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TEMPORAL VARIATION IN RATES OF MULTIPLE MATERNITIES IN SWEDEN (1751-2000)

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Abstract

In this study, we have observed strong temporal fluctuations in the rates of multiple maternities in Sweden, 1751-2000. The rates were the highest noted for a whole nation during the last three decades of the 18th century. After the 1930s, there was a marked decrease in the twinning rate. After the extreme minima for the multiple maternities in the 1960s and 1970s, steep increases in the rates are observed. These increases are caused by the introduction of artificial reproduction techniques.

Standardisation of the twinning rate for Sweden partly reduced the temporal fluctuations, but the general pattern remains. Hence, the strong variations are not related to maternal age or parity. The fluctuations in the triplet rate show similar pattern as the twinning rate.

Following the observation that maternal age and parity cannot satisfactorily explain the variation in the twinning rate, our hypothesis is that the strong demographic and socio-economic changes in Sweden

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during the second half of the 19th century and the first half of the 20th century, with increasing urbanisation, are the main causes of the decreased rates in multiple maternities. The twinning rate being consistently lower in urban than rural regions supports this finding. In addition, the effect of increasing population density and consequently, the disruption of genetic isolates, maintains these observations.

We studied statistical sources of Sweden, 1751-2000. Strong temporal fluctuations in the rates of multiple maternities were observed. The rates were the highest noted for a whole nation during the last three decades of the 18th century, the twinning rate being over 17 per 1000 and the triplet rate over 2.5 per 10,000. During 1849-1873, the twinning rate in Sweden was only 14.2 per 1000. After the 1930s, there was a second marked decrease in the twinning rate, which by the 1960s had fallen to only about half of what it had been at the end of the 18th century. The corresponding reduction for triplet rates was about 75%. We confirmed our earlier findings that maternal age and parity cannot satisfactorily explain the secular differences in twinning rates. The aim of this paper was to evaluate the temporal variations in multiple maternities in Sweden from 1751 to 2000. The increased urbanisation and industrialisation that started in the last decades of the 19th century disbanded the static agrarian isolates and caused Sweden, within 2-3 generations, to develop from a poor nation into one of the most prosperous in the world. A more urban and comfortable lifestyle accompanied by increased stress and sedentary occupations may have reduced the physical capacity of the mothers to carry gestations with multiple fetuses to completion. The increases in the rates of multiple maternities after the 1970s are mainly caused by assisted artificial reproduction techniques.

Sweden has the oldest continuous population records for a whole nation dating back to the 17th century. In 1749, a nation-wide system called "*Tabellverket*" (predecessor to Statistics Sweden) was launched for official collection of population data, including birth tables with information about twinning and higher multiple maternities. The statistical sources are considered to be of relatively high accuracy and reliability [1, 2].

Until the 1930s, the rates of multiple maternities in Sweden were among the highest known among Europeans. However, strong temporal fluctuations were noted. A strong decrease in the rates occurred in the first part of the 19th century. After the 1920s, a second marked decrease took place in Sweden; in the 1970s, the twinning rate (TWR) was hardly 50% of what it had been 200 years earlier. The TWR in the 1770s was 17.1 per 1000, but 200 years later, 1971-1980, it was only 8.7 per 1000, despite assisted reproduction being used in Sweden since the 1960s [3]. During the last three decades of the 18th century, the triplet rate (TRR), transformed according to Hellin's law, was about 16.5 per 1000. The decrease in the observed triplet rates over the two centuries was even greater, being about 75%. Consequently, for the Hellin-transformed TRR, the decrease is comparable to the decrease in the TWR [4-9].

Our earlier studies have shown that maternal age and parity cannot satisfactorily explain the temporal differences in the TWR [8, 10, 11]. Consequently, the noted fluctuations cannot be explained by differences in maternal age and parity. In the discussion section, alternative influential factors are analysed.

Fellman and Eriksson [9] analysed the regional and temporal variations in the TWR in some counties in Sweden. In the absence of parity data, they considered the crude birth rate (CBR) as a proxy variable. The CBR is defined as the number of live births per 1000 inhabitants. They confirmed the main result, earlier stressed by us, that differences in the TWRs cannot be satisfactorily explained by demographic data at the macro level [12].

This paper aimed to investigate the temporal variations in the multiple maternities in Sweden from 1751 to 2000. Following the observation that maternal age and parity cannot satisfactorily explain the variation in the TWR, our hypothesis is that the strong demographic and socio-economic changes in Sweden during the second half of the 19th century and the first half of the 20th century are the main cause of the decreased rates in multiple maternities. Urbanisation and industrialisation with improved communications caused a strong internal migration, with increasing exogamy and disintegration of isolates in the static agrarian society. The effect of increasing population density and urbanisation, and, consequently, the disruption of isolation, is supported by our observation that the TWRs in all Swedish counties converge towards a common low level, resulting in a diminished of regional heterogeneity in TWR [13].

Material and Methods

We analyse birth data in Sweden from 1751 to 2000. The data for twins and triplets were pooled for 10-year and 25-year periods, respectively. In fact, all data in this study are an update of the data presented in [8, 10, 13]. A detailed description of the data is presented in these earlier studies.

Results

In Figure 1, we present the observed and standardised TWR. The standardisation is based on observed data for 1971-1980, when the absolute minimum TWR was obtained. Standardisation of the TWR for Sweden partly reduced the temporal fluctuations in the TWR, but the general pattern remains. Hence, the strong variations are not related to maternal age or parity. For 1841-1850, the observed minimum of 13.6 is, after standardisation, reduced to 11.5, which is, however, far from the minimum TWR in Sweden during the 20th century, which is 8.7 (for 1971-1980). Modelling of the temporal variations of the TWR is difficult to perform. In the figure, we include trend lines, but in order to obtain a good fit the lines must be sixth-degree polynomials. This result holds for both the observed and the standardised TWRs. Although the trend lines give a good fit, they cannot explain the fluctuations.

In Figure 2, we present the difference between the observed and standardised TWRs. The difference shows a mainly decreasing trend up to the 1970s without marked fluctuations. These findings support our statement, given above, that standardisation according to maternal age (and parity) cannot explain the fluctuations. Consequently, in the discussion section, we discuss possible influential factors.

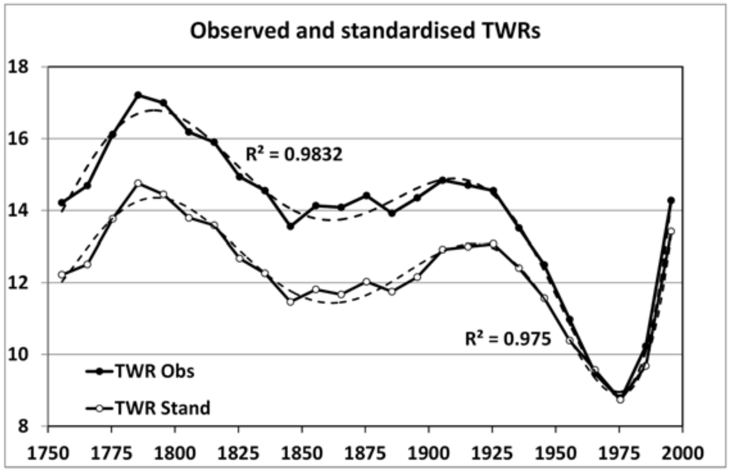

Figure 1. Temporal variation in observed and standardised twinning rates (TWRs) in Sweden (1751-2000). The standardisation is based on observations for the period 1971-1980. The trend lines are sixth-degree polynomials and the coefficients of determination, R^2 indicate a good fit.

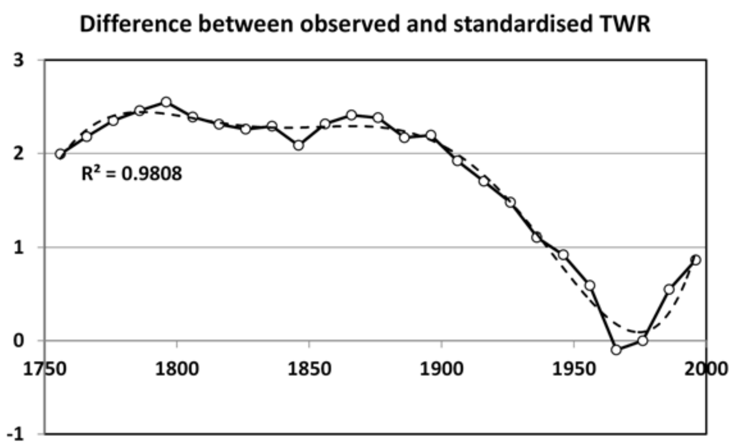

Figure 2. Temporal variation in the difference between observed and standardised twinning rates (TWRs) in Sweden (1751-2000). The trend line is a sixth-degree polynomial.

Figure 3 presents the triplet rate (TRR) transformed according to Hellin's law for the period 1751-2000. The transformation of the TRR according to

Hellin's law was performed in order to present the TWR in Figure 1 and the TRR in Figure 3 on the same scale.

After the extreme minima for the TWR and the TRR in the 1960s and 1970s, steep increases in the rates are observed. These increases are caused by the introduction of ovulation inducers and other assisted artificial reproduction techniques. Before the minimum, the transformed TRR curve is situated below the TWR curve, but after 1971, the order is the opposite, indicating that the artificial reproduction techniques had a relatively stronger influence on the occurrence of triplet than of twin maternities. Therefore, in our opinion, only series before the artificial reproduction techniques starting in the 1960s can be used for studies of the frequencies of multiple maternities.

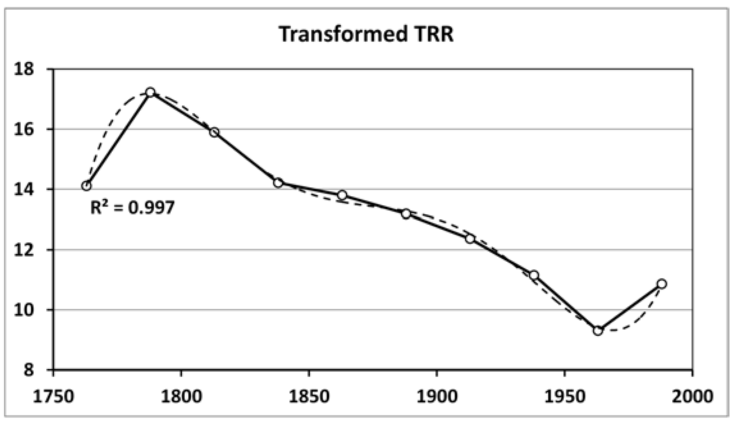

Figure 3. Temporal variation in observed triplet rates (TRRs) in Sweden (1751-2000). The rates are transformed according to Hellin's law. The transformation enables comparison of TWR and TRR. The trend line is a sixth-degree polynomial.

In France, Hemon et al. [14] noted a significant correlation between the decline in the age-adjusted dizygotic TWR and the declining excess of births over deaths. One argument in favour of this could be the strong correlation between the crude birth rate (CBR) and the mean parity. Eriksson and Fellman [8] analysed the association between TWR and CBR and calculated the correlation between these variables for Sweden as a whole and for the Swedish counties for the period 1751-1960. For Sweden, the ordinary correlation coefficient for time versus CBR is –0.879, for time versus TWR –0.744 and for CBR versus TWR 0.637. The lack of a systematic association between the variables TWR and CBR for the counties indicates that the rates may be influenced by some external, as yet unknown, time-dependent factors. To remove the effect of these factors, one possibility is to consider time as a proxy variable for them. Therefore, the partial correlation coefficients between the TWR and the CBR were calculated when time was kept fixed. Partial correlation coefficients may differ markedly from the ordinary correlation coefficients and may even have different signs. The partial correlation coefficient for Sweden in 1751-1960 obtained when time was kept fixed was –0.055 and its standard error was 0.218. Consequently, when the time effect is eliminated, no significant correlation exists between CBR and TWR.

In a more advanced attempt to keep the time fixed and eliminate the effect of unknown, time-dependent factors, Eriksson and Fellman [8] analysed the correlation coefficients between the regional data for the CBR and the TWR for all the decades during the period 1751-1960. They presented the results in their Figure 5, where they also included the 95% confidence intervals [15]. According to the χ^2 test, the temporal differences in the correlation coefficients were statistically significant ($\chi^2 = 52.5$ with 18 degrees of freedom). Eriksson and Fellman observed no systematic association between the variables TWR and CBR. For the period 1801-1870, correlation coefficients were strongly *negative*. Such negative correlations may be caused by counties having simultaneously low TWR and high CBR values and *vice versa*. Such factors may be increased internal movement with increased exogamy and the demographic transition with the increasing effect of birth control and lower maternal mean age. Hence, their findings seem to indicate that the association noted by Hemon et al. [14] may be spurious and the declines in France in both the TWR and the birth rate are due to some common external factors.

Discussion

Eriksson and Fellman [8] presented a thorough discussion concerning plausible factors influencing the rates of the multiple maternities. In this study, we review the central parts of their discussion. Berg [16] noted that in Sweden in 1849-1873, there was a trough in the TWR, although the TWR was as high as 14.2. In addition, earlier studies reveal that the age-specific TWRs show temporal variations [8, 10, 12, 17]. To obtain a more detailed explanation of the variations in the total and the age-specific TWRs, other factors, besides maternal age and CBR analysed above, should be included in the discussion. A factor that is likely to have influenced the temporal variations in at least some regions is the disruption of genetic isolates [8].

Temporal twinning rates and lifestyle. It has been argued that a diet containing fish would stimulate placental blood flow and cause a higher birth weight and that the risk of spontaneous abortions would be lower in fish-eating women than in women with more affluent urban lifestyles [18, 19]. After 1849-1873, the TWR decreased in the towns of Sweden but remained rather high in the rural areas until the 1930s. Especially, in the rural fish-eating island populations on Gotland and in the majority of coastal counties of Sweden, as well as in the south-western part of Finland (Åland and Åboland), the TWR remained relatively high [6, 8, 9].

Standard of living and twinning. Reports on variation in the TWRs by social class are conflicting and difficult to interpret because the methods of defining social class differ ([8] and for review [20]).

Following the observation that maternal age and parity cannot satisfactorily explain the variation in the TWR, our hypothesis is that the strong demographic and socio-economic changes in Sweden during the second half of the 19th century and the first half of the 20th century, with urbanisation increasing from only about 11% in densely populated areas in 1860 to 83% in 1980 [21], are the main cause of the decreased rates in multiple maternities. Urbanisation and industrialisation with improved communications caused a strong internal migration, with increasing exogamy and disintegration of the isolates in the static agrarian society. In two to three generations, Sweden changed from a poor country to one of the most affluent nations in the world [22, 23]. The effect of increasing population density and increasing urbanisation, and, consequently, the disruption of isolation, is that the TWRs in all Swedish counties converge towards a common low level, resulting in a diminished of regional heterogeneity in TWR [13].

During the 19th century, Sweden underwent a drastic economic change. In the old Swedish society, more than 80% of the population was employed in agriculture. However, Sweden depended on imported grain until about 1830 [24]. In the pre-industrial phase, Swedish agriculture achieved a production capacity so great that it could support the rapidly increasing population (growing by more than 30% from 1830 to 1860). Different opinions exist as to whether the living standard of the population fell in connection with the strong increase in the population size [8, 25-27].

Sandberg and Steckel [26] studied the average height of Swedish men aged 25-49 years over the period 1725-1854. Five-year moving averages in the height of men born between 1810 and 1840 increased by almost 6 cm, but fell steeply in the 1840s from almost 172cm to about 165cm. This fluctuation is, according to Eriksson and Fellman [8], concordant with events in the economic history of Sweden, and the 1840s is noted as a period of crisis, particularly in the western part of southern Sweden, in contrast to what some historians have claimed [24, 27].

Despite low average heights of Swedish men born in the 1780s and the 1790s, the TWR at that time reached the highest values noted in Sweden, ranging from 16 to 18 per 1000. After 1815, however, the TWR declined steadily and fell below 14 per 1000. In 1841-1850, the TWR was only 13.6 per 1000, i.e., a decrease of about 20% of the TWRs in the last decades of the 18th century.

If we suppose that an improved standard of living has an increasing effect on the TWR, then the downward trend of the TWR during the first part of the 19th century is surprising. Firstly, after 1810, the economic conditions in Sweden improved considerably. Prices for corn and other commodities decreased. An increase in the average height of soldiers born between 1790 and 1840 indicates a clear improvement in the average nutritional status of the population, probably influenced by the spread of potato cultivation [22, 26]. Mortality also declined, which is attributed to peace after 1814, a favourable climate and medical improvements, e.g., vaccination against smallpox. Secondly, the age pattern of fertility was relatively stable from 1750 to 1815, but from 1820 to 1850, there was a decrease in fertility, particularly among women of the least twinning-prone age of below 30 years (caused by later marriages), and simultaneously there was an increase in fertility among women of the most twinning-prone age, i.e., above 35 years of age [2]. In terms of these socio-economic changes, one would have expected increasing - not declining - TWRs [8].

Socio-demographic factors, physical condition and twinning. A factor not to be neglected is that gestations with twins or higher multiple embryos or fetuses make particularly heavy demands on the mother's capacity to increase her heart volume and maintain an optimal blood supply to the uterus [5]. Studies with ultrasonic scanning in an early phase of gestation indicate that one or both twins vanish more often than singletons [8, 28].

Age-standardised TWRs are significantly higher in rural than in urban areas. Higher orders of multiple maternities, such as triplets and quadruplets, also have considerably higher frequencies in rural than urban regions [6, 7]. Isolates and mainly rural counties in both Sweden and Finland show a much later onset of the decline in TWRs than urbanised ones. In the countryside in the past, mainly only healthy, physically fit women with good working capacity were married. There are indications that gestations with multiple embryos or fetuses demand a good physical condition of the mothers, as found, e.g., in native archipelago women in the past [5, 6].

Eriksson and Fellman [8] found for Sweden that the TWR was consistently lower in urban than rural regions for all classes of maternal age and parity, supporting the results obtained for Finland [7, 29]. Hence, there seem to be factors other than maternal age and birth order that can increase the TWR considerably. Also, Mosteller et al. [30] and Parisi and Caperna

[31] have commented that decreasing TWRs might be related to heavy psychosocial pressures associated with increased urbanisation and biosocial transformations. Parisi and Caperna [31] noted that already at the end of the 19th century, the industrialised northern part of Italy showed a practically continuous decline in the dizygotic TWR since the 1880s. In the southern Italy, by the contrast, the dizygotic TWR increased until the 1940s and the decline started in the 1960s.

Twinning in mixed and hybrid populations. Evidence suggests that women of mixed ancestry due to intermarriage between populations with different dizygotic twinning rates produce fewer twins than would be expected if gene actions were additive [4-6, 32, 33]. Sweden provides support for the hypothesis that regionally mixed (out-breeding) populations have fairly low twinning rates [8].

The effect of urbanisation on the TWR can also be observed elsewhere. For example, in Finland, in the county of Nyland (in Finnish, Uusimaa), including the capital of Helsinki, with the most rapid urbanisation and the highest population density, the TWR declined strongly from 17.1 to 12.5 per 1000 during 1860-1969. Only a small part of this decline can be explained by decreased maternal age. In the isolated rural counties in eastern Finland, the TWR simultaneously *increased* [29].

The decline in the twinning rates, which is not fully explained by decreased mean maternal age or lower parity, may be a consequence of changes in matrimonial migration patterns. This may be interpreted as evidence that the degree of relationship between the parents of the mothers of twins (and not between the parents of the twins themselves) is important for the manifestation of dizygotic twinning. Consequently, a marked decline in the TWR can be expected about one generation after the disruption of genetic isolation. Improved communications, with ever-increasing distances between birthplaces (provenance) of marriage partners, have led to a lower frequency of the tendency for dizygotic twinning. This hypothesis is consistent with the high twinning rates (a) in the past, (b) in rural regions and (c) in some endogamous isolates. Furthermore, it is in accord with the observation that populations with ancestors from populations with different dizygotic twinning rates have frequencies lower than would be expected from additive gene action [8].

The effect of increasing population density and urbanisation, and, consequently, a reduced degree of isolation, is supported by the observation that the twinning rates in all Swedish counties in 1751-1960 converged towards a common low level, resulting in diminished regional heterogeneity in TWR [13].

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