

Seasonality in twin birth rates, Denmark, 1936–84

BIRGITTE BONNELYKKE¹ JES SØGAARD², AND JOHANNES NIELSEN¹

From the Cytogenetic Laboratory,¹ Århus Psychiatric Hospital, and the Institute of Social Medicine,² University of Århus, Denmark

SUMMARY A study was made of seasonality in twin birth rate in Denmark between 1977 and 1984. We studied all twin births (N = 45 550) in all deliveries (N = 3 679 932) during that period. Statistical analysis using a simple harmonic sinusoidal model provided no evidence for seasonality. However, sequential polynomial analysis disclosed a significant fit to a fifth order polynomial curve with peaks in twin birth rates in May–June and December, along with troughs in February and September. A falling trend in twinning rate broke off in Denmark around 1970, and from 1970 to 1984 an increasing trend was found. The results are discussed in terms of possible environmental influences on twinning.

A variety of environmental factors are known to influence pregnancy and childbirth. Of particular interest for the present study are previous reports on the seasonality of twin births. Some studies have shown an excess in twinning rates in the spring,^{1 2} some have shown an excess in the autumn and early winter months,^{3–5} and some found no evidence of seasonality in twinning rates.^{6–10} In a study dealing with twin conceptions, an excess was found in the spring and autumn.¹¹

The influence of environmental factors on reproduction may be reflected in the fact that the dizygotic twinning rate has been falling during the last 30 to 40 years in every country where data have been available.^{12–14} This fall is one of the most pronounced changes in biological reproduction. Still we have only suppositions of the underlying mechanisms and no certain knowledge. Only part of this fall can be explained by maternal age and parity.¹⁴

The purpose of this study was to describe the pattern of seasonal variation if such variation existed in Danish twinning rates and thereby to obtain some hints concerning external factors leading to twin births.

Methods

Data on twin births and total births in Denmark were provided by Danmarks Statistik. The data covered the period from 1 January 1936 through 31 December 1984. They concerned all deliveries (live and stillborn, legitimate and illegitimate, N = 3 679 932) in Denmark during that period and involved 45 550 twin births. No information was available concerning twin zygosity, maternal age or parity for monthly data.

Twin birth rates (TBRs) were computed as follows:

$$\text{TBR}_t = \omega \frac{\text{T}_{t-1}^1}{\text{B}_t^1/1000} + (1 - \omega) \text{T}_t^1 \quad \text{for } t = 2, \dots, 588$$

T_t^1 and B_t^1 denote monthly twin and total birth frequencies, respectively, adjusted for length of month (ie, observed frequencies were multiplied by 30.4/number of days in month). A weight factor, ω , was used to adjust for differences in mean gestational length between singleton and twin pregnancies. A mean difference of 20 days has been reported in the literature,¹⁵ which corresponds to $\omega = 0.65$. It is seen from the formula above that the TBR for January 1936 is not available. In order to operate with an equal number of observations for each month the analysis of seasonality covers 1937 through 1984 only.

Secular trends in the TBR may confound the analysis of seasonal trends. Therefore, trend-adjusted monthly averages in TBR rather than crude averages were used. The data analysis is based on the following statistical model:

$$\text{TBR}_t = \sum_{i=1}^{12} \alpha_i D_{i,t} + \sum_{i=1}^{NT} \beta_i \left(\frac{t}{12}\right)^i + \varepsilon_t$$

$t = 2, \dots, 588$

where

- t = calendar time
- β_i = trend coefficients
- $D_{i,t}$ = a month-dummy variable
- α_i = seasonal coefficients of the TBR
- ε_t = error term
- NT = order of time trend polynomial

The coefficients of the model were estimated by ordinary least squares methods. Next, intra-year

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variation in the TBR was tested through the non-parametric test suggested by Edwards, and the score test by Rogers, which is a modified version of Edwards' original test against cyclic behaviour. All three tests were based on the α -coefficients and hence trend-corrected. However, a wide range of intra-year variation may be present in the TBR.

A more detailed picture of this intra-year variation can be revealed by subjecting the estimated coefficients to a nested series of hypothesis tests. Each hypothesis in the series imposes an additional restriction on the variation of the α -coefficients. The restrictions are equivalent to polynomial constraints on the α -coefficients. The unrestricted coefficients are equivalent to an 11th degree polynomial pattern. The first null hypothesis in the nested series is an n th degree polynomial, $n < 11$. If this null hypothesis is accepted, we proceed to test a $(n-1)$ th degree polynomial, et cetera. The final null-hypothesis is a zero-degree polynomial, ie, that all seasonal coefficients lie on a flat line. This null hypothesis is equivalent to no intra-year variation. If we reject a $(n-1)$ degree polynomial restriction, but have accepted the n th degree restriction, we can calculate the n th degree restricted seasonal coefficients, and they should provide a more precise estimate of the seasonal coefficients compared to the unrestricted coefficients.

Results

The number of twin births per 1000 pregnancies per year is shown in figure 1. The degree of the trend polynomial for the total period, 1937–84, was 3, and the trend line shown as the dashed line in figure 1. Note that this trend line is not calculated to provide projections but to provide a within-sample description of trends in the TBR data. The results of trend analysis for the three subperiods are reported in table 1. There was no trend in the twin birth rate for the period 1937–48. For the period 1949–69, a very well determined linear trend coefficient of -0.16 was estimated, which means that the twin birth rate declined by 0.16 per 1000 each year. For the third

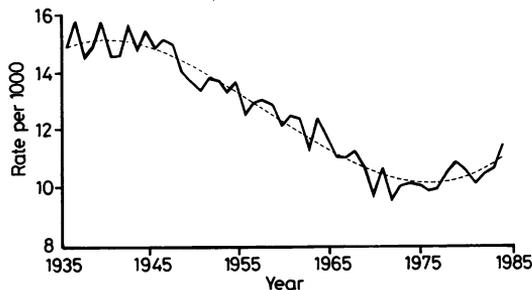


Fig 1 *Twin births per 1000 births, Denmark, 1936–84*

period, from 1970 to 1984, a significant and increasing trend of 0.07 per 1000 was found.

The monthly averages for twin births are shown in figure 2. A peak in TBRs can be seen in the spring and early summer months as well as in December. The results of statistical analyses are shown in table 2. No significant seasonality was found using either the method of Edwards or that of Rogers. However a significant excess of twin births between December and May from 1949 to 1969 and between May and October from 1970 to 1984 was shown by Hewitt's test.

The results of the nested testing procedure are reported in table 3 for the total period and for each of the three subperiods. The results suggest intra-year variation according to a fifth order polynomial curve for the periods 1949–69 and 1937–84. No systematic intra-year variation seems present for the other two subperiods.

The χ^2 statistics reported in table 3 test the validity of the imposed restrictions. For each period we can accept a fifth degree polynomial restriction. For all periods but the 1970–84 period a large increase in the χ^2 value is observed when we proceed to a fourth degree polynomial. For the most restrictive alternative (a zero degree polynomial structure (no seasonality)) the χ^2 statistics are nominally significant for the total period and the 1949–69 subperiod only. Real significance levels that are adjusted for carrying out seven

Table 1 *Results of trend analysis for subperiods*

Statistics	1937–48	1949–69	1970–84
Degrees of freedom	131	239	167
Point of estimate of trend coefficient	-0.007	-0.161	0.071
p-value $H_0: \beta=0$	0.814	0.00	0.0003
95% confidence intervals	(-0.066; 0.052)	(-0.183; -0.139)	(0.033; 0.109)

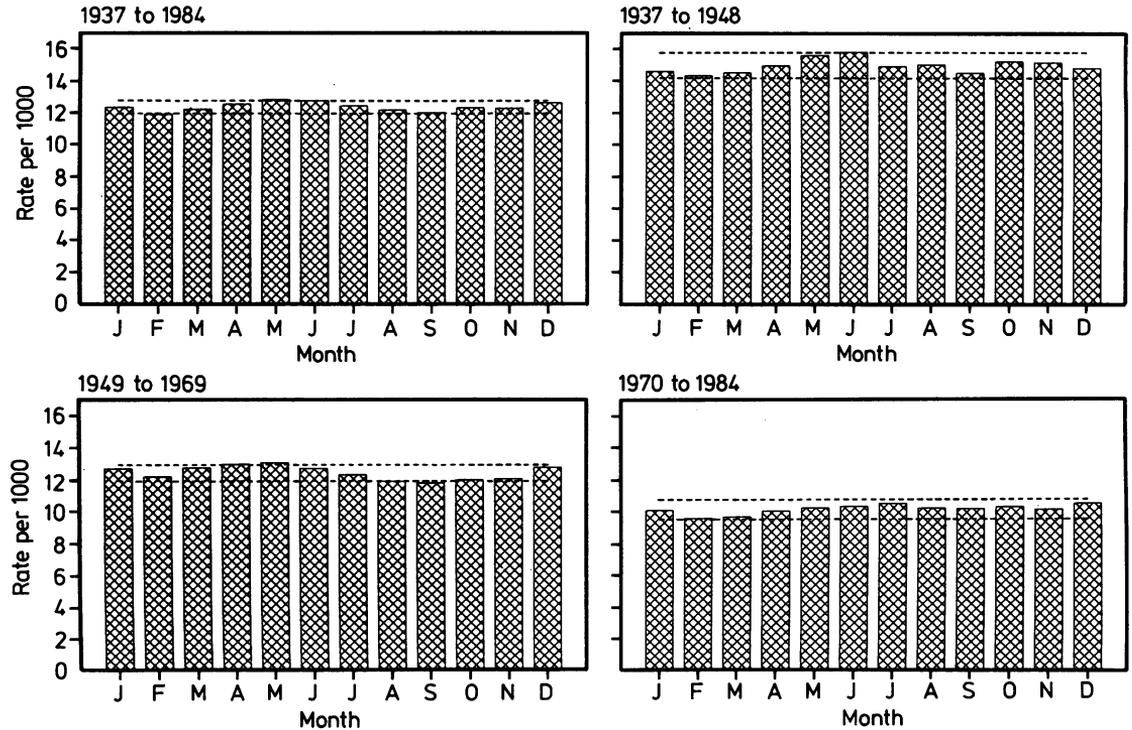


Fig 2 Twin births per 1000 births, Denmark, 1937-84 and subperiods, trend adjusted monthly averages

Table 2 Seasonality in twin births in Denmark according to Edwards', Rogers', and Hewitt's tests

Time period	Edwards' test		Rogers' test		Hewitt's test 6 months period highest rank sum	p
	χ^2	p	χ^2	p		
1937-48	0.27	0.87	0.27	0.87	May-November	0.066
1949-69	3.08	0.21	3.06	0.22	December-May	0.008
1970-84	0.35	0.84	0.35	0.84	May-October	0.021
1937-84	0.90	0.64	0.90	0.64	March-August	0.12

Table 3 Sequential tests of seasonal structure in Danish twinning rates

Nested null hypotheses	Degree of polynomial	Number of restrictions NR	Chi-squared test with NR degrees of freedom							
			1937-48*		1949-69*		1970-84*		1937-84**	
			NR	p	NR	p	NR	p	NR	p
H1	6	5	2.95	0.71	0.64	0.99	0.80	0.98	1.74	0.88
H2	5	6	3.56	0.74	2.05	0.92	0.90	0.99	1.93	0.92
H3	4	7	9.10	0.25	7.11	0.42	1.34	0.99	11.16	0.13
H4	3	8	10.38	0.24	12.16	0.14	5.57	0.70	20.97	0.007
H5	2	9	10.85	0.29	29.15	0.0006	5.66	0.77	28.92	0.001
H6	1	10	14.53	0.15	29.386	0.001	6.12	0.81	30.25	0.001
H7	0	11	15.76	0.15	35.97	0.0002	11.26	0.42	30.29	0.002

* Trend adjusted by linear time trend.

**Trend adjusted by third degree time trend polynomial.

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hypothesis tests are 0.014 and 0.0014, respectively. For these two periods the appropriate seasonal structure is found in the interval between a fifth and a third degree polynomial structure. $(\chi^2_8 - \chi^2_6) = \chi^2_2$ provides a test of the validity of the two additional restrictions implied by a third degree structure relative to a fifth degree structure. We found $\chi^2 = 15.55$, $df=2$, $p < 0.01$ for the total period and $\chi^2 = 10.11$, $df=2$, $p < 0.01$ for the 1949-69 period. Similarly, we can reject the restrictions implied by a fourth degree structure. Hence we infer a seasonal structure in the twinning rate according to a fifth degree polynomial structure for these two periods. For the 1937-48 and 1970-84 periods we cannot reject the null hypothesis of no intra-year variation. The analysis is illustrated graphically in figure 3 for the 1949-69 period.

Table 4 shows the monthly averages in the total period and the 1949-69 subperiod estimated without restrictions and with a fifth degree restriction, respectively. Note that the standard deviations of the latter estimates have decreased by up to 30%.

Discussion

According to the sequential testing procedure we found a significant seasonality for the subperiod 1949-69 and for the total period 1937-84. This

seasonality is following a fifth order polynomial curve, which is not a simple harmonic curve.

This is in agreement with results of Edwards' and Rogers' tests. These tests have high power for seasonality following a simple harmonic sinusoidal pattern but low power for a more complex seasonal structure. Hewitt's test is dependent on the spacing of the peaks. If peaks are separated by six months, the power of the test is high, but low in cases of shorter time spacing between peaks.

It is interesting to note that the decline in twinning rate has stopped, as noted also by Olsen and Rachootin²⁰ and Czeizel². The decline has apparently been replaced by a significant and slightly positive trend. Seasonality might reflect the effect of environmental factors influencing reproduction. A lack of seasonality from one time period to another might indicate that these factors are no longer working. The environmental factors causing seasonality might be the ones causing the decline in twinning rate for the years 1949-69.

The secular decline has been noted for dizygotic twinning only.¹²⁻¹⁴ In the same way, seasonality has been described for dizygotic twinning only.^{2,3,5} In the present study this distinction between monozygotic and dizygotic twinning was not possible because monthly data for each sex were not available. The

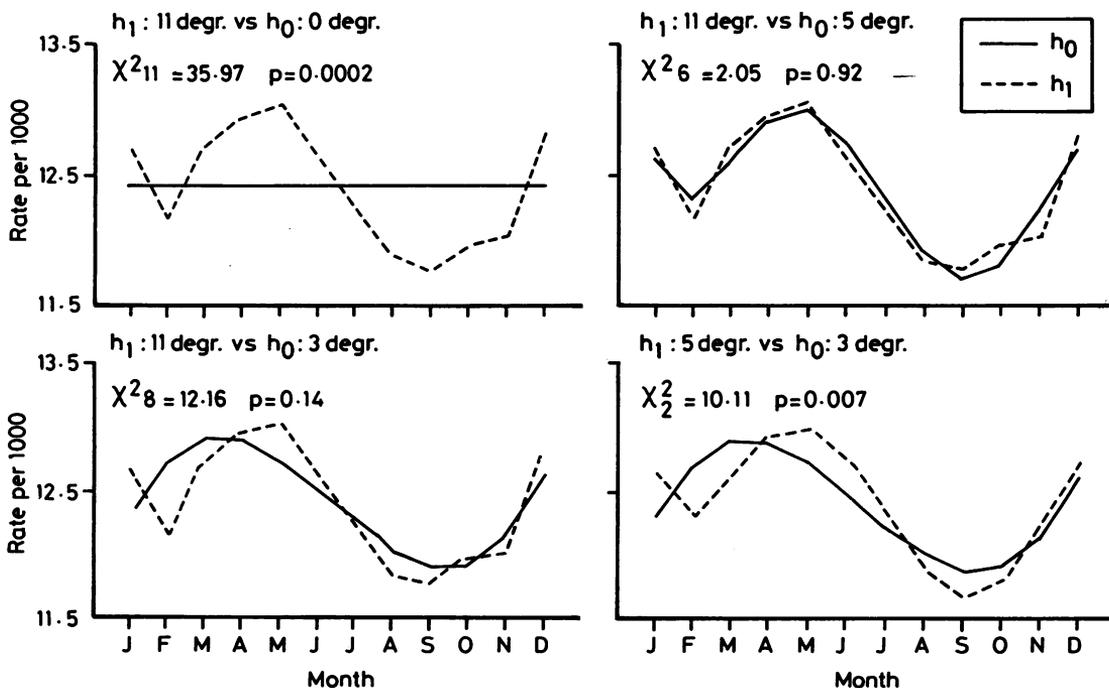


Fig 3 Twin births per 1000 births, Denmark, 1949-69. Analysis of seasonal behaviour under trend control

Table 4 Monthly trend adjusted averages of twin rates Denmark. (1937-84 average 12.35 per 1000 births)

Month	Without constraint					With 5th degree constraint				
	Monthly average	SD	95% CI		t	Monthly average	SD	95% CI		t
			Upper	Lower				Upper	Lower	
Jan	12.35	0.211	12.77	11.94	0.01	12.35	0.209	12.76	11.94	-0.01
Feb	11.98	0.211	12.39	11.56	-1.76	11.99	0.190	12.36	11.62	-1.89
Mar	12.24	0.211	12.66	11.83	-0.51	12.22	0.182	12.58	11.87	-0.70
Apr	12.51	0.211	12.92	12.09	0.75	12.54	0.178	12.89	12.19	1.08
May	12.73	0.213	13.15	12.32	1.81	12.70	0.181	13.06	12.35	1.96
Jun	12.67	0.213	13.09	12.26	1.53	12.65	0.178	12.99	12.30	1.66
Jul	12.40	0.213	12.81	11.98	0.22	12.43	0.178	12.78	12.08	0.47
Aug	12.19	0.213	12.61	11.77	-0.76	12.20	0.182	12.56	11.84	-0.82
Sept	12.04	0.213	12.45	11.62	-1.47	12.08	0.180	12.43	11.73	-1.50
Oct	12.29	0.214	12.71	11.87	-0.29	12.15	0.185	12.51	11.79	-1.09
Nov	12.26	0.214	12.68	11.84	-0.42	12.37	0.192	12.74	11.99	0.09
Dec	12.54	0.214	12.96	12.12	0.89	12.52	0.213	12.93	12.10	0.78

(1949-69 average 12.41 per 1000 births)

Jan	12.65	0.232	13.10	12.19	1.02	12.61	0.228	13.05	12.16	0.86
Feb	12.19	0.232	12.65	11.74	-0.93	12.32	0.188	12.69	11.96	-0.45
Mar	12.68	0.232	13.14	12.23	1.17	12.58	0.170	12.92	12.25	1.02
Apr	12.88	0.232	13.33	12.42	2.01	12.86	0.161	13.18	12.55	2.82
May	12.96	0.233	13.42	12.51	2.37	12.92	0.165	13.24	12.60	3.10
Jun	12.65	0.233	13.11	12.20	1.05	12.71	0.158	13.02	12.40	1.93
Jul	12.31	0.233	12.77	11.85	-0.43	12.34	0.158	12.65	12.03	-0.42
Aug	11.93	0.233	12.39	11.48	-2.04	11.98	0.167	12.31	11.65	-2.59
Sept	11.85	0.235	12.31	11.39	-2.38	11.79	0.163	12.11	11.47	-3.80
Oct	12.02	0.235	12.48	11.56	-1.67	11.89	0.172	12.23	11.55	-3.03
Nov	12.08	0.236	12.54	11.62	-1.39	12.25	0.192	12.63	11.87	-0.83
Dec	12.71	0.236	13.17	12.25	1.27	12.66	0.232	13.11	12.20	1.07

seasonality found in the present study may be caused by the dizygotic twinning only. However, the seasonal variation seems to be strong enough to be significant for the total twin pool. The lack of seasonality for the years 1937-48 and 1970-84 might be caused by the inclusion of both mono- and dizygotic twins.

Many different factors have been mentioned²¹ as possibly influencing season of birth in man: temperature, humidity, sunshine, diet, disease, illegitimacy, abortion, miscarriages, stillbirths, season of marriage, religious observances, festivals, fasts, urbanisation, industrialisation, and restriction of births. James⁵ noted that the dizygotic twinning rate was dependent on the spontaneous abortion rate, the coital rate, the probability of fertilisation of an ovum given that coitus occurred in the fertile period and the probability of double ovulation.

The findings in the literature concerning seasonality of the frequency of spontaneous abortions (recognised abortions) are inconclusive. In some studies seasonality in spontaneous abortion could not be demonstrated.²²⁻²⁴ In others, a significant seasonality with a summer maximum was found.^{25 26} If a cyclic trend of that type existed in Denmark for the years concerned, the results would have been a winter maximum in all pregnancies and perhaps a winter minimum with a greater amplitude for twin births.

There seems to be some evidence in the literature for a summer peak in coital rate. Naeye²⁷ found a significant maximum in coital rate in May-June in a study from the USA. Both Parkers²⁸ and James²⁹ reported on a greater volume of sales of contraceptive material in the summer months than in the winter in England. In some studies seasonal variation with a summer maximum was demonstrated in reported rapes.³⁰ Besides, some authors have found a seasonal variation in sexually transmitted diseases (gonorrhoea, syphilis and trichomonas infections) which show a maximum in summer and early autumn, depending on length of incubation.³⁰ The existence of a summer maximum of sexual activity may account for some part of the spring peak in twin births in our study.

Nothing is known about the probability of fertilisation, given that coitus occurred in the fertile period.

The probability of double ovulation surely is dependent on the interrelation of the concentrations of sexual, hypophysarian, and hypothalamic hormones. The findings in the literature concerning seasonal variation in these hormones are contradictory. Seasonality in follicle stimulating hormone (FSH) and luteinising hormone (LH) was demonstrated in adult men³³⁻³⁵ but not in adult women.³⁵ Circannual

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rhythms in both FSH and LH was demonstrated in both sexes before puberty.³⁶

In our searching for some basic aetiological factors leading to the birth of twins we must conclude that seasonality can be documented for some periods in Denmark. The cause of this seasonality is so far unknown. Factors such as dietary intake of certain substances found in fresh food during the summer or increasing amounts of daylight might in the past have been acting through coital rate, rate of spontaneous abortion or perhaps through the frequency of double ovulation. Only an individually based study will make it possible to control the results for factors such as maternal age and parity which are known to increase the chance of dizygotic twins. Elder women with a higher parity might to a greater extent than younger nulliparous women plan their pregnancies so as to deliver in the most favourable season—the spring.

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