Variations in the Maternal Age Effect on Twinning Rates: The Nordic Experience

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Maternal age is the most important nongenetic factor influencing the twinning rate. Every study of the effect of other factors should consider the age distribution of the mothers. Besides standardizing techniques, the age-specific twinning rates are analyzed. Especially, the slope of the regression line is considered when the age-specific twinning rates are regressed against maternal age. How well the maximum age-specific twinning rate measures the variation in the maternal age effect is also studied. The two measures, which are strongly correlated, give consistent results. The proposed methods are applied to data from Finland (1866 to 2003) and Denmark (1855 to 2000). Comparisons with Sweden (1861 to 2000) and Norway (1855 to 2003) are also made. In general, marked decreasing trends in the twinning rates are discernible up to the middle of the 20th century. In Sweden the decline starts around the beginning of the 20th century and is stronger than in Denmark and Norway. The decrease in the twinning rate for Finland, which up to World War II was rather isolated, sets in around the middle of the 20th century and is not as strong as in other Nordic countries. After the minima around 1980, strong increasing trends are noted. This is mainly caused by the influence of the artificial reproduction technologies and particularly the use of fertility-enhancing drugs on the commonly noted dependence between maternal age and the twinning rate. Similar temporal trends can be observed in the slopes of the regression line and in the maximum age-specific twinning rates.

The most important nongenetic factor influencing the twinning rate (TWR) is maternal age and, consequently, every study on the effect of other factors should consider the age distributions of the mothers. There are two main standardization techniques, the direct and the indirect. The goal of both methods is to estimate the TWR of the target population if it has the same age distribution as the reference population. The direct method requires very informative twinning data for the target population. Particularly, the age-specific TWRs of the target population must be known. Sometimes this information is not available or the target population is so small that the age-specific TWRs are subject to large random fluctuations, resulting in inaccurate estimates. These shortcomings are eliminated by the indirect standardization method, which requires only that the age-specific TWRs are available for the reference population, and for the target population, only the age distribution of the general maternities and the total TWR need be known. These methods are discussed in detail by Hill (1971) and have the advantage that nothing is assumed about the how the age-specific rates depend on the maternal age. In Fellman and Eriksson (1990, 2002), new techniques for standardization of the TWR according to maternal age were introduced. These techniques are specifically for standardization of the TWRs, as they assume that the age-specific TWRs are linearly dependent on the maternal age for ages below 40 years (cf. Figures 2 and 6). Consequently, one can build linear regression models for the age-specific TWRs and apply these models. The advantage of these techniques is that they require only the total TWR and the mean maternal age of the target population.

However, many studies have shown that, even after standardization, there still remain significant differences in the TWRs. The secular trends in the TWRs have been analyzed in several studies (e.g., Eriksson, 1962, 1964, 1973; Eriksson et al., 1995; Fellman & Eriksson, 1993, 2003, 2004, 2005). In this paper, alternative methods to the standardizing techniques are studied in order to identify variations in the effect of maternal age. The age-specific TWRs are analyzed and, especially, the slope of the regression line considered when the age-specific TWRs are regressed against maternal age. We also study how well the maximum age-specific TWR can measure the variation in the maternal age effect. The proposed methods are applied to data from Finland (1866 to 2003) and Denmark (1855 to 2000). Comparisons with Sweden (1861 to 2000) and Norway (1855 to 2003) are also made.

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Although the variations in the TWRs are mainly caused by the variation in the dizygotic (DZ) TWRs, a differentiation of the twin maternities into monozygotic (MZ) and DZ twin maternities is not possible. In our materials the sex compositions of the twin maternities are not available.

Materials

Finland, 1866 to 2003

The Finnish data are based on official registers. The data are mainly given for 10-year periods and grouped according to maternal age in 5-year age groups.

Denmark, 1855 to 2000

The time series of the TWRs for Denmark have different compositions and were collected from different sources. For the period 1855 to 1870, the data contain information on the month of birth, marital status of the mother, and number of single maternities and twin and triplet sets. Mean maternal age is not available and consequently, standardization of the TWR for this period is not possible. During the period 1896 to 1930, the data were published in 5-year periods (which we pooled to 10-year periods) and grouped according to maternal age in 5-year age groups, and marital status of the mother (Eriksson & Fellman, 1967). However, for this period, about 3% of the data are without known maternal age. The most detailed data are available for the period 1931 to 1967. The initial data were classified according to year of birth, maternal age in years, parity (birth order) and legitimacy. These data were grouped in 10-year periods and 5-year age groups. For the periods after 1896, data for which the maternal age was missing were ignored. For the years 1968 and 1969, data were completely missing. For the years 1971 to 1980, the data were obtained from official records and were compiled in 10-year periods and 5-year age groups. For the period 1981 to 2000, we have no access to the total number of maternities but only to the number of live births. Consequently for this period, the TWRs are calculated in relation to the number of live births and have slight negative biases. For the years 1974 to 1980, a discrepancy between the number of maternities and live births was identified: it varied by around 0.4%. Consequently, the biases in the TWRs can be estimated to be of the order 0.05 to 0.07 per 1000. For the period 1981 to 2000, only the total TWR and the mean maternal age are known. In spite of this, the TWR can be standardized if one applies the indirect method proposed by Fellman and Eriksson (1990).

Sweden, 1861 to 2000

These data are presented in detail and analyzed in earlier papers (Eriksson & Fellman, 2004; Fellman & Eriksson, 2003, 2005).

Norway, 1855 to 2003

These data were collected from official registers and have not been analyzed by the authors. They contain information about the total yearly number of maternities and twin maternities.

Methods

The temporal variation of the observed and standardized TWRs is studied. The standardization methods applied are the direct and indirect methods presented in Hill (1971) and the alternatives proposed by Fellman and Eriksson (1990). Alternative methods to the standardizations are also considered. These are based on the age-specific TWRs, that is, the TWRs in the different maternal age groups. One can assume that if the regional and temporal differences in the age-specific TWRs for a given age group are compared, the maternal age effect is eliminated. If the age-specific TWRs show temporal or regional variations, then one can assume that factors other than maternal age are influencing the TWR. One of the methods is based on the fact that the TWR depends rather linearly on the maternal age up to the maternal age group 35 to 39 years. Hence, the age-specific rates can be regressed against maternal age and the maternal age effect measured by the slope, here called the age regression coefficient (ARC). In fact, these regression models are used in our standardization methods (Fellman & Eriksson, 1990, 2002). The ARC, as such, gives a good measure of the variation in the effect of maternal age, because it is the average increase in the age-specific TWRs when maternal age increases by one year. A rule of thumb is that the total TWR approximately equals the value of the regression model for the mean maternal age (Fellman & Eriksson, 1990). The other method is the maximal age-specific TWR (MATR), which is, in general, the TWR for mothers in the age group 35 to 39 years. For the period 1991 to 2000, the maximal age-specific TWR is noted for the age group over 45 years. However, for this age group the maternities are so few that in this case the age-specific TWR for the age group 35 to 39 years is also used. Furthermore, this outlier for the age group over 45 years is ignored in Figure 3.

An argument for both these new attempts is that the analysis of variation in maternal age effect is more easily performed if only one measure is considered at a time. A simultaneous study of all the age-specific TWRs yields less distinct results. However, one has to be aware of the fact that the estimated ARC has a standard error, but the same can be said of the estimated age-specific TWRs and, in fact, also of the observed and standardized total TWRs.

Results

Finland, 1866 to 2003

In Figure 1 the temporal variation of the TWRs observed and standardized for maternal age in Finland, 1866 to 2003, is presented. The greater part of these data was already analyzed by Fellman and Eriksson (1993). As a reference population, Finland from 1881 to 1890 was used, that is, the first decade

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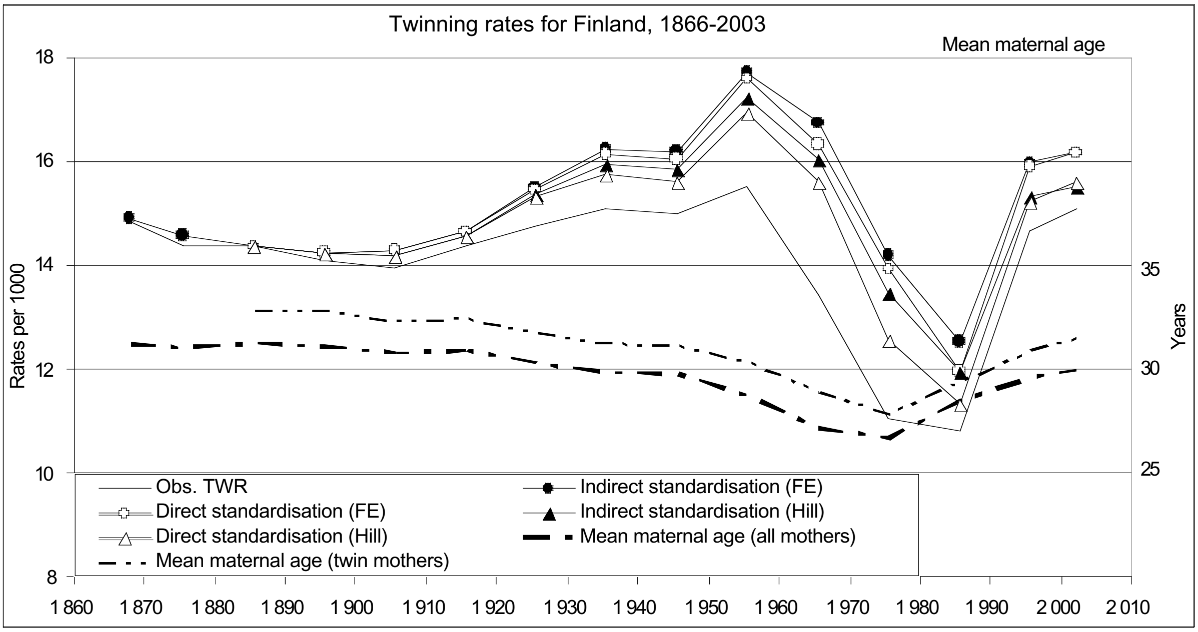

Figure 1

The mean maternal age and the twinning rates (TWRs) observed and standardized for maternal age in Finland, 1866 to 2000.

The standardizations are the direct and indirect methods presented in Hill (1971) and the alternatives (FE) proposed by Fellman and Eriksson (1990). As a reference population Finland 1881–1890 was used, that is, the first period with known age distribution of mothers of twins. Accentuated downward trends during the decades 1961–1990 and an increase for the last periods 1991–2000 and 2001–2003 in the TWRs can be observed. The mean maternal ages for all mothers and for mothers of twins are included. For details, see the text.

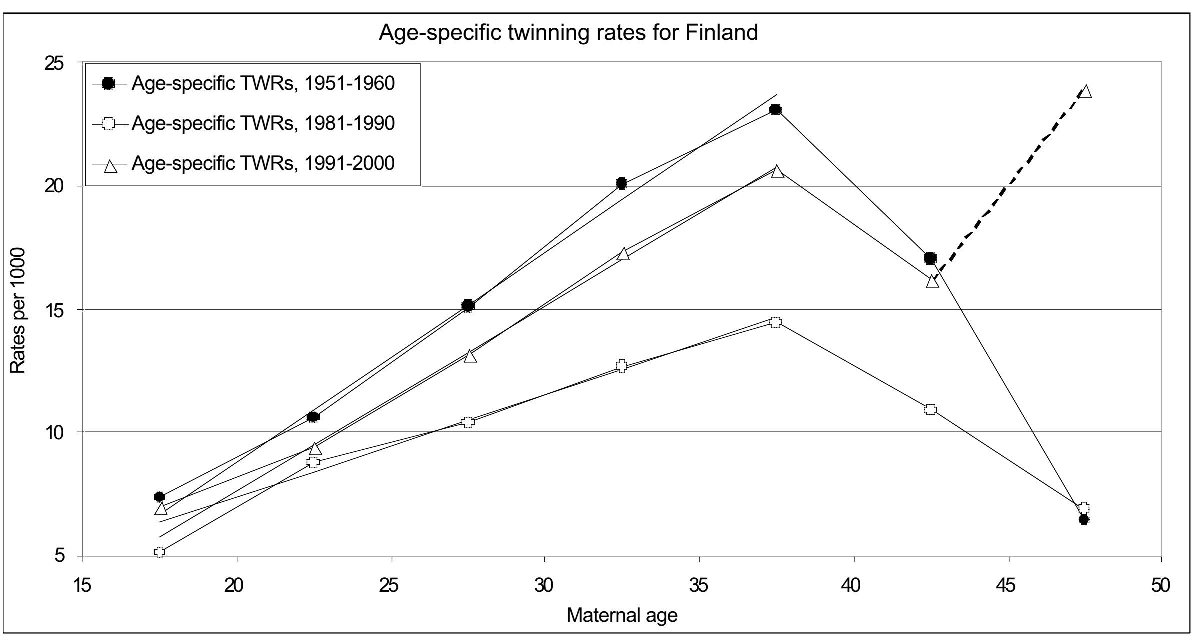

Figure 2

The age-specific twinning rates (TWRs) for Finland for the periods 1951–1960, 1981–1990 and 1991–2000.

The periods are 1951–1960, in which the total TWR attains its highest value (15.5 per 1000), 1981–1990, for which it obtains it minimum (10.8 per 1000) and 1991–2000, for which a new increase in the total TWR has resulted in a twinning rate of 14.7 per 1000. The regression lines (the slopes) are estimated with weighted least squares (Fellman & Eriksson, 1990).

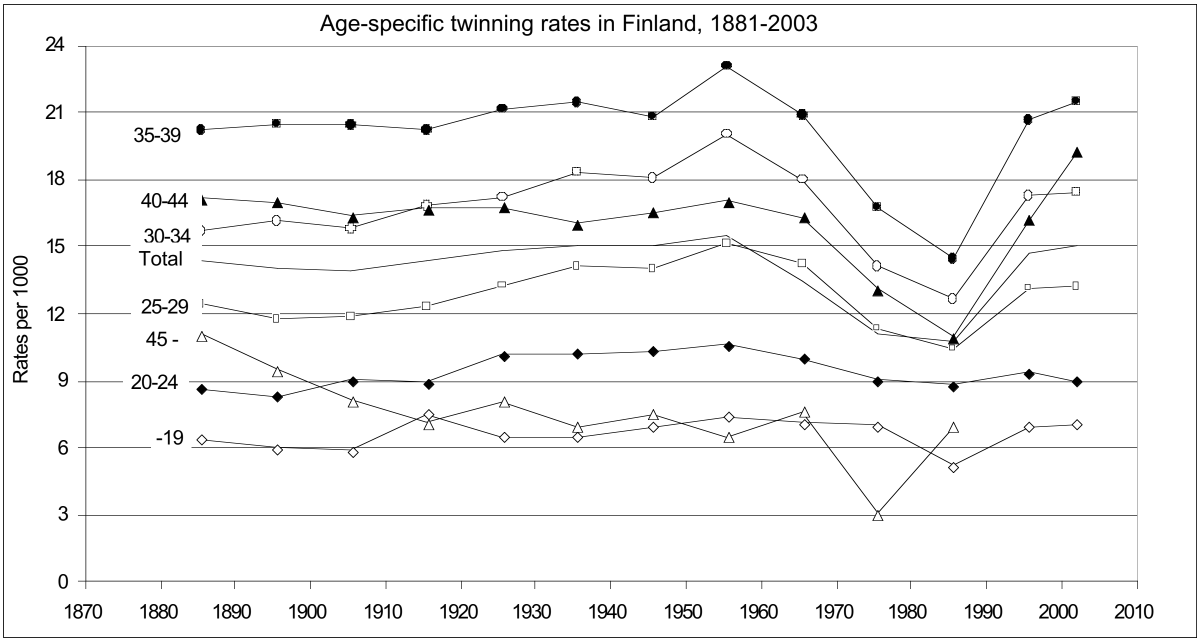

Figure 3

Age-specific and total twinning rates (TWRs) in Finland, 1881–2003.

The figure shows that the strongest fluctuations can be observed for the age groups between 30 and 44 years, that is the ages with the highest age-specific TWRs.

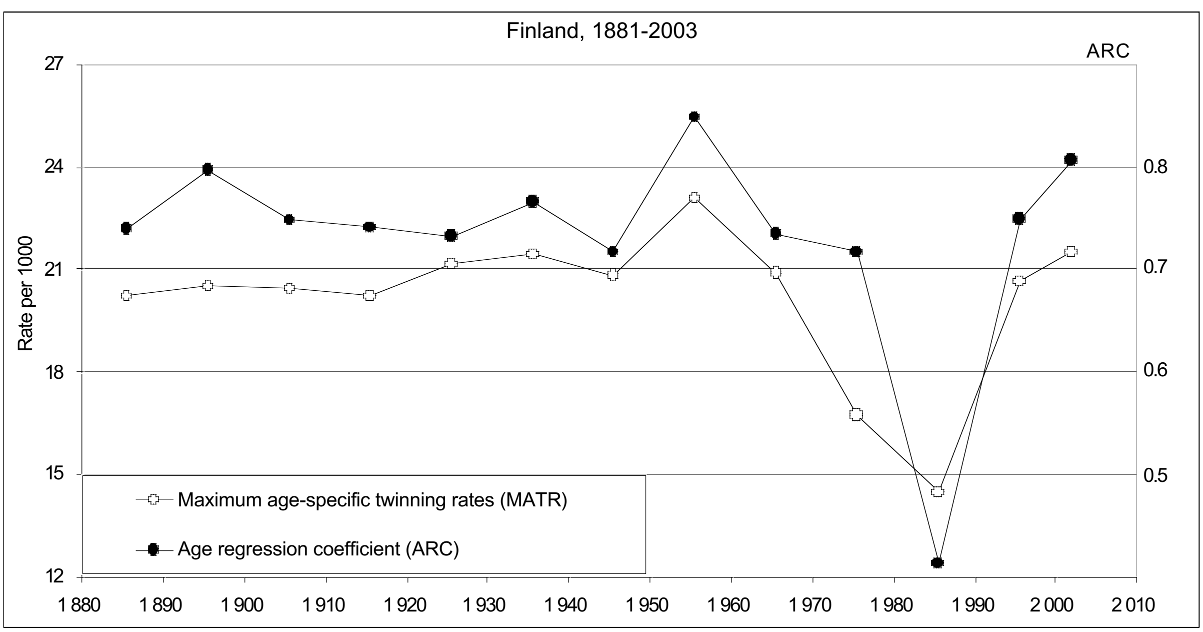

Figure 4

The maximum age-specific twinning rate (MATR) and the age regression coefficient (ARC) in Finland, 1881–2003.

The temporal variation is quite similar, showing an accentuated decreasing trend from the 1950s to the 1980s and a recovery for the period 1991–2003. Compare this variation with the variation in the total TWR (Figure 1).

with known age distributions of both total and twin maternities. Accentuated downward trends during the decades for the period 1961 to 1990 can be observed. In Figure 1, the mean maternal ages for all mothers and for mothers of twins are also included. For almost the whole period, the mean maternal age of mothers of twins is about 1.5 years more than the mean maternal age of all mothers. For the period 1981 to 1990, this difference is less than 1 year, for the period 1991 to 2000 it is 1.3 years, and for the period 2001 to 2003, it is 1.5 years. It is notable that for some periods there are marked differences in the temporal trends for the TWR and for mean maternal age. Particularly, one can observe that during the period 1866 to 1960, the mean maternal age was decreased monotonously, but, in spite of this fact and decreasing mean parity, the TWR increased. After 1990, a marked increase in the TWR can be noted but it cannot be explained by the slight increase in mean maternal age. The main cause of the recovery of the TWR seems to be the influence of artificial reproduction technologies (ART) and particularly the use of fertility-enhancing drugs on the commonly noted dependence between maternal age and the TWR. The increased use of ART may also be one cause of the increased difference, observed after 1990, between the mean maternal age of mothers of twins and of all mothers. Twin maternities resulting from ART are mainly observed among mothers of greater ages.

In Figure 2, it is observed that the age-specific TWRs depend strongly on the magnitude of the ARC. The selected periods are 1951 to 1960, in which the total TWR attains its highest value (15.5 per 1000, which is the highest noted for a whole nation during this period), 1981 to 1990, for which it obtains its minimum (10.8 per 1000), and 1991 to 2000, for which a new increase in the total TWR resulted in a twinning rate of 14.7 per 1000. The figure shows the well-known fact that in every population, the age-specific TWRs start from a very low and approximately constant level (about 5 to 7 per 1000) for young mothers, and subsequently increase rather linearly. The explanation for this is that, in the youngest age group of mothers, twinning is mainly MZ and the MZ TWR (around 4 per 1000) is fairly constant in different populations (Bressers et al., 1987). The linear increase is caused by the increase in DZ age-specific TWRs which show both temporal and regional variations. The slope for the period 1951 to 1960 is 0.849, with the standard error (*SE*) of 0.045. Hence the coefficient of variation (CV) is 5.3%. The corresponding figures for the period 1981 to 1990 are 0.413, 0.036 and 8.7, and for the period 1991 to 2000, 0.750, 0.031 and 4.1. In comparison to these figures, the CVs for the maximum age-specific TWR during the first period is 2.0%, for the second period 3.7%, and for the last period 2.5%. From this point of view, the statistical precision of the alternative attempts are comparable.

Figure 3 shows that the temporal trends in the age-specific TWRs in Finland are parallel to the total TWR. It should be noted that the strongest fluctuations in the age-specific TWRs can be observed for age groups between 30 and 44 years, the ages with the highest age-specific TWRs. This finding is in good agreement with Figure 2, because the cumulative effect of the ARC is more marked for higher ages.

The MATR and ARC in Finland, 1881 to 2003, are presented in Figure 4. The temporal variations are quite similar, showing accentuated decreasing trends from the 1950s to the 1980s and recoveries for the period 1991 to 2003. This variation should be compared with the variation in the total TWR (Figure 1). Figure 4 indicates that both ARC and MATR are valuable measures of the variable effect of maternal age on the TWR. In fact, the correlation coefficient between the ARC and the MATR is .868. After elimination of time, the partial correlation coefficient is still .845. Both correlation coefficients are statistically significant. The observed strong correlation indicates that the proposed measures are equally good alternatives.

Denmark, 1855 to 2000

The TWR for Denmark is fairly constant for the period 1855 to 1895, but then shows an increasing trend between 1896 and 1930 followed by a decreasing trend until a minimum in the period 1971 to 1980 and subsequently another increasing trend. Figure 5 shows that standardization according to maternal age can only explain these trends to a small extent. The direct and indirect standardizations yield almost identical results. However, for the period 1981 to 2000, only the Fellman–Eriksson indirect standardization is useable as only the mean maternal age, not the maternal age distribution, is available. It is notable that during the period 1901 to 1930, the mean maternal age and the TWR show quite different trends: the mean maternal age decreases slowly and the TWR increases rapidly. For the whole period 1901 to 1980, with known age distribution among the mothers of twins, the mean maternal age for mothers of twins is almost constantly 1.5 years higher than for all mothers. This difference is comparable with the corresponding difference for Finland (cf. Figure 1). After 1980, the age distribution of mothers of twins is not available.

The effect of maternal age on the TWR shows marked variations in Denmark (1896 to 2000). In Figure 6, the periods 1921 to 1930 and 1971 to 1980 are compared and marked differences are observed. These periods were chosen as, during the period 1896 to 1980 with known maternal age distribution, the TWR had a maximum for the period 1921 to 1930 (15.8 per 1000), and a minimum for the period 1971 to 1980 (9.8 per 1000).

The ARC and the MATR can be estimated for the period 1896 to 1980 and are estimated separately for the period 1896 to 1900, and the following 10-year periods. For the period 1981 to 2000, the ARC and the MATR are not estimable. The results are presented in Figure 7.

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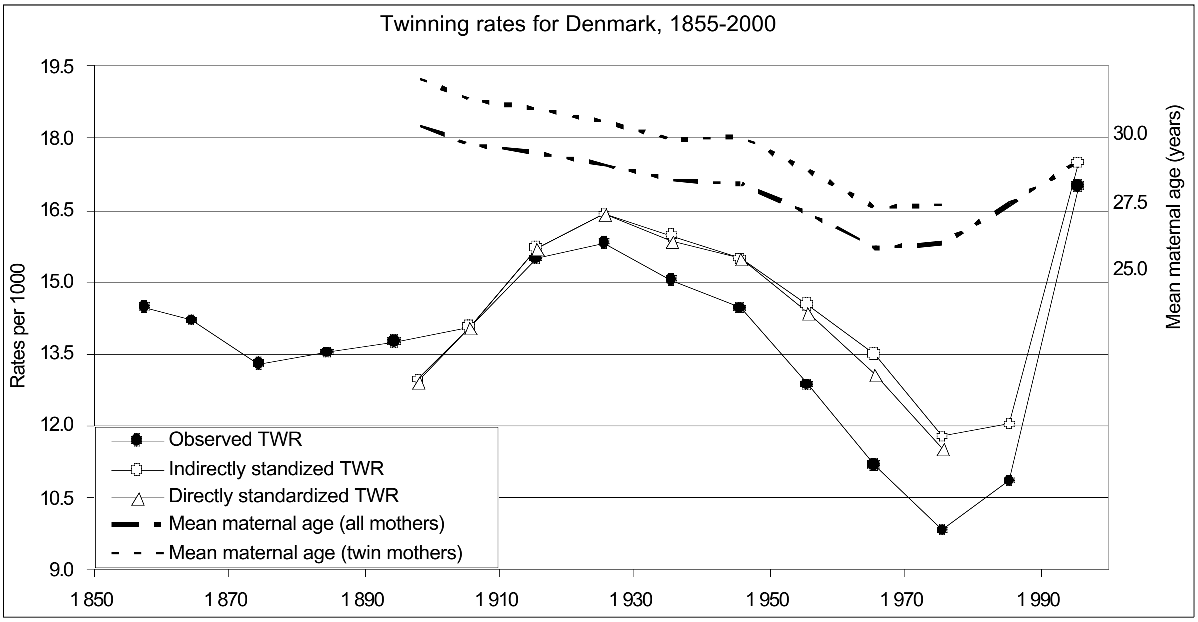

Figure 5

The mean maternal age and the observed and standardized twinning rates (TWRs) for Denmark, 1855–2000.

The TWRs show marked temporal variations. Both direct and indirect standardizations are performed according to Fellman and Eriksson (1990). No standardization can be performed before 1896 and the direct standardization cannot be applied to the period after 1980. The standardizations do not explain the observed trend.

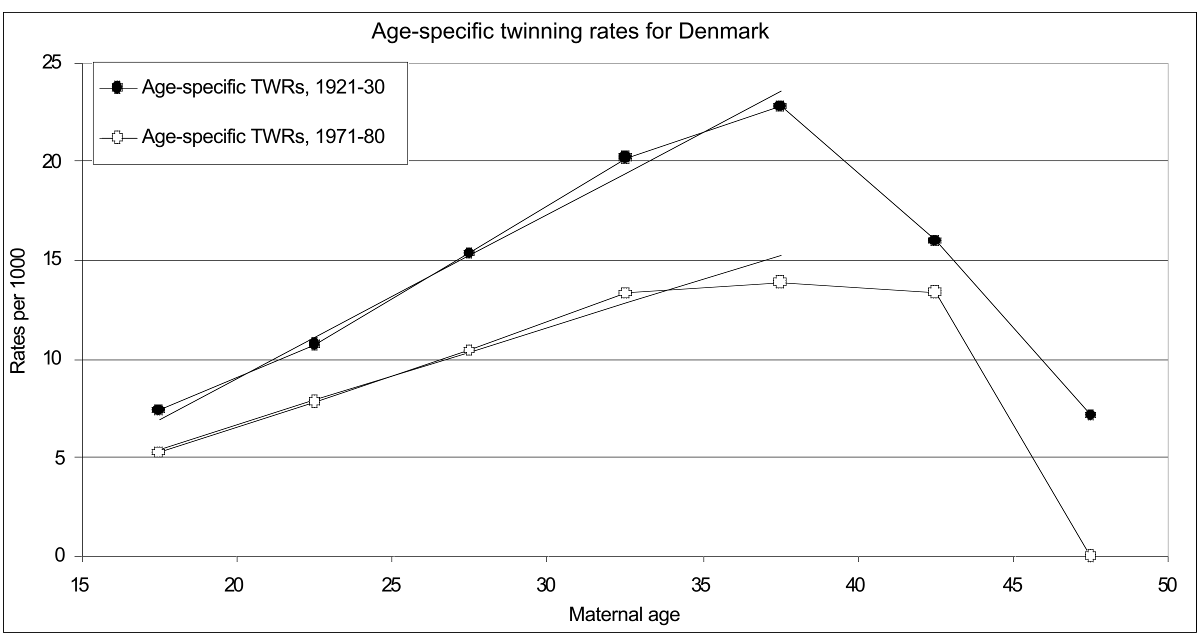

Figure 6

The age-specific twinning rates (TWR) for Denmark for the periods 1921–1930 and 1971–1980.

The periods are chosen because, for the period 1901–1980, with known maternal age distributions, the TWR has a maximum for the period 1921–1930 (15.8 per 1000) and a minimum for the period 1971–1980 (9.8 per 1000). Marked differences between the two periods can be observed.

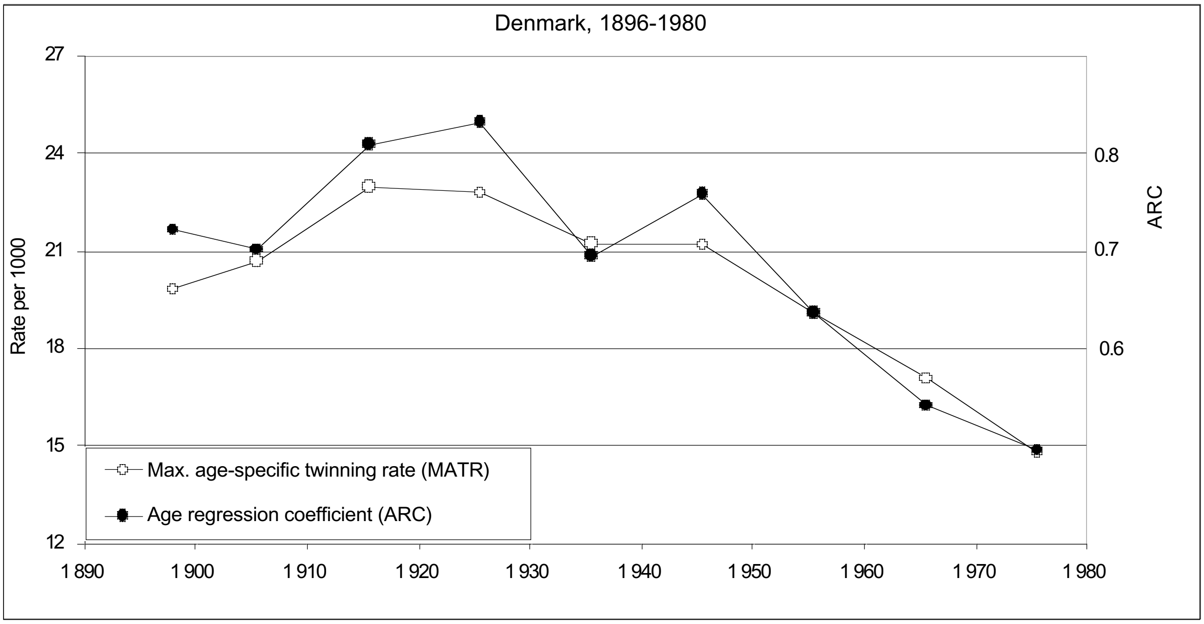

Figure 7

The maximum age-specific twinning rate (MATR) and the age regression coefficient (ARC) for Denmark, 1896–1980.

The trends are similar and after 1910 the decreasing trends are rather linear. Compare this variation with the variation in the total twinning rate (TWR; Figure 5).

The correlation coefficient between the ARC and the MATR is .954. After elimination of the time, the partial correlation coefficient is still .937. We observe that the temporal trends of the ARC and the MATR are curved, ending with an accentuated downward trend, and are similar trends to the total TWR (Figure 5).

Discussion

The two measures ARC and MATR have different advantages. Being the slope of the regression line, the ARC gives the average increase in the age-specific TWRs when the maternal age increases by 1 year, and therefore has an obvious connection with the effect of maternal age. Studies of ARC have been done by Fellman and Eriksson (1990, 1993). On the other hand, the MATR has the advantage that it is easier to obtain. A comparison of these in Figure 4 indicates that both the ARC and the MATR show similar accentuated downward trends during the recent decades, ending with a final peak for the last periods 1991 to 2000 and 2001 to 2003. This finding is in good agreement with the trends in the observed and standardized TWRs given in Figure 1. Consequently, the temporal variations in the TWR are largely caused by influential factors other than maternal age and the effect of such influential factors can be traced in the variations in ARC and MATR. The accentuated downward trend has already been observed by Fellman and Eriksson (1993). A model was applied in Fellman and Eriksson (1993) assuming that the ARCs have linear time trends for the period 1881 to 1990. However, in Figure 4 it is observed that curved temporal trends are more consistent with the empirical data than linear ones. Figure 1 also indicates that the TWR has a curved trend.

Our studies of the longitudinal rates of the TWRs in Finland indicate that the temporal trend in the TWR is caused not only by a temporal trend in the mean maternal age but also by variations in the maternal age effect. The fluctuations in the age-specific TWR after the 1950s are most marked in age groups between 30 and 44 years, which are the ages with the highest age-specific TWRs (Figure 3). In Sweden in the 1960s the TWR was 9.5 per 1000, being hardly 60% of what it had been about 200 years earlier (about 17 per 1000). But the mean age of all the mothers in Sweden only decreased from 31.3 years in 1781 to 1790 to 26.6 in 1961 to 1970. In Finland, a maternal mean age of 31.3 years was obtained for the period 1881 to 1890, 28.5 for the period 1981 to 1990, and 29.6 for the period 1991 to 2000.

In addition it is noted that in Finland, the correlation between the TWR and the ARC is .746, and the partial correlation coefficient, after elimination of the mean maternal age, is .774. The corresponding correlation coefficients for the TWR and the MATR are .943 and .956. For Denmark, the correlation between the TWR and the ARC is .921 and the partial correlation coefficient, after elimination of the mean maternal age, is .871. The corresponding correlation coefficients for the TWR and the MATR are .992 and .922, respectively. These findings support the general hypothesis that there are factors other than maternal

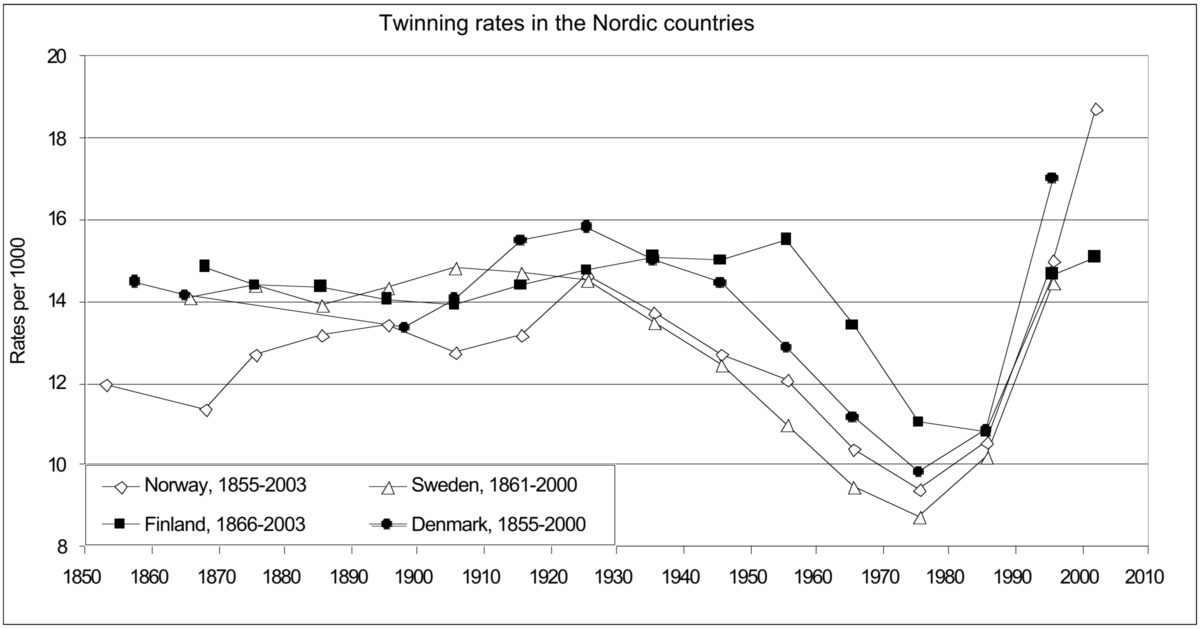

Figure 8

The twinning rates (TWRs) for Denmark, 1860–2000, Finland, 1866–2003, Norway, 1901–2000, and Sweden, 1861–2000.

The main pattern is quite similar for the different countries. From rather high TWR levels, deep troughs are observed and at the end of the 20th century, marked increases are observed. However, careful inspection identifies some differences in the locations of the troughs. For details, see the text.

age that simultaneously influence the TWR, the ARC and the MATR.

It is notable that in Finland the indirect standardizations yield slightly higher values than the direct one. The indirect standardizations are based on the age-specific TWRs for the reference population (Finland, 1881 to 1890). When ignoring the parity, it has a hidden increasing effect on the age-specific TWRs, as maternal age and parity are strongly correlated (Fellman & Eriksson, 2002). As a consequence of the fact that the mean parity has a decreasing time trend (Pitkänen, 1977), one can expect that this effect on the age-specific TWRs is more marked for earlier decades, including 1881 to 1890. In Figure 5, the direct and indirect standardizations of the Danish data give almost the same results. If the discrepancies between the results of direct and indirect standardization methods for Finland (Figure 1) are caused by the variation in the mean parity, then the parity effect in Denmark will only be slight. In fact, Bønnelykke (1990) stated that there was no association between DZ twinning and parity for mothers of all twins born alive in Denmark in 1984 and 1985. This conclusion by Bønnelykke (1990) was drawn from logistic regression analysis where the association between DZ twinning and parity was adjusted for maternal age. This result is not in concordance with the majority of literature, although a few other authors have also previously failed to demonstrate this association (Dahlberg, 1926; Gedda, 1961; Lamy et al., 1955). The lack of an association or a low association between DZ twinning and parity may be related to the fact that the mean number of maternities for women in the 'modern' Nordic society is not as high as in the past. In Sweden, the total fertility commenced at 4.8 in 1751 to 1760, reached a minimum of 1.8 in 1931 to 1940, and subsequently showed a small increase to 2.2 in 1991 to 2000.

In addition, it is necessary at this stage to stress that Fellman and Eriksson (2002) have shown that, in comparison with standardization according to maternal age, inclusion of parity in the standardization does not influence the results to a greater extent. Furthermore, they stressed that in comparison with standardization according to both maternal age and parity, due to the correlation between the factors, with standardization according to only one factor the corresponding effect was exaggerated.

Comparisons of Figures 1 and 4 for Finland and Figures 5 and 7 for Denmark show that the temporal variations in the total TWR are also discernible in the trends of ARC and MATR, which are defined as measures of how the TWRs depend on maternal age. Consequently, these findings indicate that the temporal variations in the TWRs depend not only on variations in the maternal age distributions, but also on variations in the maternal age effects, caused by other influential factors.

The increasing TWR during the last decades of the 20th century observed in Finland (Figure 1 and 3) and in Denmark (Figure 5) can also be observed in other countries, for example in Sweden (Fellman & Eriksson, 2003, 2004) and in Norway. In Figure 8, this pattern is compared in Denmark, Finland, Norway and Sweden. Similar tendencies are observed in all of these countries: firstly, strong declines in the middle of the 20th century resulting in marked troughs, and subsequently strong increases. However, careful inspection of the figure identifies some differences between the countries. In Sweden, the decline had already started from a top level of 14.8 per 1000 in the period 1901 to 1910, and the trough is very deep. The minimum TWR is only 8.7 and is located in the period 1971 to 1980, and the increase starts in the period 1981 to 1990. For Denmark and Norway, the decreases start in the period 1921 to 1930 from 15.8 and 14.6, respectively. These minima can also be found in the period 1971 to 1980 (9.4 for Norway and 9.8 for Denmark) and there are subsequent strong increases. For Finland, the development comes later. The maximum TWR is as high as 15.5 and is obtained as late as the period 1951 to 1960. The minimum is still relatively high, 10.8, and is located in the period 1981 to 1990. Consequently, an increase cannot be observed until 1991 to 2000.

During the last century, bicycles, cars, motorboats, steamers, trains and so forth, resulted in a strong improvement in communications, and distances between birthplaces of marriage partners increased dramatically (Eriksson et al., 1973). This, as well as industrialization and urbanization, have resulted in a disintegration of the isolation of old static agrarian societies in Nordic countries, with strongly increased exogamy. All these factors contributed strongly to the steep decline of the TWR (Eriksson & Fellman, 2004). Figure 8 indicates that this development occurred initially and most strongly in Sweden and more recently in Finland. This difference between these countries has also been noted in other studies.

At the end of the 20th century, strong increasing trends are noted. These are mainly caused by the influence of artificial reproduction technologies and particularly the use of fertility-enhancing drugs on the commonly noted dependence between maternal age and the twinning rate.

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References

Bressers, W. M. A., Eriksson, A. W., Kostense, P. J., & Parisi, P. (1987). Increasing trend in the homozygotic twinning rate. *Acta Geneticae Medicae et Gemellologiae, 36*, 397–408.

Bønnelykke, B. (1990). Maternal age and parity as predictors of human twinning. *Acta Geneticae Medicae et Gemellologiae, 39,* 329–334.

Dahlberg, G. (1926). *Twin births and twins from a hereditary point of view*. Stockholm, Sweden: AB Tidens Tryckeri.

Eriksson, A. W. (1962). Variations in the human twinning rate. *Acta Genetica*, *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 Åland Islands. *Commentationes Biologicae, 64,* 1–159.

Eriksson, A. W., Abbott, C., Kostense, P. J., & Fellman, J. O. (1995). Secular changes of twinning rates in Nordic populations. *Acta Geneticae Medicae et Gemellologiae, 44*, 141–162.

Eriksson, A. W., & Fellman, J. (1967). Twinning in relation to the marital status of the mother. *Acta Genetica et Statistica Medica, 17*, 385–398.

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., Fellman, J. O., Workman, P. L., & Lalouel, J. M. (1973). Population studies on the Åland Islands: I. Prediction of kinship from migration and isolation by distance. *Human Heredity*, *23*, 422–433.

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 the multiple maternities in Finland 1881–1990, and in Sweden since 1751. *Human Biology, 65,* 463–479.

Fellman, J., & Eriksson, A. W. (2002). On the standardisation of the twinning rate. *Twin Research*, *5*, 19–29.

Fellman, J., & Eriksson, A. W. (2003). Temporal differences in the 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.

Fellman, J., & Eriksson, A. W. (2005). *Weinberg´s differential rule reconsidered*. Manuscript submitted for publication.

Gedda, L. (1961). *Twins in history and science*. Springfield, IL: Charles S. Thomas.

Hill, A. B. (1971). *Principles of medical statistics*. London: Lancet.

Lamy, M., Frézal, J., de Grouchy, J., & Chryssostomidou, M. (1955). L'age maternel et le rang de naissance dans un échantillon de jumeaux [Maternal age and birth order in a sample of twins]. *Acta Genetica* (*Basel*), *5,* 403–419.

Pitkänen, K. (1977). The reliability of the registration of births and deaths in the eighteen and nineteen centuries in Finland: Some examples. *Scandinavian Economic History Review (Odense, Denmark)*, *25*, 138–159.