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Changing seasonality of birth—a possible environmental effect

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Abstract

***Study objective*—Seasonality of birth was examined to determine whether this has changed over the last half century.**

***Design*—Time-series analysis was carried out on retrospective data, both for the full 50 year period and for the five decades within that period. Although the primary objective was to investigate seasonality by fitting an appropriate model and examining changes over the period studied, non-seasonal trends were also examined.**

***Setting*—Data by month were obtained from the Registrar General on all births in Scotland during the years 1938–87.**

***Subjects*—There was a total of 4 325 000 births in the 50 years examined.**

***Measurements and main results*—There are two peaks to the seasonality rhythm—one wide, in spring/early summer and one narrow, in October. Cosinor analysis, modified to allow for the second peak, was used to fit a sine curve model. Analysis of variance showed that this was adequate and established the significance of both peaks. The main peak of seasonal excess rose to a maximum in 1948–57, and thereafter declined by two thirds. While the position of the main peak moved forward two months over the 50 years, the October peak remained unchanged until the final decade, when it rose slightly; thus its relative importance increased steadily from 1948 onwards.**

***Conclusions*—The changing biological rhythm may be related to alterations in the climate and environment or to social differences.**

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During the past two centuries the seasonal rhythms of births and deaths have been studied using acceptable data. These rhythms have altered because of social change[1] but also probably because of climatic change. Bearing in mind the concern about global warming, the greenhouse effect, the hole in the ozone layer, atmospheric pollution, and other environmental changes, this study examines the seasonality of births in Scotland over the 50 years 1938–87.

Methods

The monthly data on births were obtained from the Registrar General for Scotland (1938–87) (table I). Males and females are considered together. The data are examined for each of the five decades and for all 50 years combined.

The statistical analysis was in five stages:

(1) Correction for unequal month length.

(2) Correction for secular (non-seasonal) trend.

(3) Estimation of a single cyclic trend using a sine curve model: cosinor analysis.

(4) Modification of the sine curve model to allow for a second distinct peak in the data: modified cosinor analysis.

(5) Analysis of variance to test the significance of the components of the sine model.

(1) CORRECTION FOR UNEQUAL MONTH LENGTH

Each monthly total was corrected to the value it would have in a month of 31 days.

(2) CORRECTION FOR TREND

Long and medium term trends were present in the data. These had to be eliminated as far as possible in order to test and assess the seasonal variation independently. This was done in two stages:

(a) To eliminate medium term variation between years, each month's (31 day corrected) value was expressed as a proportion of the whole year's total, multiplied by 12 so that the average monthly value in each year was 1.

(b) This still left a bias in the monthly averages if there was a net increase or decrease over the 10 or 50 year period, as the December values are on average a year later than the January values. This bias can be quite important when, as in 1968–77, birth rates are rising or falling sharply.

Thus, the overall trend was fitted to the original yearly totals by linear regression, and the proportional drop through one year calculated from the slope of the regression equation. This was used to correct the values used in (a), so that the average monthly value was still 1. For example, if the birth rate is falling, December values will be increased by a proportion (5·5/12) of the yearly proportional drop, and January values decreased by the same proportion (as the midpoint of a year is between June and July).

(3) COSINOR ANALYSIS

A computer program called cosinor analysis was used[2 3 4]. This uses 12 monthly totals or averages to determine how much of the seasonal variation can be explained by a sine curve and to fit the best curve to the data by least squares. The output from the program includes:

(a) The amplitude (largest distance from the mean) of the sine curve, and the position of the peak and trough (these are six months apart, and need not be exactly at one of the 12 plotted points).

(b) A correlation coefficient R and a corresponding significance level. R is the proportion of between-month variation explained by the sine curve. The significance level is based on an F test; of the (12–1=11) degrees of freedom available, two are used to estimate the curve, leaving nine for the deviations from the curve.

(c) A graph of the fitted curve, the actual monthly totals, and 95% confidence intervals for deviations from the curve, based on the unexplained variation.

The program makes allowance for varying lengths of month, plotting each point at the midpoint of the month on a scale of 365 days. It does not, however, take account of year to year variation, which is considered in (5).

(4) MODIFIED COSINOR ANALYSIS

The most important deviation from the sine curve was found to be an extra sharp peak in October. To see how well the sine curve fits the rest of the data, the cosinor program was rerun with the actual October value replaced by the average of the September and November values. In all cases a considerably better fit was obtained. The correlation coefficient and its significance level need to be modified, as there are now only 11 independent values. In addition an approximate test of the significance of the October peak as a deviation from the modified sine curve fit is available.

(5) ANALYSIS OF VARIANCE

The components of the between month variations are (a) the sine component (estimated for 11 months) (b) the 11 deviations from this, and (c) the October deviation. The data are examined to determine whether these are significantly larger than would be expected from the year to year within month variations of the (linear trend adjusted) invidual values. The within month variation is an estimate of basic non-systematic variability—the within month mean square is the average of the 11 monthly variances which are assumed equal (in the basic model, October is not assumed to be equally variable), and thus has 99 degrees of freedom (10 year series) or 539 degrees of freedom (50 year series); it can be compared with mean squares for (a), (b), and (c) above. (See table III).

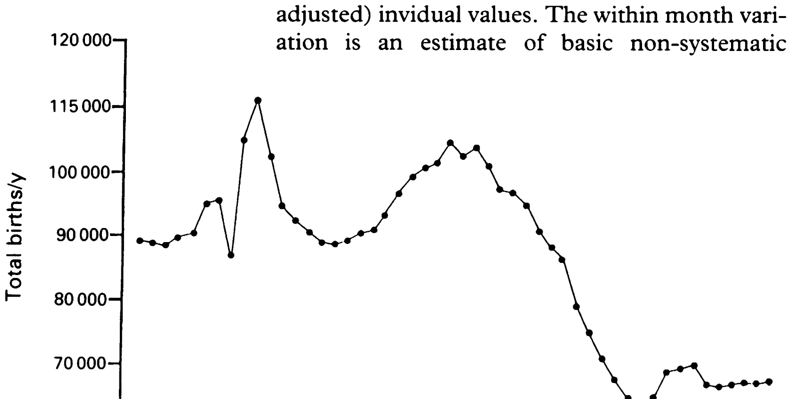

Figure 1 The secular trend of births in Scotland over 50 years. The ordinate shows absolute numbers of births per year. The abscissa provides calendar years.

Results

The data after month correction are presented in table I. Figure 1 shows the secular trend of births in Scotland over 50 years. After the 1939–45 war there was an increased number of births for three or four years followed by a return to the pre-war number by 1955. Thereafter, the numbers rose again to a peak around 1965, followed by a steady decline until the mid 1970s.

The data can be visualised in figure 2A (total 50 years), which shows the main, spring peak and the small (but persistent) subsidiary peak in October. Figure 2B shows the same data with the October peak replaced by the mean of September and November. The features of cosinor analysis are shown, with 95% CI, mesor line, and amplitude.

Table II and figure 3 deal with the correction for linear trend. Table II shows the regression coefficients, while figure 3 exemplifies the correction for 1968–77 (a period of falling births).

The further results are concerned with fitting a sine curve (table III, figs 2 and 4) to the data by decade, both without and with the October correction. Table III confirms by analysis of variance that the data are well described by a sine curve. The significance levels, correlation coefficients, and amplitudes are greater when the October value is modified. Over the 50 years the peak has tended to move fowards from April–May to June–July as the seasonal difference has become smaller.

In all cases, the October deviation is significantly larger than other deviations, and is always positive. This is strong support for the overall hypothesis of a systematic special effect in October only. No other month shows a consistent pattern of large deviations in the same direction. Thus, in all decades the October peak is established as real; moreover, its size is relatively constant, although the latest decade has the largest peak.

The sine component is also very strong, even in the later years, although, like the amplitude and R-value, its significance decreases with time, so that its relative importance compared with the October peak declines.

In contrast, the deviations from the sine curve are not much larger than expected: although they reach (5%) significance in two cases, this is because the within-month variation is low in those years. Deviations in the 50 year series are also significant, but it is easier to establish significance

Table I Corrected monthly births for all series

Period	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1938–47	78 442	78 764	81 226	84 037	86 285	83 354	81 517	76 278	76 138	79 537	73 336	75 658
1948–57	80 836	80 635	84 254	84 892	85 007	81 605	80 131	76 553	74 475	78 539	73 109	76 016
1958–67	86 295	86 582	89 827	87 937	88 891	86 816	84 827	83 605	82 090	87 274	79 377	80 865
1968–77	68 255	67 120	69 379	67 444	67 076	66 132	66 513	64 927	63 996	66 781	61 399	62 540
1978–87	56 090	55 492	55 964	57 410	55 671	57 354	57 846	57 099	56 139	60 531	54 633	53 598
1938–87	369 918	368 593	380 650	381 720	382 930	375 261	370 834	358 462	352 838	372 662	341 854	348 677

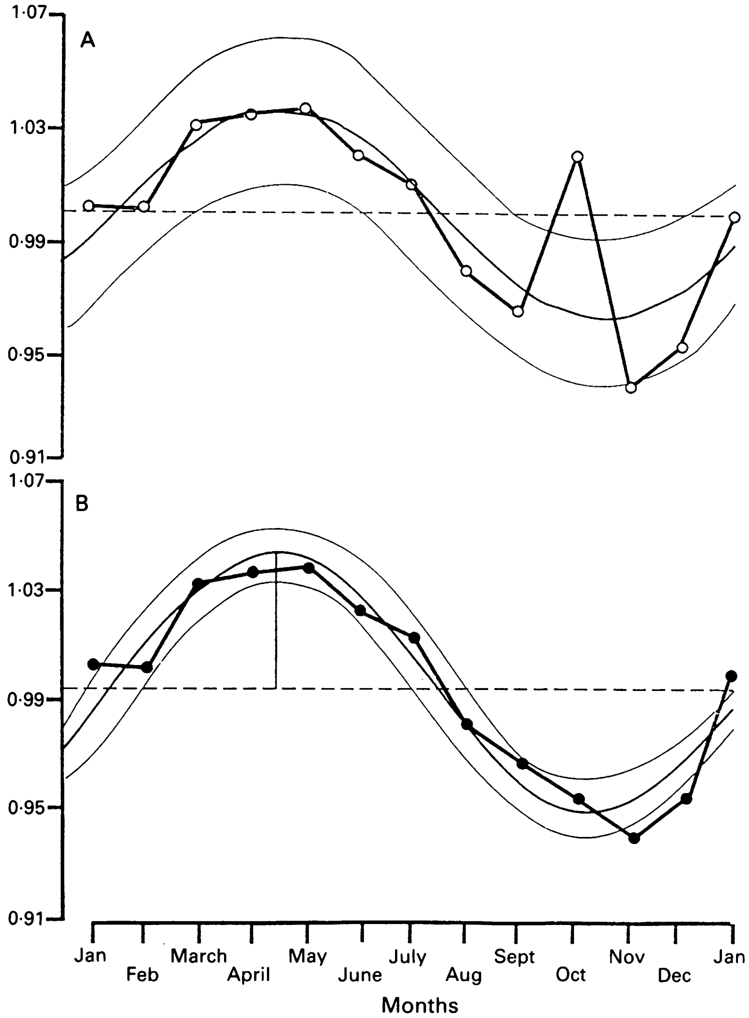

Figure 2 (A) Original cosinor analysis of total 50 years' birth data. (B) Modified cosinor analysis with October figure calculated as mean of September and November. In each the sine curve with its 95% confidence interval has been shown. In B the vertical line illustrates the amplitude. The broken horizontal line is the average monthly value.

from more observations. It is reasonable to conclude that a sine curve and an October single month peak is an adequate model for the data.

With regard to conceptions, the results show that in Scotland in the years 1938–47 there was a "hill" starting in April and rising to a peak in July–August, with a small secondary one month peak in January. The height of the "hill" rose in the 1950s and then fell progressively in the following three decades so that the seasonal excess fell by two thirds. The October peak in births (January conceptions) was showing an increase in the final decade especially in relation to the falling earlier peak.

Discussion

Our findings show that in Scotland during the 50 years studied, seasonal variation in the birth rate showed two main features: a smooth cycle with a peak in late spring and a trough in late autumn, and a single month deviation from this cycle, resulting in an extra second peak in October. Over the 50 years the relative importance of these two features has steadily shifted, with the main cycle becoming less prominent and the October peak progressively more important. The date of the spring peak has stayed relatively constant until the final decade, when it moved from April/May to June.

There are many possible explanations for this changing pattern of birth seasonality[5 7]; before considering them it is useful to compare these Scottish results with those encountered elsewhere.

Examination of the birth rhythm found in different parts of the world show either one or (more frequently) two peaks. The classic European pattern is the one observed here, with a main peak in spring (summer conceptions) and a smaller one in the autumn (winter conceptions). Changing seasonality of the birth rythm over the last half century has not previously been reported in the United Kingdom, but instability of birth rhythms at other places in other times is well known. In some countries the smaller, secondary peaks have disappeared and there is a single rhythm. In East Germany, in one area followed from 1675 to 1816 there was a two-peak rhythm with frequent changes of amplitudes and timing, although the peaks remained about six months apart.[1] The experience of the USA is enigmatic. In the 1930s the shape of the annual rhythm was reversed from the classic European pattern into a small early spring peak and a larger plateau in the autumn. This change did not, however, occur to the north, in Canada,[8] or to the south, in Mexico,[9] where the European pattern persisted.

Patterns of seasonality vary with latitude: in very hot climates (for example, in the Indian subcontinent and in Hong Kong) conceptions are mainly in the cooler winter, while in temperate zones they are in the summer. Towards the Equator the amplitude lessens and in mid-latitude it increases. In Chile, which stretches from latitude 15° in the north to 55° in the south, the greatest seasonal excess is at mid-latitude (35–40°)).[10] The amplitude in USA is greater in the southern states than in the north-east.[11]

Photoperiod (the ratio of daylight to hours of darkness) is critical to the onset of reproduction in many animals. Seasonal extremes in day-length are found in northern latitudes. Ehrenkranz[12] reported the seasonality from birth records kept for 162 years in Eskimo communities in Labrador, Canada (close to the Arctic Circle). The characteristic temperate zone spring birth peak was present, but the seasonal excess was 10 times greater than in our Scottish series—that is, there were many more conceptions when day-length was long than when darkness was long.

There are many possible explanations for birth seasonality. There could be differential survival with loss of early conceptions. Measurement of human chorionic gonadotrophin suggests loss of about 30% of early conceptuses, the women often unaware of having conceived. There are no data on seasonality of these losses.[13] Conception in India increases in the cool winter months, and

Table II Regression coefficients for linear trend

Series	*Mean value*	*Slope*	*SE of slope*	*Proportional change in 1 y*
1938–47	93 700	2233	655	0·0238
1948–57	93 900	−111	390	−0·0012
1958–67	100 600	−264	317	−0·0026
1968–77	77 700	−3762	181	−0·0484
1978–87	66 600	−148	188	−0·0022
1938–87	86 500	−693	99	−0·0080

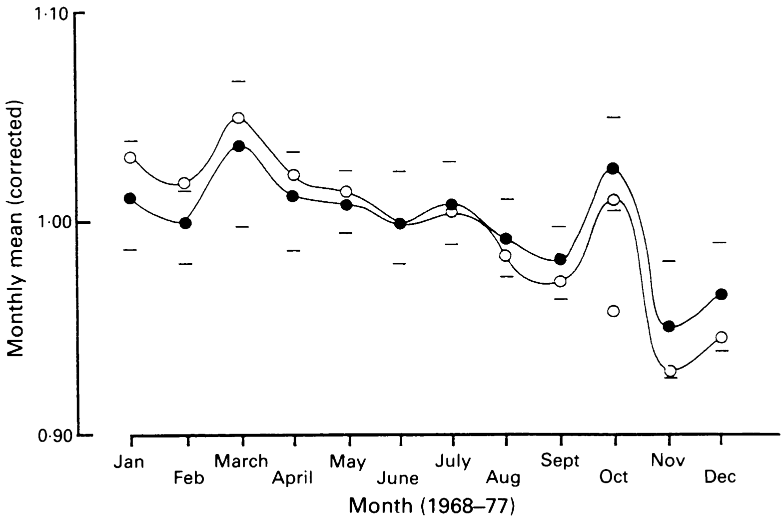

Figure 3 The correction for the linear trend during the years 1968–77 when births were falling. The line with open circles is the raw data and the line with closed circles the correction for the linear trend. The additional value in October is the mean of September and November. SDs are shown on the corrections for linear trend. X axis, monthly mean corrected for medium term variation.

clinically recognised abortions are seasonally increased in spring.[14] In the UK there is the finding of increased success with artificial insemination in spring/summer.[15] In vitro fertilisation in non-human primates shows that oocyte maturation rate is faster in spring/summer.[16] There may be seasonality in the ovulation rate and endometrial receptivity. Observations in ovulation rate and endometrial receptivity close to the Arctic Circle[17-20] have been studied. Endometrial changes attributed to anovulatory cycles were commoner during the darker period of the year. Plasma progesterone and luteinising hormones values were raised during the luteal phase of menstruation, and the levels were greater during spring and autumn.[20]

Semen can be examined by sperm concentration, total sperm per ejaculate and mobility. The peak is in autumn/winter and the nadir in summer, as reported from Scotland, southern USA, and Switzerland.[21-23] The peaks in winter fit the American increase in conceptions but not the European one and any relationship is unclear.

In temperate zones in the days before the contraceptive pill there is evidence of increased male sexual activity in spring and summer, as shown by increased beard growth,[24] increased sale of condoms,[5 25] and increased frequency of intramarital coitus, rape, and sexually transmitted diseases.[26] In hot areas, for example Iraq, conception is higher in the pleasant cooler winter than in the unpleasantly hot summer, but intercourse is not less frequent in the hot summer months.[8 27]

The amplitude of the seasonal excess of birth, although significant, is relatively small, and its causes could be social or environmental or both. Possible reasons for the changing patterns are now discussed.

Evolution causes birth to occur when there is the best chance for parents and offspring to survive. Sudden infant death syndrome (SIDS) is the most common cause of infant deaths and there are advantages for those born in April, May and June (A S Douglas, unpublished data).[28] Because of the sexual imperative in animals, the annual timing reflects a selective pressure for the best seasonal window. The evidence is that day-length (photoperiod) and temperature are important in men, although in very hot climates coolness rather than photoperiod becomes the dominant influence. In animal studies, when one of these is kept constant and the other varied, photoperiod is the more influential. In man, fertility is at its greatest in winter in very hot countries and in summer in very cold countries. The testes are maintained in the scrotum at lower temperature than in the rest of the body. The effect of heat on the sperm count is seen three to four weeks after exposure. Parkes[5] reports from Hong Kong where conception was maximal at 15°C and minimal at 27°C. The optimal temperature in Japan is reported to be 20°.[29] In the same culture, in two different parts of Australia climate determines the seasonality of conception.[5] In inland Queensland, the summer is very hot, and the excess of conceptions is in the winter, whereas in Tasmania, with a cold wet winter, the increase is in summer.

In temperate zones such as Finland,[30] photoperiod may be more important than temperature. When there are two peaks these are six months

Table III Analysis of variation between and within months: cosinor analyses and analysis of variance

Original cosinor analysis: sine curve estimated from 12 months						
Years of series	1938–47	1948–57	1958–67	1968–77	1978–87	All 50
Peak	Mid May	Late April	Late April	Late April	Late July	Early May
Amplitude	0·055	0·064	0·040	0·018	0·019	0·037
F2,9	11·7	24·6	6·1	1·8	1·2	6·9
Significance level	1%	0·1%	5%	NS	NS	5%
R	0·85	0·92	0·76	0·53	0·46	0·78
Modified cosinor analysis: sine curve estimated from 11 months (not Oct)						
Years of series	1938–47	1948–57	1958–67	1968–77	1978–87	All 50
Peak	Early May	Mid April	Mid April	Late April	Mid June	April/May
Amplitude	0·064	0·074	0·053	0·028	0·023	0·049
F2,8	35·3	114	32·1	6·7	6·7	59·3
Significance level	0·1%	≤0·1%	0·1%	5%	5%	0·1%
Modified R	0·95	0·98	0·94	0·79	0·79	0·97
Analysis of variance assessing modified cosinor analysis						
Years of series	1938–47	1948–57	1958–67	1968–77	1978–87	All 50
Within month mean square	0·00222	0·00048	0·00090	0·00141	0·00142	0·00157
Sine component:						
F2,99	45·8	276	743	12·0	11·0	180 (F2,539)
						F2,539
Significance level	≤0·1%	≤0·1%	≤0·1%	0·1%	0·1%	≤0·1%
11 monthly deviations:						
F8,99	1·30	2·43	2·32	1·81	1·61	3·0 (F8,539)
Significance level	NS	5%	5%	NS	NS	1%
October deviations:						
average value	0·069	0·065	0·081	0·061	0·091	0·074
F1,99	21·4	87·4	73·5	26·4	58·3	172 (F1,539)
						F1,539
Significance level	≤0·1%	≤0·1%	≤0·1%	≤0·1%	≤0·1%	≤0·1%

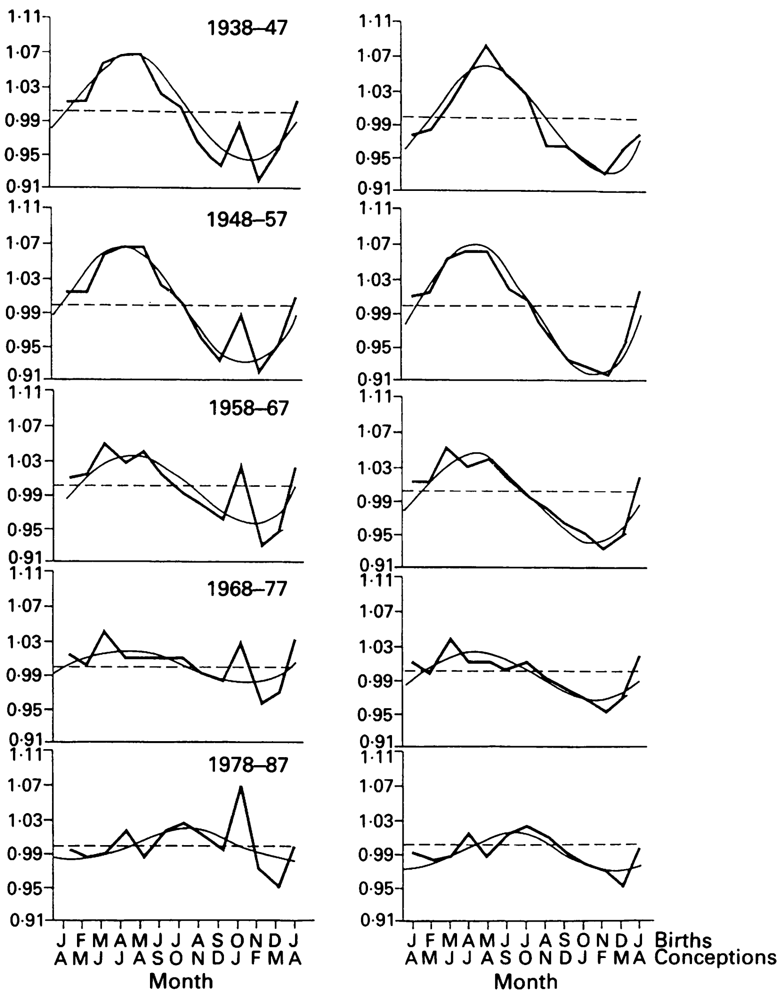

Figure 4 The original cosinor analysis is shown on the left hand and the modified cosinor analysis on the right hand for each of the five decades.

apart and triggering by 12:12 hour photoperiod is probable. In evolution, photoperiod is a critical trigger for starting reproduction, and it is likely that the 12:12 photoperiod around the equinoxes is influential in man. When the body senses that day-length is decreasing after 23 September the process is aborted, whereas it is allowed to proceed after 21 March.

Changes in the environment may explain the changes over the last 50 years. The reductions in amplitude described here were the greatest since the 1960s, during which time there was a temperature rise of half a degree centigrade.[31] Spermatogenesis is sensitive to temperature. Photoperiod will not have changed, but the amount of solar radiation reaching the earth surface will have varied because of lessening city winter fogs, while summer smogs have taken their place. Vitamin D is known to be involved in the reproductive endocrine system,[32] and the thinning of the ozone layer means more ultraviolet radiation on skin and increased vitamin D production.

Social factors can also be influential. James,[25] using Scottish data, found different seasonal birth rhythms depending on social class. In the wealthier social class I the trend was to a single and larger summer peak; in class II two similar peaks, and in the middle and lower classes III, IV, and V it was as described in this paper, with two unequal peaks. The higher amplitude in the wealthier may have been due to better planning.

Religious beliefs and taxation laws have defined marriage dates. In 1938 marriage was quickly followed by conception. The end of the tax year being in April may have contributed to extra conceptions in summer. Our data comprise all births, and other authors have found that the seasonality of birth is the same for first and subsequent pregnancies.[11 25] In 1987 many couples delayed having children, and oral contraception, available from the middle of the period examined, may lead to easier planning of the birth date thereby encouraging the trends in the main peak. Holidays are claimed to be associated with increased sexual activity and slackness in contraceptive use. Changing holiday patterns may explain the relative decline in the main peak. In the 1930s the usual pattern was a single holiday in July or August, plus one or two days at Christmas and New Year. The modern style is for two or more holidays a year with the summer one spread over June to September. This may have spread conception over the summer lowering seasonal amplitude. In recent years, the festive seasonal break has been extended to a week or longer. The secondary birth peak is in October, nine months after, the Christmas/New Year holiday in Scotland. However, New Zealand, where this holiday occurs in summer, still exhibits two birth peaks, the second of which is not linked to any festivities nine months previously.[9] Thus, holidays are unlikely to provide a complete explanation of seasonality.

Over the 50 years of the study housing for most of the people has improved, especially the provision of central heating. People are more isolated from the environment and this is an important social change. Again this could have lowered the main peak.

This discussion has been limited to the reported results. There are other fascinating aspects of birth seasonality. The male/female birth ratio changes by season. In the same community singleton births have a different seasonality from multiple birth.

In conclusion, this paper has shown both significant seasonal variation in births, and considerable changes in the form of that variation over the 50 years studied. It seems likely that photoperiod is an important messenger to initiate onset of the seasonal excess, with the size of the seasonal excess related to latitude. Microclimate differences in adjacent geographic locations can also have a major effect. Environmental influences may have contributed to the changes; recently there has been much debate about the role of pollution. The social changes of the past 50 years have been profound and it could be that the mechanism is both social and environmental.

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