variation in BW. From the Danish Meteorological institute information was retrieved on hours of sunshine on daily basis covering the entire time period [19]. To include sunshine hours in the model we calculated cumulative sunshine hours during pregnancy and 1st, 2nd and 3rd trimester by calculating backwards from the date of birth.

We adjusted BW for sunshine hours by a linear regression model with BW as the dependent variable and sunshine hours as the predicting variable. The residuals were entered in the non-stationary seasonal model similarly as BW was in the initial analyses. We performed analyses adjusted for cumulative sunshine hours in pregnancy and in 1st, 2nd and 3rd trimester, respectively. The seasonal pattern, amplitudes and peak and low months from the adjusted models were compared to the ones from the unadjusted model manually.

Analyses were performed using R [20] (Season, 2014) [21] and STATA [22].

3. Results

We identified 326 520 children born during 1936 to 1989. The total number of children included in the study was 276 339 (50.77 % boys) after exclusion of 48 313 children with missing BW information, 1 007 children with BWs below 1.5 kg, and 860 children with BWs above 5.5 kg. The number of children born per year ranged from 2 243 in 1983 to 10 697 in 1946 (Fig. 1).

Mean BW in the study population was 3353.4 (SD 568) grams, and mean BW was not stable across the period. There was a decreasing trend in mean BW from 1936 until approximately 1955, where an increasing trend in mean BW took over and continued until approximately 1965. From 1965 until the beginning of the 1980s the mean BW was stable and during the 1980s the mean BW was increasing steeply. Monthly mean BW per year is presented in the top panel of Fig. 2.

We observed seasonal patterns in BW with two seasonal cycles one of 12 months and one of 6 months corresponding to either one or two annual peaks (panel 2 and 3 in Fig. 2). The amplitude of the seasonal patterns varied over time for both these seasonal patterns, which indicated that neither of the seasonal patterns was stable across time. To interpret the seasonal patterns in terms of annual peak and low BW months the two seasonal cycles (6 and 12 month periodicities) were combined. A presentation of peak and low months can be seen in Fig. 3 and Table 1. From 1936–1963 BWs peaked during fall (September – October), but from 1964–1989 BWs peaked during early summer (May – June) (Table 1). BWs were the lowest during early summer (May – June) from 1936–1946, but from 1947–1989 the lowest BWs were during winter (January – March) (Table 1). The amplitude decreased across the time period from a difference of 25.5 (95%CI 24.6; 25.9) grams to one of 10.3 (95%CI 8.8; 11.8) grams in the months with the highest BW compared to the mean BW (Table 1). The difference between the months with the lowest BW and the mean BW also changed across the time period but there was no clear pattern in the change (Table 1).

In the initial regression analyses sunshine hours in pregnancy, 1st, 2nd or 3rd trimester explained very little of the variation in BW (R^2 0.001 – 0.007). The seasonal patterns in BW were essentially the same before and after adjusting BW for sunshine exposure during pregnancy, and results were essentially similar after adjusting the analyses for cumulative sunshine hours during pregnancy, 1st, 2nd, or 3rd trimester (Fig. 4). According to our hypothesis inclusion of sunshine hours in the model would decrease the seasonal variation in BW; however, this was not the case (Fig. 4). The seasonal variation in the

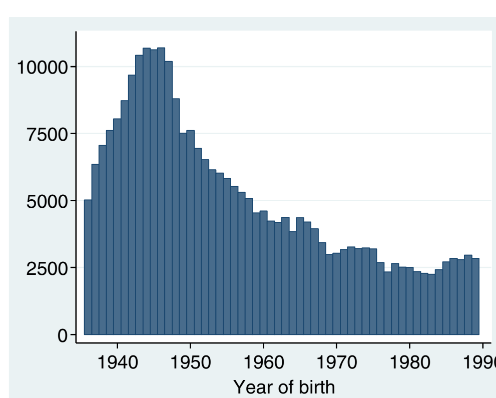

Fig. 1. Number of observations per year included in the study.