The Convergence of the Regional Twinning Rates in Sweden, 1751–1960

Johan Fellman and Aldur W. Eriksson

Folkhälsan Institute of Genetics, Population Genetics Unit, Helsinki, Finland

Sweden has, as a whole nation, the oldest continuous population register of births, including twin and higher multiple maternities, starting in the 17th century. Until the 1920s, the rates of multiple maternities in Sweden were among the highest known among Europeans. Strong secular and regional fluctuations were noted. Some of the eastern counties showed especially marked decreasing trends. The twinning rate had no clear associations with the anthropometric and serological data. In this paper we study the temporal and regional variations of the twinning rate in the 25 counties of Sweden from 1751 to 1960. Different statistical methods were applied in order to test the hypothesis that, irrespective of the initial levels, the twinning rates for the counties converge towards a common low level. We present and interpret a geometrical model for the trends of the regional twinning rates. We also analyze the regional heterogeneity using the ranges and the coefficients of variation of the regional twinning rates. All the methods gave consistent results, supporting our convergence hypothesis that the regional differences in the twinning rate are gradually disappearing. In addition, this study supports our earlier findings that the regional heterogeneity cannot be explained by differences in the distribution of maternal age and parity. We suggest that the convergence may be caused by increased urbanization and industrialization and by the increased interregional migration of citizens as a consequence of better communications, which lead to the breaking up of isolates and decreased endogamy.

Sweden has the oldest continuous population records for a whole nation, beginning in the 17th century with information about twinning or higher multiple maternities. The rates of multiple maternities have been among the highest known in Europeans. Strong temporal and regional fluctuations have been noted. After the 1920s, an accentuated decrease in the rates of multiple maternities took place in Sweden as a whole; in the 1970s, the twinning rate (TWR) was hardly 50% of what it had been 200 years earlier (Eriksson, 1962, 1964, 1973; Eriksson & Fellman, 1973; Fellman & Eriksson, 2003). Earlier studies have shown that maternal age and parity (birth order) cannot satisfactorily explain the temporal and regional differences in the TWR (Eriksson et al., 1996; Fellman & Eriksson, 1993). Recently, the regional and temporal variations in the TWRs were analyzed in some counties in Sweden and, in the absence of parity data, the crude birth rate (CBR; usually defined as the number of live births per year per 1000 inhabitants) was considered as a proxy variable for parity (Fellman & Eriksson, 2003). The main result stressed previously was confirmed, namely that differences in the TWRs cannot be satisfactorily explained by demographic data on a macro level (Fellman & Eriksson, 1987).

In this study the temporal and regional variations in the TWR are considered in the 25 counties of Sweden between 1751 and the start of the era of artificial reproduction techniques in the 1960s. The data are pooled for 10-year periods. Several different statistical methods are applied in order to test the hypothesis that, irrespective of the initial levels, the TWRs for the counties converge towards a common low level. A geometrical model for the trends in the regional TWRs is presented and interpreted. The range of the regional TWRs during the period 1751 to 1960 are also considered. The regional heterogeneity of the TWRs is also measured with the coefficient of variation (CV). These methods all give consistent results supporting the convergence hypothesis that the regional variation is gradually disappearing. In addition, this study supports earlier findings that the regional heterogeneity cannot be explained by differences in the distribution of maternal age. It is suggested that the convergence may be caused by increased urbanization and industrialization and by the increased interregional migration of citizens as a consequence of better communications, leading to the breaking up of isolates. A detailed discussion of the

Received 21 October, 2004; accepted 10 January, 2005.

Address for correspondence: Professor Johan Fellman, Folkhälsan Institute of Genetics, Population Genetics Unit POB 211, FIN-00251, Helsinki, Finland. E-mail: johan.fellman@shh.fi

effects of different factors on the TWR as well as a map of Sweden with its counties are presented in Eriksson and Fellman (2004).

Materials

Demographic data was analyzed for the years 1751 to 1960 in the 25 counties of Sweden. The data were pooled for 10-year periods. The data set analyzed included all the periods for which regional data was available. For some counties, annual twinning data were occasionally missing, the whole year for this county was therefore ignored. In spite of this, the remaining available data was assumed to represent the whole decade. A gap exists in most of the counties for the time series 1774 to 1794 as the parish data were pooled during this period, according to the partition of Sweden into dioceses. The diocese and the county partition coincide only for the counties Stockholm city and Gotland. Consequently, data for the rest of the counties for the period 1781 to 1790 are completely missing. A detailed description of the data is given in Fellman and Eriksson (2003).

Methods and Results

Disappearing Regional Differences in the TWRs

In an earlier study (Fellman & Eriksson, 2003), the marked regional differences in the TWRs were considered for four regions: the city of Stockholm and the counties of Stockholm, Gotland and Älvsborg. For the county of Älvsborg, the TWR was low (between 10.6 and 14.6 per 1000 for the whole period 1751 to 1960 with exception of 1811 to 1820, when it was 15.9). Careful reading of the published data gives the impression that the number of twin maternities for 1811 may contain an error resulting in too high a TWR. A possible explanation for this is that for this year, the number of twins and not the number of twin sets (maternities) is registered. The controls, based on other registers, have not resolved this problem and as a result, no corrections have been made in the database.

The continuously low TWR indicates that Älvsborg shows no statistically significant trend. In the counties of Gotland, Stockholm and in Stockholm city, the decreasing trends of the TWR were statistically significant. The decreasing TWRs for these counties converge towards the low rate which has been observed for Älvsborg since the 1750s. In Figure 1, the trends for these four counties are presented. Gotland starts from a very high level with an extremely steep slope, Stockholm city and county start from medium high levels with medium steep slopes, and Älvsborg starts from a low level with a slightly increasing slope. It is also of special interest that Stockholm city and county are neighbouring regions, urban and rural respectively.

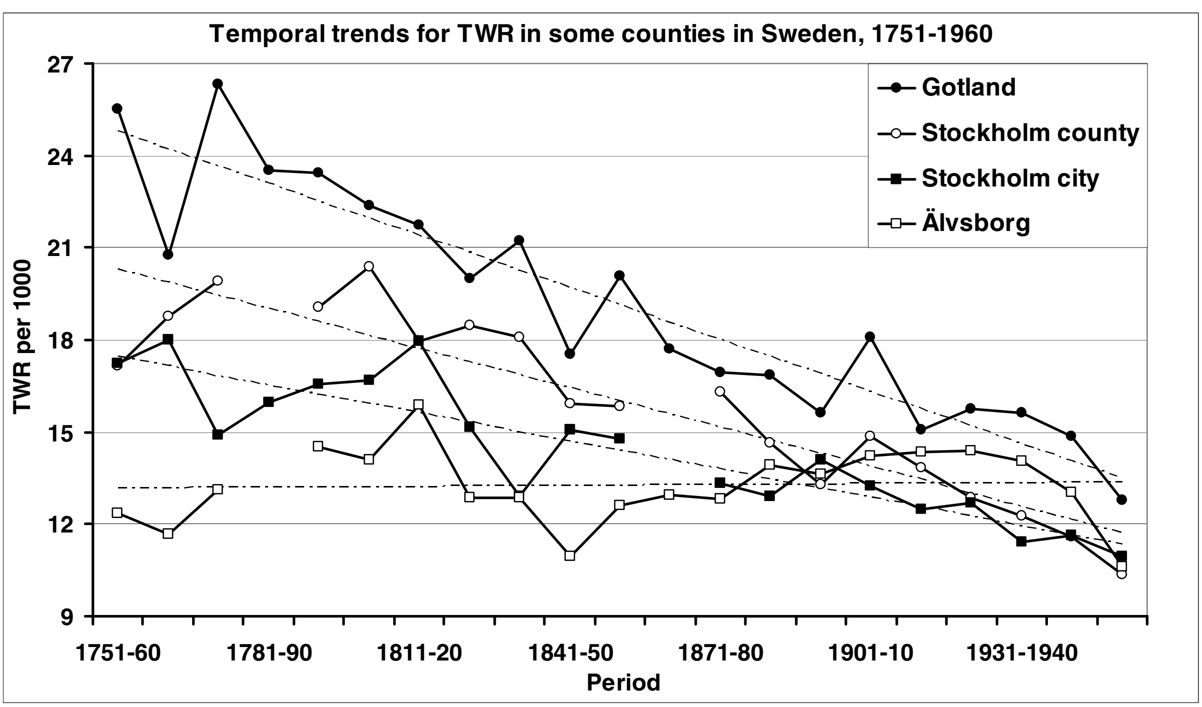

Figure 1

The twinning rates for Stockholm city and the counties of Stockholm, Gotland and Älvsborg.

Linear trends are also included in the figure. The counties discussed in Fellman and Eriksson (2003) represent counties with different temporal patterns. Counties with high (Gotland), medium (Stockholm city and county) and low (Älvsborg) starting levels are noted. Gotland shows the steepest decreasing trend, Stockholm city and county show moderate, but still statistically significant, decreasing trends. Älvsborg shows a slightly increasing, but not significant trend. Note also that Stockholm city and county are neighbouring regions, the former urban and the latter rural.

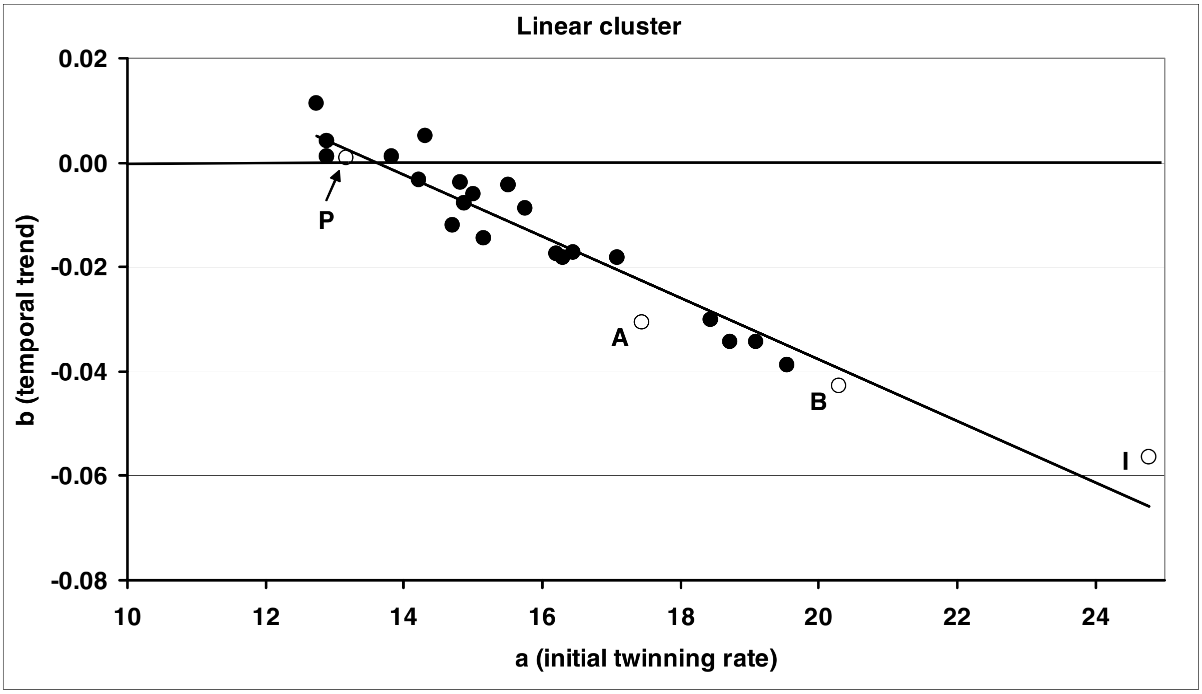

Figure 2

The estimates of the pairs of parameters in the linear trends in the regional TWRs.

The approximate linearity indicates a tendency for the disappearance of regional heterogeneity. The correlation between a and b is –.964. The points corresponding to Stockholm city (A) and the counties of Stockholm (B), Gotland (I) and Älvsborg (P) in Figure 1 are located well within the cluster.

In this study, all 25 counties of Sweden are considered and, using three different methods, analyzed to see whether the TWRs in the counties all converge towards a common low level resulting in a gradually disappearing regional heterogeneity of the TWR.

The Linear Cluster

If exact linear trends are assumed in the regional twinning rates, one has the simple mathematical model:

$$TWR_i(t) = a_i + b_i t \qquad (i = 1,\ldots,I) \qquad [1]$$

where is the TWR at time t for county number i, the intercept is the TWR at the starting time (in this study the period 1751 to 1760), and the slope is the (decreasing) trend. If all the rates converge towards a common level L at the final time (in this study the period 1951 to 1960), then we obtain the general formula:

$$a_i + b_i T = L \qquad [2]$$

holding for all the counties ($i = 1,2,\ldots,I$), that is, all the points in the plane representing the parameter pairs (a_i,b_i) are located on the same line defined by the constants T and L. Equations [1] and [2] are exact only if the mathematical model holds. In practice, the decreasing trends are by no means exactly linear. Therefore, it cannot be expected that the relationship between the pairs (a_i,b_i) is exactly linear. If the convergence proposed holds approximately, then the parameter pairs should form a cluster of points gathered around a line with a negative slope.

The points (a_i,b_i) are distributed in the graph (Figure 2) according to the following rules: If the TWR for a specific county starts from a high level, then the corresponding point is located on the right-hand side and, accordingly, if the starting level is low, the point is located on the left-hand side of the figure. If the TWR shows a marked temporal decrease, then the corresponding point is located in the lower part and, accordingly, if the decrease is minute or if there is an increasing trend, then the point is located in the upper part of the figure. Exceptions to the convergence hypothesis should result in outliers from the linear cluster. Furthermore, the type of outlier gives an indication of how the TWR for the corresponding county behaves. If the point is located in the upper right-hand corner, then the TWR for this county starts from a high level and the high level persists. If the point is located in the lower left-hand corner, then the TWR starts from a low level and continues to decrease. In both cases, outliers from the linear cluster and exceptions to the universal convergence hypothesis are found.

In order to apply formulae [1] and [2], the temporal trends had to be linearized. Therefore, linear regression analyses were applied and the parameters (a_i,b_i) estimated in model [1] for all the counties.

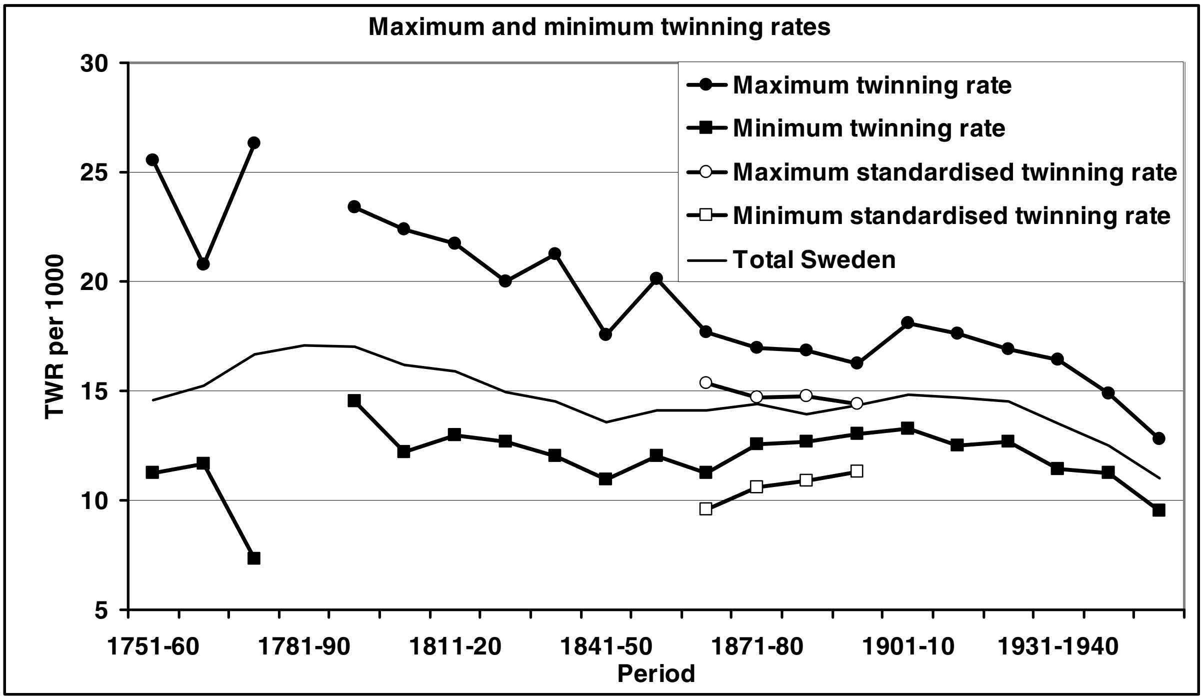

Figure 3

The difference between the maximum and minimum for the regional twinning rates for the period 1751 to 1960.

The period 1781 to 1790 is ignored, as data are missing for all but two counties. An apparently decreasing difference from over 10 per 1000 units in 1751 to 1780 to less than 5 per 1000 units in 1931 to 1960 is discernible. In addition, the maximum and the minimum curves decrease simultaneously towards a common low level. The maximum and minimum of the standardized twinning rates for the period 1861 to 1900 are slightly below the observed rates, but the general tendency remains. Consequently, standardization has no effect on the convergence. In order to stress the convergence towards a common level, the TWR for Sweden has been included as a whole in the figure.

According to the regression analyses, there are statistically significant decreasing temporal trends in the TWRs for 14 counties. For these, it was noted that the slopes indicate a reduction in the TWR of more than 2 per 1000 units during the period considered. For the rest of the counties, the trends in the TWR are not significant, being both negative (5 cases) and positive (6 cases).

The cluster obtained is presented in Figure 2. The result is a linear cluster, which can be interpreted as support for the convergence hypothesis. The correlation between the *a*s and *b*s is as strong as –.964. In Figure 2 it is also noted that some counties with low TWRs at the start (low a_is) show increasing trends ($b_i > 0$), but the corresponding parameter pairs are still close to the line indicating convergence from below. Furthermore, it is noted that the points corresponding to Stockholm city (A) and the counties of Stockholm (B), Gotland (I) and Älvsborg (P) discussed in Fellman and Eriksson (2003) and presented in Figure 1, are located well within the cluster. The letter codes are the official codes for the counties according to *Statistics Sweden*. The point for Älvsborg represents a county with a low *a* value and a *b* value close to zero. These observations confirm the hypothesis that the TWRs for these four counties converge towards the low rate which has been observed for Älvsborg since the 1750s (Fellman & Eriksson, 2003).

In a recent paper, Ravallion (2003) studied the variation in income inequality for different countries. An apparent convergence in the Gini indices was observed and it was concluded that there was a reasonably strong negative correlation between the initial Gini index and the subsequent change in the index. Ravallion's correlation analysis of the inequality indices is closely related to the geometric interpretation presented here.

Diminishing Range for the Regional TWRs

Support for the hypothesis that the regional TWRs converge towards a common level can also be seen in Figure 3. The temporal variation of the maximum and minimum of the regional TWRs is presented. For the period 1781 to 1790, the TWR is known only for two regions (the city of Stockholm and the county of Gotland). Therefore, this period is ignored. A marked secular reduction in the range is observed. During the observation period, the range of the regional TWR decreases from over 10 per 1000 units between 1751 and 1780 to less than 5 per 1000 units between 1931 and 1960. In addition, the maximum and the minimum curves decrease simultaneously towards a low level. These results indicate a convergence of the

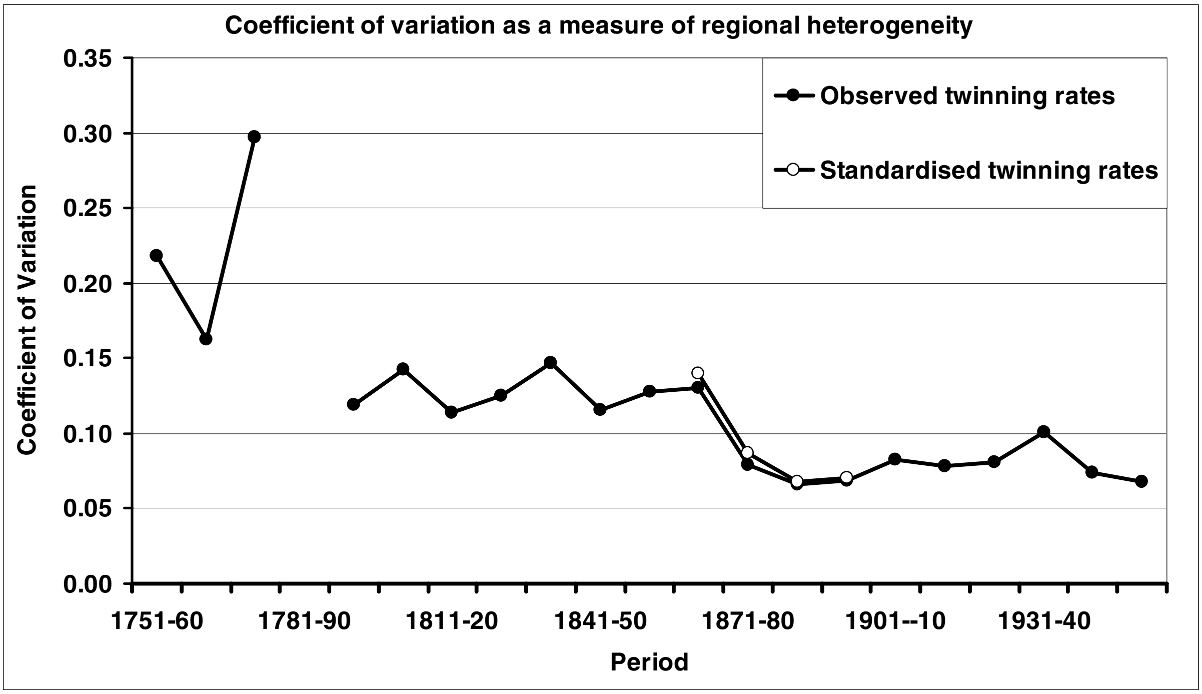

Figure 4

The coefficient of variation (CV) of the observed (1751–1960) and standardized (1861–1900) twinning rates.

The period 1781 to 1790 is ignored, as data are missing for all but two counties. A decreasing trend is observed which indicates that the regional variation in the TWR is continuously reduced. The coefficient of variation is not reduced after standardization, indicating that the regional differences cannot be explained by differences in maternal age alone.

regional TWRs towards a common low level. For the period 1861 to 1900, the mean maternal ages are known for the counties and, for comparison, the maximum and minimum of the standardized TWRs for this period have been included. The details of the standardization are discussed in Fellman and Eriksson (2003). The standardized values are slightly below the observed values, but the tendency remains. Consequently, standardization according to maternal age has no marked effect on the convergence towards a common low level. The effect of the temporal variation in parity is not estimable, but Gotland, characterized by the strongest decreasing trend in TWR, had a low CBR indicating a low parity already in the 1850s. Consequently one cannot expect a strong parity effect on the decrease in the TWR.

The Coefficient of Variation as a Measure of Heterogeneity

The CV, defined as the ratio between the standard deviation (*SD*) and the mean, is a suitable measure of the heterogeneity. It considers all the observations and is a standardized measure independent of the levels of the initial observations. The temporal variations in the CV for the observed TWRs are considered for the period 1751 to 1960, and for the standardized TWRs are considered for the period 1861 to 1900. The results are presented in Figure 4. The data are missing for all but two counties for the period 1781 to 1790, and this period is therefore ignored. For nine counties, data are also missing for the period 1861 to 1870. However, this period contains 16 counties and is included in the analysis. The corresponding point in Figure 4 does not differ markedly from the general trend. For the period 1861 to 1900, the CV can also be calculated for the TWR standardized for maternal age. In both the observed and the standardized TWR, a decreasing trend is seen which confirms that the regional variation of the TWR is continuously reduced. It is also observed that the CV is not reduced after standardization. This finding supports the statement that maternal age alone cannot explain the regional variation in the TWR. However, Figure 4 does not give any indication of the limiting level of the TWRs.

Discussion

The various attempts to test the convergence of the regional TWRs give consistent support for our hypothesis. In Fellman and Eriksson (2003) and Eriksson and Fellman (2004), the temporal variation in the rates of the multiple maternities for Sweden were analyzed. Only 50% to 60% of the TWR decline between the 1920s and the 1970s can be explained by the change in the age distribution or the parity of the mothers (Eriksson & Fellman 1973, 2004; Fellman & Eriksson 1990, 2003). It is suggested that the identified convergence may be caused by increased migration of citizens as a consequence of better communications leading to the break-up of isolates and to increased urbanization and industrialization. Whether these interpretations are supported is investigated below.

For the period 1849 to 1873 (before industrialization, urbanization, the demographic transition with birth control, and the progressive break-up of genetic isolates that began at the end of the 19th century), Berg (1880) noted that the counties on the east coast (Gävleborg, Uppsala, Stockholm, Södermanland, Östergötland, Gotland and Kalmar) and in central Sweden (Kopparberg, Västmanland and Örebro) formed a continuity with rather high twinning rates. Moreover, the frequency of triplet maternities in these counties was also relatively high (Berg 1880; Eriksson 1973). The TWRs were lowest (below 14 — between 12.6 and 13.9) in southwestern Sweden in the coherent counties of Älvsborg, Jönköping, Kronoberg, Blekinge, Halland, Gothenburg and Bohus, Värmland and Skaraborg. During this period, the northernmost counties, Norrbotten and Västerbotten, had low TWRs, 13.3. and 13.1 respectively. The southernmost counties, Malmöhus and Kristianstad, had intermediate TWRs, 14.9 and 14.2, respectively. For the period 1849 to 1873, the correlation between the TWR and the triplet rate (TRR) was .475. This is in agreement with the correlation between the TWR and the TRR obtained for the time series from Sweden (Fellman & Eriksson 2004).

The TWRs for the counties of Älvsborg and Gotland show quite different temporal trends for the period 1751 to 1960. In Älvsborg, the TWR starts at a low level which is rather constant for the whole period, whereas on Gotland, the TWR starts at a high level, about twice as high as in Älvsborg, and shows a continuously decreasing trend. However, there are considerable differences in the population structure between Älvsborg and Gotland. The former has, for a long period, been a more or less randomly interbreeded (panmixed) and relatively densely populated region with strong emigration starting in the last part of the 19th century. Gotland had been a rather isolated island up until recent times. The density of the population for Älvsborg started at 13 per km^2 in 1810. After that the density increased rather monotonically to almost 34 per km^2 by 1967. For Gotland, the population density had increased from 7.8 per km^2 in 1751, 10.4 in 1810, and 17.2 in 1869 to 17.3 per km^2 in 1960. In 1810, the density in Älvsborg was slightly higher than the density on Gotland, but in 1967 the density was twice as high in Älvsborg as Gotland.

Hemon et al. (1981) compared the secular changes in dizygotic TWRs in different parts of France between 1901 and 1968 to changes in the factors affecting isolation. They concluded, however, that the differential fecundability rather than the genetic hypothesis, was a more likely explanation of the geographical and temporal differences in French TWRs between 1901 and 1968. No convincing support for Hemon's findings in France has been found in recent studies (Eriksson & Fellman 2004; Fellman & Eriksson 2003). In 1923, the density of the population in France was as high as 72 inhabitants per km^2 and by 1950, it had increased to 76. The corresponding figures for Sweden as a whole were only 13 and 16, respectively. Particularly in the past, Sweden has shown a markedly lower population density and consequently a more marked tendency towards a rural and isolated population with higher rates of endogamy. Beckman (1980) noted that in northern Sweden, the endogamy rate and inbreeding level were high and may have reached a maximum around 1930.

The association between the density of population, considered as a measure of isolation, and the TWR based on regional data from all the counties in Sweden has been studied. The density of the population for a specific year has been paired with the TWRs for the following 10-year period. According to the initial hypothesis, there should be a negative correlation between these variables. The correlation coefficient between the density of population in 1930 and the TWR for the period 1931 to 1940 is negative (–.134). Although this period shows the strongest negative correlation, the obtained correlation coefficient is insignificant.

According to Sundbärg (1907), Sweden around 1850 could be divided demographically into three main regions. According to Lindqvist (1947), there was also a 'language border' between eastern, central and western (south-western) Sweden. Up until the 1880s with the start of the demographic transition in Sweden, the marital fertility was highest in northern Sweden and lowest in eastern Sweden. It is of interest to note that, in spite of the high CBR, the TWR was low (13.2) in the two northernmost counties of Sweden. In this area, the Saami (Lapps) and the Swedes have been assimilated, resulting in a strong gene flow from the Saami to the Swedes (causing, e.g., stronger pigmentation, shorter stature and a relatively high frequency of the 'Lappish' genes ABO*A2, GC*1F, 6PGD*C). The Saami are a European autochthonous population with a unique genetic composition (Beckman, 1959, 1996; Eriksson, 1988). The Saami, like the Basques, are supposedly ancient populations in Europe. Both have had some of the lowest TWRs among Europeans, only 7 to 9 per 1000, that is, only about half of what other Fennoscandian populations have had (Eriksson, 1973). Such a low TWR cannot be attributed to low maternal age. In the second half of the 19th century, the maternal mean age in Norrbotten was quite similar to the maternal mean age for the whole of Sweden.

The serological borderline between western and eastern gene markers is rather sharp, going in the south–north direction through the Baltic Sea (Mourant et al., 1976). The Finns and Estonians in the east are Finno–Ugrians speaking a non-Indo-European language. They have relatively high frequencies of eastern genes, that is ABO*B and MN*M, and a low frequency of the western Rhesus negativity gene cde. It is of interest to note that the Finns and Estonians have high TWRs in spite of the fact that it has been estimated that 25% to 30% of the Finnish ancestry is of eastern, non-European origin (Nevanlinna, 1972). As a whole nation, Finland had in the 1950s the highest noted TWR in the world at that time, 15.5 per 1000. The TWR was highest in the most isolated counties of Finland, that is, the counties of Mikkeli and Kuopio. The lowest was observed in the county of Nyland (Uusimaa), the melting pot of different subpopulations of Finland where the capital Helsinki is located and which has the highest industrialization and the highest density of population. About 100 years earlier, the TWR in Nyland was the highest on the Finnish mainland (Eriksson et al., 1976).

It is of particular interest that, in regions where eastern (Finno–Ugric) and western (Scandinavian) genes meet, as in the archipelagos of south-western Finland (Åboland and Åland), on Gotland, in the northern Baltic states (Estonia and Latvia) and in eastern Sweden, the rates of multiple maternities are considerably higher than in the surrounding populations. In the 18th and 19th centuries, some insular isolates in the Baltic Sea (Åboland, Åland and Gotland) had TWRs of around 20 to 25, that is, about 50% higher than in the surrounding mainland populations, which have had TWRs among the highest noted in Europe (Eriksson 1964, 1973; Fellman & Eriksson, 2003).

Tchouriloff (1877) already noted that populations with high stature were more likely to produce twins than populations with low stature. MacArthur (1942) observed that multiple maternities reached their highest frequency in populations where the average height was the greatest, as in the Nordic populations and in those states in the United States of America where the population was tall or the proportion of Scandinavian immigrants was high. MacArthur suggested these links to be a large anterior pituitary gland producing much growth and gonadotrophic hormones, a large body and frequent polyovulation. Analyses of data from Ibadan (Nigeria) and Aberdeen (1969 to 1983) showed that a marked gradient of twinning with maternal height persisted after standardization for age and parity (MacGillivray et al., 1988).

The Nordic populations are among the tallest in the world and they have or have had as whole nations some of the highest rates of multiple maternities ever recorded. The island populations on Åland and Gotland and in the Åboland archipelago are among those with the highest average statures in the world (Arho, 1934; Kajanoja, 1971; Lundborg & Linders, 1926), and have also had the highest TWRs so far reported among white populations (Eriksson, 1973). According to anthropometrical studies, the 'purest' Nordic race (tall stature, mainly dolichocephalic individuals, high frequency of blue eyes and blond hair) is in central parts of Sweden (mainly eastern Sweden according to Lundman, 1946; Sundbärg, 1907). With the exception of the city of Stockholm, the TWR in the 19th century was high (about 16) in this area, particularly in the coastal districts (about 16 to 20).

If the average stature of men (recruits) born around 1900 (Lundborg & Linders, 1926) is compared with the TWRs in the different counties of Sweden for the same time (1901 to 1910), no clear correlation is observed. The correlation between TWR and the mean stature is –.014. If the proportion of males over 180 cm is considered as an alternative measure of the stature of the population, the correlation is –.092. Both correlation coefficients are statistically nonsignificant. In eastern Sweden with the counties of Stockholm and Uppland and particularly on Gotland, the populations have a tall average stature and a high TWR, particularly before the 20th century. In the northernmost county of Sweden, Norrbotten, a relatively low TWR and a low average stature can be noted. Stature and TWR both diminish as one goes northwards in Norway, Sweden and Finland (Eriksson, 1973; Torgersen, 1951). This may at least partly be a consequence of gene flow to the Nordic majority populations from the Saami, who are among the shortest populations in Europe and have a TWR of only around half that of other Nordic peoples (Eriksson, 1973).

The marked secular trend in height has been attributed to better nutrition and generally improved environmental conditions. The increasing trend in adult stature may also be genetic in origin and caused by the progressive break-up of isolates. Urbanization with an increasing degree of exogamy is probably an additional important cause of the falling TWR and the increasing adult height (*hybrid vigor seu heterosis*). Although height has increased by about 10 cm during the last century (Kajanoja, 1971), the TWRs standardized for maternal age have shown a strong decrease both in Sweden and Finland during the 20th century and in particular, in some isolated populations with past high TWRs (Eriksson, 1973, Eriksson & Fellman, 1973, Fellman & Eriksson, 1987, 2003). In conclusion, in some Nordic populations there has been a correlation between height and TWR. However, the secular changes of the TWR and height are going in reverse directions. Up until the 1970s, the TWR decreased strongly, whereas stature has increased considerably over the last 100 years. These processes may have been enhanced through urbanization and the breaking up of isolates (Eriksson & Fellman, 1973). This inverse association is caused by external factors and, therefore, comparisons between stature and the TWR cannot be based on temporal data. Only studies based on cross-sectional studies are reliable.

The central region of Sweden is characterized anthropometrically in the south by the subpopulation ('stock') of the Scandinavian inland, which is dolichocephalic, fair and relatively short with broad faces and the nasal bridge profile frequently concave (Lundman, 1946). In the northern part of central Sweden (mainly in the counties of Kopparberg and Gävleborg), there is an overlapping area with the strongest influence of the 'Nordic race' that Beckman (1959) characterizes as 'the serologically indeterminable area'. There is also archaeological, historical, demographic and serological evidence for differences between the regions with low TWRs (the counties of Älvsborg, Jönköping, Skaraborg, Halland, Göteborg and Bohus) and the highest TWRs (the counties of Stockholm, Gotland, Gävleborg, Västmanland and Uppsala). Archaeological evidence supports the view that around 3000 BC, south-western Sweden received a considerable immigration, the megalithic people. The megalithic culture occupied mainly south-west Sweden with a central area in Västergötland, that is, the region in and around the county of Älvsborg with the lowest TWR and where Beckman (1959) noted the highest A_2-blood group frequencies: about 9% in northern Västergötland (i.e., the northern parts of the counties Älvsborg and Skaraborg). High frequencies of D-negative individuals were also found in this area.

Flodström (1915, 1918) claimed that the racial and demographic differences between south-western and south-eastern Sweden went back to Stone Age conditions. The serological results obtained by Beckman (1959) showed that south-west Sweden is characterized by higher O-gene frequencies and lower B-gene frequencies than south-east Sweden. These data suggest that the people with the hunting culture of south-east Sweden were of eastern origin, possibly from the Baltic States. There was an additional eastern influence later: immigration of the eastern group of Boat-axe people. Värmland, Kopparberg, Västmanland and Södermanland are mainly distinguished by low frequencies of A_2. Central Sweden thus contains a relatively large continuous area characterized by low A_2-frequencies. This area is also characterized by relatively high TWR.

Neither of these differences in the TWR seem to be explainable by differences in socioeconomic circumstances, improvements in antenatal care, and so forth, that may be expected to lead to a lower risk of spontaneous abortion and thus higher TWR. Studies on spontaneous abortions and ultrasound diagnoses indicate that many twins are lost in early gestation (Boklage, 1995; Landy & Keith, 1998). The causes of this are not known in detail.

If the temporal changes in the density of the population and TWR are considered, additional support is attained for the initial hypothesis. According to the hypothesis, a marked increase in the density of the population should be associated with a simultaneous decrease in the TWR. If the increased regional density is compared from 1810 to 1950, and the decreased regional TWR from 1811–1820 to 1951–1960, a negative, statistically significant correlation (–.633) is obtained.

Omran (1971) proposed three stages of epidemiological transition, and Olshansky and Ault (1986) later proposed a fourth. They proposed that the first stage, *the age of pestilence and famine*, ended around 1875. Within this framework, Fellman and Eriksson (2002) have studied the seasonality of mortality, in Iceland and Finland mainly. Up until 1875 one can observe marked troughs in the TWR in Sweden and especially in Älvsborg (Fellman & Eriksson, 2003). Could these observations be explained by poor conditions with long-lasting chronic malnutrition in the population? The CBR for Sweden during the period 1750 to 1870 was very high (around 33), but also very stable. During the period 1751 to 1800, the population of Sweden increased by 32%. However, during the equally long period between 1816 and 1865 and in spite of cholera epidemics in the 1830s and 1850s and a violent outbreak of dysentery in 1857, the increase was no less than 67%. The main reason for this was a decrease in the annual death rate with normal living conditions — from around 27 per 1000 inhabitants in the 1750s and during the first half of the 1810s to values below 20 in the first half of the 1860s. Causes of these socioeconomic improvements that may be mentioned are the greater agricultural production and thereby greater supply of food in the country, the growing diversity of economic life, improved social hygiene, and the greater ability of medical science to combat destructive plagues. Particularly notable with regard to medical science advances were the effects of the smallpox (variola) vaccination, which started in 1804 in Sweden and became compulsory for all children in 1816. In 1779, some 60% of all deaths in children under 10 years of age were caused by smallpox alone (Hofsten & Lundström, 1976). Over the period 1800 to 1850, infant mortality rates declined from 200 to around 150 per 1000. This progress indicates the start of the second stage of epidemiological transition around 1875, *the age of receding pandemics* (Fellman & Eriksson, 2002; Olshansky & Ault, 1986; Omran, 1971). In spite of this, the TWR decreased.

The observed differences in the TWR do not seem to be explained by differences in socioeconomic circumstances, improvements in antenatal care, and so forth. These are factors which might be expected to lead to a lower risk of spontaneous abortion and thus to a higher TWR. If TWRs standardized for maternal age and parity are considered, there are still higher TWRs in the countryside than in urban areas. Our hypothesis is that this could at least partly be attributed to the fact that women in rural areas have better physical capacity to manage a gestation with multiple embryos or fetuses than women in urban and industrialized areas where work is more sedentary.

Acknowledgments

This work was supported by grants from the 'Liv och Hälsa' Foundation and from The Finnish Society of Sciences and Letters. This paper is based on a poster presented at the 11th International

Congress on Twin Studies, Odense, Denmark, July 2004. We are very grateful to the Statistics Sweden for the cooperation in sending us information on the details of twin maternities.

References

Arho, A. O. (1934). *Anthropologische Untersuchungen in den Landschaften Åland und Varsinais-Suomi*. [Anthropological studies on the counties of Åland and Proper Finland.] Suomen Tiedeakatemian Toim. *Sarja A, 40,* 1–216.

Beckman, L. (1959). A contribution to the physical anthropology and population genetics of Sweden: Variations of the ABO, Rh, MN and P blood groups. *Hereditas, 45*, 1–189.

Beckman, L. (1980). Time trends in endogamy rates in northern Sweden. In A. W. Eriksson, H. Forsius, H. R. Nevanlinna, P. L. Workman, & R. K. Norio (Eds.), *Population structure and genetic disorders* (pp. 73–80). London: Academic Press.

Beckman, L. (1996). *Samerna: En genetiskt unik befolkning*. [Saami: A genetically unique population.] Umeå, Sweden: University of Umeå.

Berg, F. T. (1880). Om flerfostriga barnsbörder. [On multiple maternities]. *Hygiea (Stockholm), 42,* 331–342.

Boklage, C. E. (1995). The frequency and survival probability of natural twin conceptions. In L. G. Kieth, E. Papiernik, D. M. Keith, & B. Luke (Eds.), *Monographs on twins: Multiple pregnancy, epidemiology, gestation and perinatal outcome* (pp. 41–50). New York: Parathen.

Eriksson, A. W. (1962). Variations in the human twinning rate. *Acta Genetica (Basel), 12*, 242–250.

Eriksson, A. W. (1964). Pituitary gonadotrophin and dizygotic twinning. *Lancet, 2,* 1298–1299.

Eriksson, A. W. (1973). Human twinning in and around the Åland Islands. *Commentationes Biologicae, 64*, 1–154.

Eriksson, A. W. (1988). Anthropology and health in Lapps. *Collegium Antropologicum, 12*, 197–235.

Eriksson, A. W., & Fellman, J. (1973). Differences in the twinning trends between Finns and Swedes. *American Journal of Human Genetics, 25,* 141–151.

Eriksson, A. W., & Fellman, J. (2004). Demographic analysis of the variation in the rates of multiple maternities in Sweden since 1751. *Human Biology, 76,* 343–359.

Eriksson, A. W., Eskola, M. R., & Fellman, J. O. (1976). Retrospective studies on the twinning rate in Scandinavia. *Acta Geneticae Medicae et Gemellologiae, 25,* 29–35.

Eriksson, A. W., Fellman, J., & Lundström, H. (1996). Temporal variation in the rates of multiple maternities in Sweden, 1750–1995. *Archives of Perinatal Medicine, 2,* 11–15.

Fellman, J., & Eriksson, A. W. (1987). Statistical models for the twinning rate. *Acta Geneticae Medicae et Gemellologiae, 36*, 297–312.

Fellman, J. O., & Eriksson, A. W. (1990). Standardization of the twinning rate. *Human Biology, 62,* 803–816.

Fellman, J. O., & Eriksson, A. W. (1993). Biometric analysis of multiple maternities in Finland, 1881–1990, and Sweden since 1750. *Human Biology, 65*, 463–479.

Fellman, J., & Eriksson, A. W. (2002). Regional, temporal and seasonal variations in births and deaths: The effects of famines. *Social Biology, 48*, 86–104.

Fellman, J., & Eriksson, A. W. (2003). Temporal differences in regional twinning rates in Sweden after 1750. *Twin Research, 6*, 183–191.

Fellman, J., & Eriksson, A. W. (2004). Association between the rates of multiple maternities. *Twin Research, 7,* 387–397.

Flodström, I. (1915). Till frågan om rasskillnader inom Sverige. [On race differences in Sweden]. *Ymer , 25,* 212–266.

Flodström, I. (1918). *Sveriges folk*. [The people of Sweden]. Uppsala, Sweden.

Hemon, D., Berger, C., & Lazar, P. (1981). Some observations concerning the decline of dizygotic twinning rate in France between 1901 and 1968. In L. Gedda, P. Parisi, & W. E. Nance (Eds.), *Twin research 3: Part A. Twin biology and multiple pregnancy*. New York: Alan R. Liss.

Hofsten, E., & Lundström, H. (1976). *Swedish population history: Main trends from 1750 to 1970* (p. 186). Stockholm: Statistiska Centralbyrån.

Kajanoja, P. (1971) A study in the morphology of the Finns and its relation to the settlement of Finland. *Annales Academiae Scientiarum Fennicae Series AV Medica, 146,* 61.

Landy, H. J., & Keith, L. G. (1998). The vanishing twin: A review. *Human Reproduction Update, 4,* 177–183.

Lindqvist, N. (1947). Sydväst-Sverige i språkgeografisk belysning. [Language-geographic aspects of southwestern Sweden.] *Skrifter utgivna genom Landsmålsarkivet i Lund, 2,* 1–76 + maps.

Lundborg, H., & Linders, F. (1926). *The racial characters of the Swedish nation* (pp. 1–242). Uppsala, Sweden: Almqvist & Wiksell.

Lundman, B. (1946). *Raser och folkstockar i Baltoskandia*. [Races and subpopulations in Baltoscandia.] Uppsala, Sweden: Author.

MacArthur, J. W. (1942). Relations of body size to litter size and to the incidence of fraternal twins. *Journal of Heredity, 33,* 87–91.

MacGillivray, I., Samphier, M., & Little, J. (1988). Factors affecting twinning. In I. MacGillivray, D. M. Campell, & B. Thompson (Eds.), *Twinning and twins* (pp. 67–97). Chichester, UK: John Wiley.

Mourant, A. E., Kopec, A. C., & Domaniewska-Sobczak, K. (1976). *The distribution of the human blood groups and other polymorphisms*. Oxford, UK: Oxford University Press.

Nevanlinna, H. (1972). The Finnish population structure. A genetic and genealogical study. *Hereditas, 71,* 195–236.

Olshansky, S. J., & Ault, A. B. (1986). The fourth stage of the epidemiologic transition: The age of delayed degenerative diseases. *The Milbank Quarterly, 64,* 355–391.

Omran, A. R. (1971). The epidemiologic transition: A theory of the epidemiology of population change. *The Milbank Quarterly, 49*, 509–538.

Ravallion, M. (2003). Inequality convergence. *Economics Letters*, *80*, 351–356.

Sundbärg, G. (1907). *Bevölkerungsstatistik Schwedens 1750–1900: Einige Hauptresultate*. [Population statistics of Sweden, 1750–1900: Some main results (p.70).] Stockholm: P. A. Norstedt & Söner.

Tchouriloff, M. M. (1877). Sur la statistique de naissances gémellaires et leur rapport avec la taille. *Bulletin de la Societe de Anthropologie de Paris, 12,* 440–446.

Torgersen, J. (1951). Hereditary and environmental factors in twinning. *American Journal of Physical Anthropology, 9*, 441–454.