RESEARCH REPORT

# Decline and loss of birth seasonality in Spain: analysis of 33 421 731 births over 60 years

**Ramón Cancho-Candela, Jesús María Andrés-de Llano, Julio Ardura-Fernández**

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See end of article for authors' affiliations

Correspondence to: Dr R C Candela, Chronobiology Group, Department of Pediatrics, Medicine Faculty, C/Ramón y Cajal 7, 47005 Valladolid, Spain; rcancho@hrcr.sacyl.es

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**Background and aim:** Several seasonal variations have been found in birth rates in different countries at different periods. The characteristics of the rhythmic patterns vary according to geographical location and chronological changes. This study presents data on spanish birth seasonality over six decades.
**Methods:** A time series composed of 33 421 731 births in Spain in the period 1941–2000 was analysed. The series comes from the National Institute of Statistics and was processed according to the following norms: (1) normalisation of the duration of months and years; (2) clinical analysis of temporal series (isolation of seasonal component); (3) Fourier's spectral analysis; and (4) cosinor analysis (adjustment to the cosine curve of two harmonics).
**Results:** Significant seasonal rhythm was found in the set of births, both for a 12-month period and a 6-month period. The rhythm shows bimodal morphology, with a pronounced birth peak in April and a smaller one in September. These peaks correspond to July and December conceptions, respectively. The major birth peak shifted to March–May between the 1940s and the 1980s. Birth rhythm changed after the 1960s, with a decrease in amplitude and later loss of seasonality in the 1990s.
**Conclusions:** In Spain, seasonal birth rhythm shows a decline from 1970, and, finally, lack of birth seasonality in 1991–2000. This trend is similar to other European countries, although Spain shows a more intense loss of seasonality.

The human species is fertile at any moment of the year. However, the existence of rhythms in the distribution of births throughout the year—that is, seasonality—has been documented for different groups.[1 2] The absence of seasonal rhythm is considered as abnormal.[3 4] However, this rhythmic pattern, when it exists, is not uniform; significant differences in its characteristics have been shown, based on geographical and temporal variables.

Birth rhythm is considered to be a product of the rate of conceptions that occurred 9 months earlier. Premature births and the possible existence of seasonal rhythms of abortions and fetal losses would be objections against this postulate, although most authors take their effect on basal rhythm as minimum or null.[1 2]

Conception rate can be a product of the inter-relation between several factors.[5 6] These are biological mechanisms with known seasonal variation that could express a pre-programmed rhythm.[7 8] They are semen quality,[9–11] ovulation rate,[12–14] zygote quality,[12–14] endometrial receptivity[13] and coital frequency.[15 16] Varied environmental factors, such as temperature and photoperiod[17 18] and sociocultural factors such as seasonality within the marriage, birth order, legitimacy and race also exist.[1 2 19–21] These factors would modulate biological rhythm, either in a programmed manner[22 23] or by modifying environmental factors such as temperature, light or continual availability of food.

Birth rhythm patterns vary greatly from country to country. Most Occidental countries show a spring peak with a secondary autumn elevation.[1 2 17 19 24–26]. The USA is an exception, which presents a single autumn maximum.[1 2 20 27] There have been several studies in Spain on birth rhythms, but are only of partial, local or geographically and time-limited character.[1 2 28] Until now the existence of rhythms and their characteristics have not been studied on the Spanish population as a whole. This paper presents the first national study on seasonal birth and conception rhythms, their characteristics and their evolving modifications for >60 years in Spain.

## METHODS

### Population

The study group consists of 33 421 731 births in Spain between 1 January 1941 and 31 December 2000, thus constituting a time series. On the basis of the definition of the World Health Organization and the Statistical Commission of the United Nations, birth was considered to be a viable product of conception, extracted or completely expelled, that shows signs of life (breathing, heart or umbilical cord beats or muscle movements).[29] The data were provided by the National Statistics Institute (Instituto Nacional de Estadística, Madrid, Spain), taken from the Registry of Births, Deaths and Marriages. Registration of newborns is obligatory for all children born in Spain, whether the mother is of Spanish nationality or a foreigner. No data from Ceuta and Melilla or from births to Spanish mothers abroad have been included. The

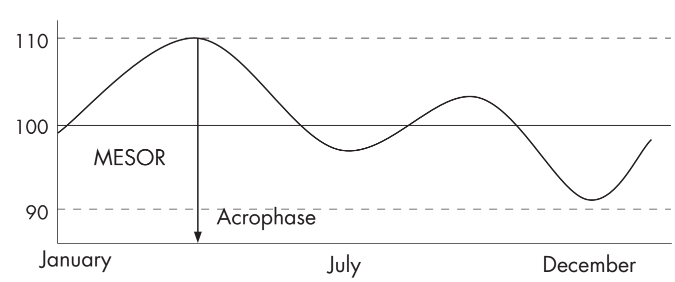


**Figure 1** Parameters of a cosine function. The graphic example shows a circannual and half-yearly pattern rhythm. MESOR (Midline-estimating Statistic of Rhythm) value is 100, amplitude is 20, and acrophase is situated around April.

database was registered as a monthly series. Multiple births have been included separately for each newborn.

### Methods

The guidelines for the analyses on the birth series are the following.

#### (A) Series normalisation

The monthly data on the absolute number of newborns were adjusted to months of 30 days (years of 360 days) to normalise the unequal length of each month and the existence of leap years.

#### (B) Classic time series analysis

A sequence of deviations with respect to mobile averages of 12 months was obtained, expressed in percentage. For a given number of births in a specific month, the deviation of that figure against the average of the six previous and six subsequent months was calculated, expressing the average as 100. Thus, the figure obtained is a percentage that expresses the deviation with respect to the 12-month Mobile Average (DMA). This method eliminates the cyclic component and the tendency, and shows the seasonal and irregular components.

#### (C) Fourier spectral analysis

Time series can be analysed as a combination of underlying sine and cosine functions. The method of analysis was developed by Fourier in 1807. The ''wave length'' of a sine or cosine function is typically expressed in terms of the number of cycles per unit time or ''frequency''. The ''period'' of a sine or cosine function is defined as the length of time required for one full cycle. Fourier analysis looks for those frequencies that seem to be particularly strong or important in time series (''periodogram''). If a large correlation (sine or cosine coefficient) is identified, one can conclude that there is a strong periodicity of the respective frequency (or period) in the data. In practice, when analysing actual data, it is usually not of crucial importance to identify exactly the frequencies for particular underlying sine or cosine functions. Rather, it is better to find the frequencies with the greatest ''spectral densities''—that is, the frequency regions—consisting of many adjacent frequencies that contribute most to the overall periodic behaviour of the series. The birth series were analysed looking for temporal periods with high spectral density. Computer analysis was performed using Statistica V.6.0 program (Statsoft, Tulsa, Oklahoma, USA, 2001).

#### (D) Cosinor analysis

The DMA time series is submitted to rhythmometric analysis based on the least squares method.[30 31] The cosinoidal curve of the two harmonics (12 and 6 months) that best adjust to the time series is determined. The time period in which a cycle of the curve obtained is completed is a year. This adjustment is applied by means of MATLAB program. The resulting curve is defined by a series of parameters (fig 1).

- MESOR (Midline-estimating Statistic of Rhythm dynamic measurement: this is always 100 in our series, given the way the series was obtained.
- Acrophase: the moment in the yearly cycle when the maximum value is produced.
- Batiphase: the moment in the yearly cycle in which the minimum value is produced. Acrophase and batiphase can thus vary between 0 and 12 months; results are expressed in days instead of monthly decimal ciphers, because of clarity, varying between 1 and 360, and being assimilated to the days of the annual calendar.
- Amplitude: the difference between the maximum and minimum curve value. The existence of circannual rhythm was verified by the zero-test (based on Snedecor's F): rhythm exists if the amplitude of the cosine function is significantly different from zero—that is, if the cosine curve adjusts better than a straight line, which would correspond to zero amplitude, $p<0.05$. First, all births between 1941 and 2000 were analysed, then births by decades from 1941 to 1950 successively through 1990–2000.
- Once the time series analyses were complete, the characteristics of the rhythm from the total birth series were described, as well as those of the six-decade series between 1941 and 2000. This verified the existence of seasonality and established the similarities and differences in the evolution by decades. The findings were then contrasted with other international series.

## RESULTS

The series of monthly births in Spain during the period 1941–2000 shows an increase in number until the middle of the 1970s. At that point, an abrupt decrease occurs, which is prolonged until the middle of the 1990s (fig 2). The 12-month DMA series produced a time series that expresses the seasonality component of the original series (fig 3). Changes in the deviation measures can be observed, with a more restricted DMA amplitude in the 1960s and the 1980s.

With Fourier spectral analysis, the DMA series shows a high spectral density of births in the 12-month period, with densities near zero in the 11- and 13-month periods (fig 4). Significant densities also appear in the periods of 6, 4 and 2 months, so birth sequence presents a rhythmic component with a predominantly circannual period.

Using Cosinor analysis, the DMA series for the period 1941–2000 also shows significant circannual and half-yearly rhythm (fig 5G). Analysis with two harmonics revealed a curve with a bimodal fit, with two maximum birth peaks. The highest peak was in April, with a lesser peak in September, corresponding to July and December conceptions, respectively. Cosinor analysis of the births in each decade shows six fitting curves, whose characteristics reflect the evolving changes of the global series over the 60-year study period (figs 5A–F). The birth rhythm pattern in the 1940s and 1950s is similar (figs 5A,B), with bimodal morphology, acrophase at the beginning of spring and a second birth peak in September. A loss of amplitude occurs in the 1960s, with a displacement of the acrophase from March to April (fig 5C). The changes in rhythm are more notable in the decade of the 1970s, showing a unimodal pattern with acrophase at the end of spring (fig 5D). During the 1980s, the pattern of 1960s reappears (fig 5E), while in the 1990s the curve loses amplitude and the seasonal rhythm of births in Spain thus disappears (fig 5F).

## DISCUSSION

The history of Spain, as that of other European counties, is characterised by rapid industrial development in the second half of the 20th century. Owing that period, a massive migration took place from the rural zones towards the cities. In other countries the phenomenon of birth seasonality has been observed to show evolving variations parallel to sociological changes.[2 19 21 24] However, no data on birth seasonality and its changes in Spain have been published before.

The fact that births must be registered in Spain, and the official origin of the data on newborns mean that the present study includes the totality of births in the country for the 60 years between 1941 and 2000. Following the guidelines of most authors, we assume that birth rhythm shown by

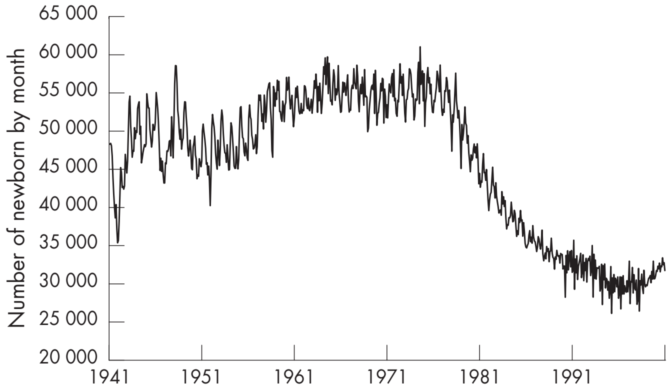


**Figure 2** Number of newborns (normalised) by month in Spain during 1941–2000.

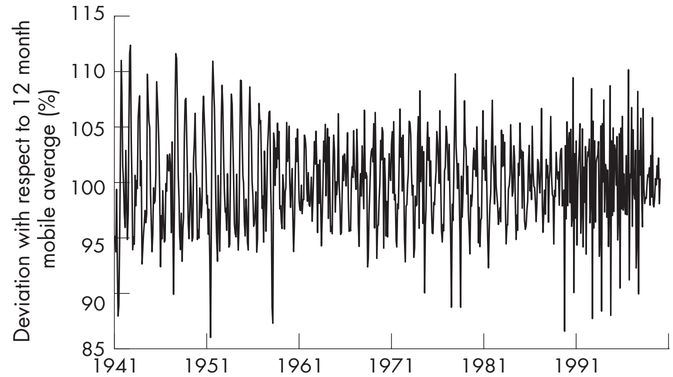


**Figure 3** Sequence of deviation with respect to the 12-month mobile averages referred to the number of newborns (normalised) by month in Spain during 1941–2000.

newbirths is based on the rhythm of conceptions that precede by 9 months. However, this assumption requires clarification of a few points. The first is related to premature births. There is no official count of the number of premature births in Spain for the period studied; in the US, premature births constituted 12.3% of the total live births for 2003.[32] Other points to be considered are the possible seasonality of abortions and fetal deaths,[33–35] and, finally, a different seasonal pattern for multiple pregnancies.[36 37] The importance of these contributions seems to be limited.

Various birth seasonality patterns have been described for different countries or territories. A certain similarity exists among European countries as to maximum births in spring with secondary peaks in September; this translates to a tendency for maximum conceptions in summer and December.[1 2 17 21 24–26] These patterns have also been found in Canada[17] and Australia.[19] However, the rhythm is different in the US, with one major peak in autumn.[1 2 17 20 27]

Evolving changes in the birth rhythm pattern have been reported. In most cases, there is a common trend towards a decrease in spring births and increase in fall births, with a decline in amplitude (but without absence of seasonality), as in Australia,[19] Scotland[24] or Germany.[26] It is possible that the current lack of birth seasonality in Spain precedes a change in birth rhythm pattern.

Cosinor analysis for the fit of births with seasonality has been used by several authors.[2 20 24 26] The potential existence of other patterns besides the unimodal of 12 months, with bimodal or trimodal rhythms, requires a fit analysis with at least two harmonics, as has been documented in our study.[2 20 26] Fitting with only one harmonic would not detect the probable appearance of secondary peaks.[24]

Our study provides descriptive data on the seasonality of births in Spain. No investigation of the probable aetiological factors implied is contemplated. However, the evolution of birth rhythm patterns allows us to point out some considerations as to their origin and implications. In the 1940s and 1950s, Spain was predominantly rural, with an uncontrolled demographic regime of fertility and no development in anticontraceptive methods. However, the fitting curves are characterised by an elevated amplitude, greater than that observed in later decades. There was a tendency towards sustained increase in the number of conceptions during spring months, which reached its maximum in June, followed by a decrease in conceptions over the entire summer.

Various environmental factors have been implicated in the genesis or modulation of seasonal birth rhythms. The possible favourable effect on the chances of conception owing to an increase in the spring photoperiod is especially noteworthy,[13 18 38] as well as a certain negative effect of extreme summer and winter temperatures.[17 18 39] It is possible that both these elements were more evident in Spain before the period of industrial development, which occurred rapidly from the time of the 1960s. From that moment onwards, birth seasonality has existed, but to a lesser degree. The progressive loss in seasonal rhythm in the births of the last decades of the 20th century has been documented in several countries in the context of the general decline of various human seasonal rhythms.[2 18 19 24 26 40] By 1990s, no significant seasonality existed in Spain. Complete lack of birth seasonality in a whole country has not been previously reported in any other Occidental country.

Currently, the use of birth-control methods is common in Spain, as evidenced by it having of the lowest birth rates in the world (10.5 births per 1000 inhabitants in 2003).[41] However, apparently, this fact is not reflected in the moment of conception chosen, in contrast to the strict control exercised over the number of children. It is also possible that seasonality exists, but without coinciding with the annual moment chosen among different geographical regions or among different social groups.

Roenneberg and Aschoff[18] have extensively investigated the possible contribution of social and/or environmental factors in multiple series of births in the world between the 19th century and the end of the 20th century. They concluded that

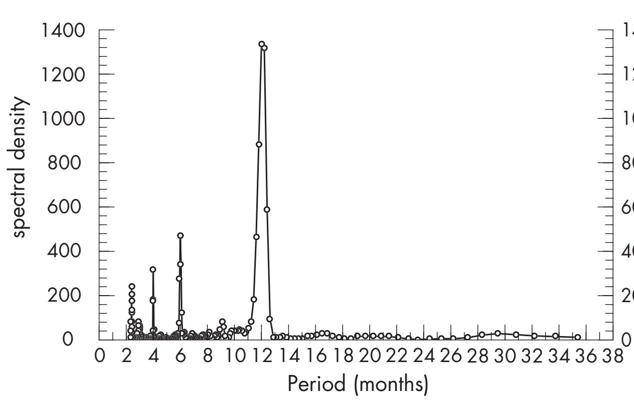


**Figure 4** Fourier spectral analysis of the monthly sequence of deviations with respect to 12-month mobile average of the number of newborns (normalised) in Spain during 1941–2000. Spectral density is shown (values in the periodogram) for periods <36 months.

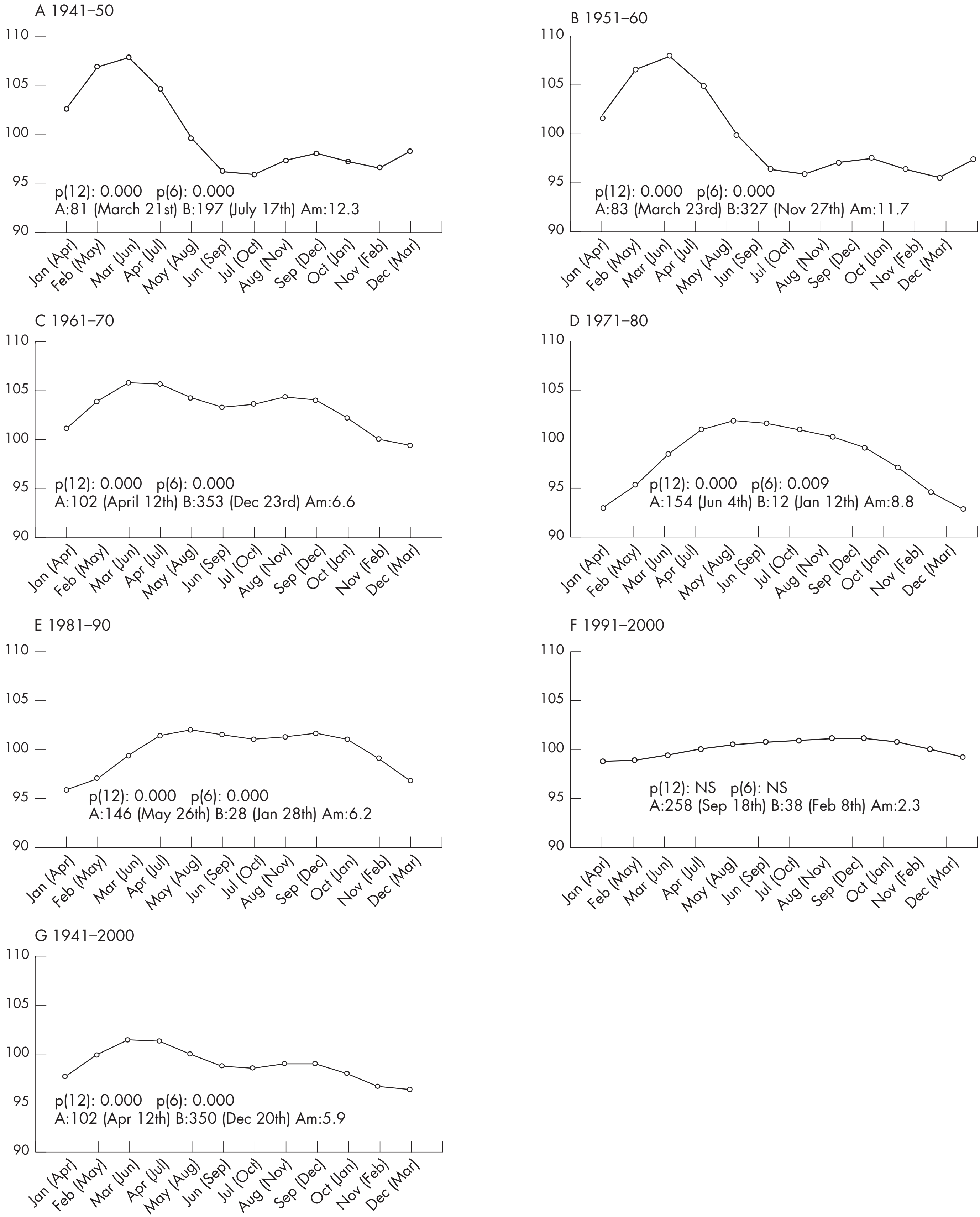


**Figure 5** Results of the best adjustment to a two-harmonics cosinoidal curve of the monthly sequence of deviations with respect to 12-month mobile average of the number of newborns (normalised) in Spain by decades from 1941 to 2000 and for the period 1941–2000. The month of conception is shown in brackets after month of birth. Parameters of the adjustment are expressed in the graph. Significance degrees for 12 and 6 months adjustment, acrophase (A) and batiphase (B) values and amplitude (Am) are shown.

## What is already known

- Reproductive seasonality in humans is present throught the world, but with different patterns according to the geographical site.
- Birth seasonality is probably a multifactorial phenomenon, with a biological basis modulated by environmental and social factors.
- A decrease in birth seasonality amplitude has been reported in the last few decades in some Western countries.

## What this paper adds

- Birth seasonality in Spain is analysed for the first time, for the whole country and for six decades.
- The decrease in birth seasonality in Spain is so significant that there is a complete loss of rhythm in the decade 1991–2000.

environmental factors were the principal instigators of conception rhythm, and that before 1940, photoperiod was specifically influential; the posterior decline in reproductive seasonality was related to environmental control. The evolution of seasonal rhythms of Spanish births agrees with this explanation.

The calendar of annual vacations has been implicated as a cause of the seasonality in conceptions.[24 42] It is true that the appearance of conception maximums coincides with summer and December, but we believe that annual vacations are insufficient to generate the rhythm found. This hypothesis does not explain the sustained elevation in conception from spring on. An increase in conception confined to holiday periods should produce an increase clearly limited to the summer, which is not found in our data. In addition, from this point of view, it is difficult to explain the wide amplitude of the decades before 1960, against the slight amplitude following that time, as the later period was precisely when most of the population began to have vacation periods imposed.

Environmental or social visions of the phenomenon of reproductive seasonality in humans are possibly complementary. The contribution of each factor probably changes according to the historical period considered and the period of the annual calendar of conception analysed. The role of the varied factors implied should be clarified in further epidemiological studies.

On the basis of the results discussed previously, we can conclude that the pattern of seasonality of conception in Spain between 1941 and 1960 is equivalent to the pattern in other European countries, with a peak of conceptions in spring and a smaller peak in autumn. After the 1960s, there has been a progressive decline in rhythmic amplitude until the disappearance of seasonality in Spain, a similar phenomenon to other European countries, but in a particularly intense manner.

### Authors' affiliations

**Ramón Cancho-Candela, Jesús María Andrés-de Llano, Julio Ardura-Fernández,** Chronobiology Group, Department of Pediatrics, Facultad de Medicina, C/Ramón y Cajal, Valladolid, Spain

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Competing interests: None declared.

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# THE *JECH* GALLERY

## Natural alternatives

Patients may choose alternative medicine because it is more congruent with their own values, beliefs and philosophical orientations,[1] or because of concerns about possible side effects of conventional treatments.[2] Whatever the evidence of the efficacy[3] or safety[4] of Chinese medicines, there is certainly a convenient choice of alternatives in Glasgow, UK.

**David S Morrison**
NHS Greater Glasgow & Clyde, Glasgow, UK
**Keith Beard**
Mansionhouse Unit, Victoria Infirmary, Glasgow, UK

Correspondence to: D S Morrison, NHS Greater Glasgow & Clyde, Dalian House, PO Box 15329, 350 St Vincent Street, Glasgow G3 8YZ, UK; david.morrison@ggc.scot.nhs.uk


**Figure 1** Chinese Medicine Centre with pharmacy next door.

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