The correlates of infant and childhood mortality. A theoretical overview and new evidence from the analysis of longitudinal data from Bejsce parish register reconstitution study 18th-20th centuries, Poland.

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Abstract

The paper reviews theoretical background of the infant mortality studies and adds new evidence from longitudinal study of Bejsce parish registers. Applied multilevel hazard models of mortality over first 60 months of life include rich set of covariates, for instance: sex, birth rank, birth intervals, survival of previous child, presence of extended family (grandmother effect). The analysis also demonstrates the change in relative importance of analysed factors during the process of mortality decline. Obtained mortality patterns overlap with those reported in other studies. Moreover results provide an evidence for crucial role of post-reproductive family members on survival during the first 60 months of life.

1. Introduction

1.1. Aims of the paper

In traditional and historical populations, or more widely, in pre-transitional populations, infant mortality was one of the main barrier preventing the growth of the population. On the course of demographic transition the improvement in infant and child survival led, at the beginning, to rapid population growth and subsequently to a shift in reproductive behaviour (Galloway et al. 1998, Matthiessen and McCann 1978, Schoefield et al. 1991). From this perspective, the decline in fertility might be seen as a response of the couples for the improvement in survival chances of their offspring. Hence, assuming presence of natural fertility, most of the couples “overproduced” children anticipating high and varying mortality levels of young children.

For that reason, the topic of mortality at young ages is one of the “corner stones” of demography and it has been used in description of demographic transition in historical European populations (for instance: Bideau et al. 1997). Subsequently, the models and the methods were applied to the analysis of developing countries which exhibited (or they still do) levels and patterns of infant mortality, typical for Europe in the past. Thus, this topic is still alive in demography although the research area moved out from Europe and other developed countries.

The issue of infant and early childhood mortality is important also from the perspective of evolution and ecological constraints of human reproduction and reproductive success (Voland 1998). From this perspective, what matters in not only the number of children produced but also the number of children who have reached sexual maturity and manage to reproduce themselves. Thus, in the light of evolutionary perspective on human reproduction, offspring survival stands for the most important factor of the individual reproductive success. Hence, by looking at the correlates of mortality we can learn, which factors could potentially increase or decrease number of surviving offspring and thus reproductive success.

Finally, although the topic of mortality at young ages is relatively well explored in the literature the case of Bejsce parish offers a unique opportunity to trace the changes in the relative importance of various mortality factors during the change of fertility levels from low to high.

1.2 Theoretical background

In order to provide comprehensive theoretical framework for the analysis of mortality at young ages it is necessary to review the terminology used in the field. Since the incidence of mortality at young ages depends on the age of the child it is important to discriminate stages of life which could be characterized by different levels of intensity as well as different causes of deaths.

For the purpose of mortality analysis, researchers have split the first five years of kid's life into periods, which have critical effect on the survival (see: Dupaquier 1997, Knodel and Hermalin 1984):

- *Neo-natal mortality* describes the mortality over the first month of life. Additionally within this period we can select the *perinatal mortality*, which refers to fetal mortality and mortality over first week of life.
- *Post-neonatal mortality* covers the period from one month to twelve month of life.
- *Infant mortality* is a wider term used to select the mortality over the whole first year of life.
- *Early childhood* refers to the period between first birthday and fifth birthday of the child.

These periods differ not only in the intensity of events (deaths) but also in the causes of the events. In the case of *neo-natal* and *perinatal* mortality deaths mostly result from fetal malformation, low birthweight, high susceptibility for infections or abnormalities in the body functions. As estimated by Dupaquier (1997) the mortality during the first week of life in the historical populations of Europe was incredibly high ranging from 5% to 10% and the neo-natal mortality usually reached 10% to 15% of the total number of births. It has to be noted that these figures might be overestimated since they also cover children who were actually stillbirths but baptized privately prior to the formal church ceremony. This was usual practice also in historical Poland, since the laws of Catholic Church with respect to baptisms were flexible and the infant could baptized by anyone who was catholic and who did it in "the good will" (Kumor 1976).

The mortality in the *post-neonatal* and *early childhood* periods was much lower in comparison with the previous period. For instance in the Bejsce parish, the mortality in the first month of life (neonatal) reached 17% of the total number of birth whereas the mortality in the post-neonatal period (1 to 12 month of life) reached 30% of the total number of birth.

The causes of death in the young ages could be roughly divided between endogenous and exogenous (Lalou 1997). The term endogenous refers to all deaths caused by factors that are independent from the pathological socio-economic and cultural conditions into which a child is born. The endogenous causes are therefore associated with biological and genetic factors influencing the survival chances after birth. It has to be noted that the endogenous factors are strongly influenced by the environmental factors such as, for instance, poor hygienic conditions. It is quite difficult to imagine an exogenous factor, which would not operate through endogenous causes of child's death. In our opinion such solely exogenous cause is preferential infanticide, which is determined culturally and is not mediated by any biological mechanisms.

The above-defined terminology provides useful reference for the investigation of determinants of mortality over first five years of human life. The FIGURE 1 presents schematically the relations between endogenous and exogenous determinants. It has to be stressed that the biological (endogenous) factors are closely related and influenced by cultural (exogenous) factors.

The figure presented below shows two distinct causal chains, namely environmental and bio-genetic factors. The biological factors such as developmental deficiencies or chromosomal anomalies are usually assumed to be the main causes of death in the first days of life. However the environmental (cultural) factors also contribute to the survival chances by influencing mother's health either directly or through the demographic variables. Mother's poor health status might translate into premature or hypothrophic[1] birth. Therefore, in both of these causal chains mother is the most important factor through which external environment influences the fetal development of the child.

[FIGURE 1 ABOUT HERE]

The child's health status might be also influenced directly by the demographic variables like: sex, survival status of the adjacent siblings, season of birth, survival of the parents or presence of extended family. Especially sex of the newborn child greatly influenced its fate. Male infants are much more likely to die within first 24 hours after delivery than female infants.

Since parish registers do not provide accurate information required to conduct the analysis of endogenous causes, present paper focuses on the analysis of effect of demographic variables from FIGURE 1 on infant and early childhood mortality. Therefore, like most of the analyses based on historical data, we are only able to account for indirect effects of endogenous causes using

[1] Infants weighting less than 2500 grams at birth

demographic variables. The characteristics of the variables used in the analysis along with theoretical background are given in the section 2.3.

In historical populations delivery itself was quite perilous and traumatic event for both mother and child. It influenced both child's and mother's health. Poor sanitary conditions and lack of professional medical care could cause severe malformations and deterioration of mother's reproductive system. This in turn could increase chances of failure future deliveries as well as endanger mother's life. Malnutrition in the early stages of girl's life could cause difficulties in delivery in the future adult life.

Another important source of danger for both mother and child was also various epidemics, infection and contagious diseases. The historical European populations accordingly to the predictions of Malthus followed the patterns of consecutive prosperity and crisis. This was due to exposure to periodic short term exogenous shocks associated with famines, wars or epidemics (Cotts Watkins and Menken 1985, Livi-Bacci 1991, Lummaa 2003, Scott et. al 1995). These exogenous shocks might affect infant mortality as well as health status of the populations. The health status of the population was greatly influenced by nutrition, which was negatively related to the mentioned exogenous shocks (Livi-Bacci 1991). Periods of malnutrition associated with these shocks affected the infant mortality directly by lower food intake of the youth and indirectly *via* health status of adult women which resulted in lower birth weight and faster weaning.

1.3 Trends in mortality over first five years of life in Bejsce parish

The trends in human mortality over the first five years of life exhibit surprisingly constant pattern across time and populations, with dramatically high mortality in the neo-natal period and lower mortality in the period of later childhood. The critical period after birth of the child brings different risk with respect to sex of the infant. Usually boys have much higher mortality rates than girls in the neo-natal period. As we shall see later, such difference is mainly due to socio-economic and physiological mechanisms. Male pregnancies are usually much more difficult, and much often result in premature or hypothrophic deliveries and foetal malformation. Also the efficiency of the immune system is much weaker for male infants as an effect of increased level of androgens.

As it could be seen from the FIGURE 2, Bejsce parish was no exception from the general trend in mortality over the first five years of life. There is an apparent excess of male mortality during the first 12 months of life. This difference seems to disappear in the later period. For males, almost 18% out of the total number of deaths in the period of first 5 years of life, occurred in the first month of life. Analogous figure for females yields 15%. For males, for the period of first 5 years of life, 51% of deaths occurred in the first year. Analogous figure for females yields 47%.

[FIGURE 2 ABOUT HERE]

These results are confirmed by the analysis of the Kaplan-Meier estimate of the survivor function for the first five years of life with respect to sex of the child (FIGURE 3). According to these estimates the proportion of males who survived until first birthday was 0,84 and this same figure for females was 0,86.

[FIGURE 3 ABOUT HERE]

Apparently not only sex of the child influences survival chances. Along with the economic progress there has been major improvement in child survival in many historical populations. This was associated with improvement in nutrition, hygiene and the level of medical care. Also for the population of Bejsce parish the survival over the first five years of life improved significantly. The Kaplan-Meier estimate of survivor function with respect to the birth cohort of the child shows that for the youngest cohort (born after the WWII) almost 94% of children survived until the first birthday whereas for the cohort born between 1820 and 1917 it was only 83% (compare FIGURE 4). As could be seen from the figure, significant improvement in the survival starts from the youngest cohort and there was no apparent improvement in survival until the end of WWII.

[FIGURE 4 ABOUT HERE]

Surprisingly, apart of the youngest cohort, the patterns of mortality during the first 12 months of life are quite similar for the remaining three cohorts. This might confirm the hypothesis about the physiological causes of death in early infancy. Apparently there was no radical improvement in the level of medical care and hygiene.

2. Data and methods

2.1 Sample selection and preparation

In order to analyze the mortality of children over the first 60 months of life, from the total sample reconstructed on the base of parish registers, we have selected cases with complete information about date of birth and death. From the total sample we have also excluded still births, since the objective of the study was to examine the exogenous mortality. Another reason for exclusion of the cases from the analysis was death of the mother before death of the child (over the period under examination). Death of the mother could severely decrease chances of infant's survival due to lack of maternal care or difficult delivery. In the whole sample there were only 200 cases where mother died before her child during the period of 60 months that is under observation.

The individuals were censored in the case of death during the first 60 months of life. Moreover, since we wanted to capture the differential effect of covariates during the first 12 months of life and afterwards, it was necessary to split the initial sample. In order obtain one sample, which was used to model the risk of death during first 12 months and the second which was used to model the risk of death in the period of 12 to 60 months of life.

As it was already mentioned previously, we have to be aware of the fact that the parish registers contain the dates of baptisms and burials, which do not necessarily have to overlap with the actual dates of births and deaths. In the case of birth the parish registers, at least in Poland, are quite reliable since baptism was one of the most important events from the religious point of view. Therefore, parents were quite concerned to baptize child as soon possible especially in the cases when the child's life was in danger (Kumor 1976). The case of death dates is not so straightforward, however as noted by Piasecki (1990), the book of deaths in the Bejsce parish was run in a quite strict way thus reliably reflecting the actual date of death. Usually the difference between actual date and registered date was no more than one week.

Another important issue, which is linked with the next section, is the fact that we have included the information about mother of the child. Since the individuals within the database are linked genealogically it was possible to mark children coming from this same mother. This information is useful if we want to build multilevel model. Multilevel structure of the model (mother level vs. child level) allows controlling for the shared genetic and biological background.

Since we know which children come from this same mother it is possible *via* multilevel structure of the model to control for the shared genetic and biological background. Moreover using the set of below described covariates we were trying to control for other effects that might affect child survival over the first 60 months of life.

2.2 Specification of multilevel hazard model

In order to account for the effect of various correlates on the risk of death we applied multilevel event history analysis. Multilevel structure of the hazard model is particularly important in modeling of fertility and mortality. For instance, while analyzing fertility, we have to be aware that one woman could contribute several children to the analysis. Therefore it is plausible that children from this same mother share some characteristics due to genetic endowment and widely understood family background. However, such an assumption violates postulate of independence between observations that is required in single-level statistical models. Solution to this problem might be estimation of multilevel model which allows accounting for the fact that observations are dependent. Moreover a combination of multilevel approach with control for unobserved heterogeneity might significantly improve the quality and accuracy of the estimates. The mathematical representation of the transition rate, in this case death over first 60 months of life in the multilevel model containing unobserved heterogeneity could be given by following formula:

$$\ln \mu_{ij}(t) = y(t) + \sum_{k} \beta_{jk} x_{ijk} + \sum_{k'} \gamma_{k'} v_{ik'} + u_{ij} + \delta_i \qquad (1)$$

In the model of infant and early childhood mortality the basic duration denoted as *(t)* stands for the time since birth of the index child and the whole term $\mu_{ij}(t)$ refers to the rate of occurrence of an event at time t (the death of jth infant) for the ith woman. The component $y(t)$ captures the baseline hazard (i.e. the effect of duration on the intensity of studied event). The x_k represents kth covariate specific to the child level with β as the respective regression parameter and. The $\gamma_{k'}$ represents k'th covariate on the mother's specific level. Two last parameters are responsible for unobserved heterogeneity, u_{ij} refer to child level heterogeneity and δ_i refer to mother specific heterogeneity factor[2].

[2] It is assumed that the heterogeneity parameter δ_j is normally distributed.

The mathematical formulation of the model contains above-mentioned heterogeneity and has a multilevel structure. The hierarchical structure of the model was necessary since one woman could contribute several children to the analysis. Moreover multilevel structure allows controlling for mother-specific effects (genetic or biological). It could be assumed that children from this same mother share some characteristics due to genetic endowment and widely understood family background. Such an assumption violates the postulate of independence between observation that is required in single-level statistical models.

In order to estimate the multilevel hazard regression model of the influence of kin variables on transition to subsequent parities we use aML software (Lillard and Panis 2000).

2.3 Variables considered in the analysis

The statistical description of the sample and the variables used in the models are given in the TABLE 1. As noticed earlier the basic duration for which the hazard model was estimated was the age of child (in months) since birth. The shape of the mortality rates over the infancy period (up to 12 months of life) and in the later childhood period (12 months to 60 months) differ quite considerably. First 12 months of life are crucial with respect to infant survival. Especially first month of life where mortality rates are far higher that in the rest of the period. Therefore it was crucial to select proper intervals in order to capture the shape of the baseline hazard function. In the general model (mortality over period of 0-60 months) the nodes were selected at 1, 6, 12, 24, 36, 60 moths. In the model of infant mortality (period 0-12 months) the nodes were selected at each month (1,2,….etc.) and in the model of later childhood mortality (period 12-60 months) the nodes were selected each six months, i.e. 12, 18….54, 60.

The list of the variables included into the models is by no means exhaustive. Other studies investigating the correlates of infant and children mortality in historical and traditional populations included important physiological variables like birthweight or calories intake of mother. Here we have only proxy variables for that or variables that measure effect of these physiological effects indirectly.

[TABLE 1 ABOUT HERE]

2.3.1 Sex of child

The sex of the newborn infant is one of the most typical correlates of the survival. Usually girls experience lower infant mortality than boys however this difference losses its' statistical significance in the later childhood (after first birthday). Higher survival chances for one of the sexes could be attributed to socio-cultural and physiological mechanisms. In the latter case higher male mortality is mostly due to greater immaturity (slightly shorter gestation period), and differential effect of estrogens and androgens on the immune system (Worthman 1996). On the other hand there has been well-established fact that parental investments are frequently sex-biased resulting in lower survival of the less preferred sex (Kumm et al. 1994). Sex-biased parental investments might take form of lower resource investments in the less favourable child or even infanticide.

2.3.2 Multiple vs. single birth

The multiplicity of births stands for an important factor influencing child and infant mortality. Its effect is mainly associated with lower birth-weight of twins or triplets, which in turn is one of the most important factors affecting neo-natal survival. Arrival of more than one child creates also an extra demand for food. Taking into account fact that during early stages of infancy breastfeeding is one of the main sources of nutrition, multiple birth might led to lower calories intake and thus lower survival chances.

It has to be noted that this variable was not included to the model of mortality over first 12 months of life. It was caused by convergence problems due to insufficient number of occurrences. In order to capture the effect of multiple births we have constructed a dummy variable indicating whether the birth was multiple or single.

2.3.3 Birth rank

The birth rank of an individual is frequently used in the studies, which aim to model the infant or late-childhood mortality (Cohen 1975, Knodel and Hermalin 1984, Modin 2002). The standard finding is that the risk of mortality is positively related to the birth rank of an individual. Of course birth rank (or birth order) cannot be itself related to the risk of mortality however the number of siblings could be related to important conditions that might lead to increase in the risk of mortality. For instance as family grows larger parental resources might be insufficient to maintain this same level of nutrition for children, thus those earlier born children might enjoy better nutritional status. Such relation between family size and resources has been labelled as quality-quantity trade-off indicating the fact that, holding resources constant, as family grows larger, the per capita investments decline (Blake 1981). However, not only the resources become limited when the family grows. It has been found that laterborns of large families run a higher risk of experiencing accidents during early childhood, which results from less parental attention (Bijur et al. 1988).

Another important factor, relating birth order to the risk of death, is associated with the fact that higher birth order children were born to already crowded house. Therefore they run higher risk of catching life-threatening infection during the first critical weeks and months of life than the children with few or no older siblings (Burnett 1991). In the present analysis the birth rank is represented by variable indicating whether child was first born (rank 1), was second or third born or is was higher that 4th born child.

2.3.4 Length of birth intervals

In the present analysis we have included both the length of preceding and subsequent birth interval. The length of the preceding birth interval was included in all models and the length of the subsequent birth interval was included only into the model of later childhood mortality i.e. over the period of 12 to 60 months after the birth. The length of the interval in both cases was included as categorical variable. In the case of subsequent birth interval the variable indicated whether the interval was longer or shorter than 22 months. In the case of preceding birth interval the variable has three values: when the birth interval was shorter than 24 moths, between 24 and 48 months and longer than 48 months.

Many studies revealed that the length of the birth interval was positively related to the survival of the index child[3] (Boerma and Bicego 1992, Knodel and Hermalin 1984, Palloni and Millman, 1986, Retel-Laurentin and Benoit 1976). This is mostly related to the duration of breast-feeding. Shorter subsequent birth interval means shorter period of breast-feeding which affects survival of the index child. In the case of preceding birth interval there also has been established a positive relation with respect to survival of the child. Children born after short birth interval exhibit significantly higher risk of death especially in the period of first 6 months after birth (Boerma and Bicego 1992, Hobcraft et al. 1985). As the main mechanisms responsible for this effect researchers point out that pregnancies conceived in short proximity might lead to intrauterine growth retardation. Basically, women with short intervals between pregnancies have insufficient time to restore nutritional reserves, which in turn affects the foetal growth and subsequently survival of the newborn child. Also the overlap between breastfeeding and gestation

[3] The term index child refers to the child under the analysis. Here: the child whose mortality we are studying.

might have unfavourable effect on the pregnancy outcome. Both these mechanisms lead to low birthweight babies and thus higher mortality over first 6 months of life.

Another possible source of influence is a post-natal mechanism associated with sibling competition over parental resources and mother's care. Similarly, as in the case of the birth-rank effect, siblings may compete, which might have a negative effect on the youngest child in the family (i.e. born after short birth interval)? As mentioned in the paragraph 2.3.3, presence of many younger siblings might expose newborn baby for the risk of infectious diseases brought by siblings to the household.

2.3.5 Survival of previous child

Above described effect of the birth-rank and birth interval is directly linked with the next covariate included into the models. The survival of the previous sibling should be strongly correlated with the survival of the index child since both of them should experience similar mortality conditions (Alam and David 1998). Thus, we are interested in this effect when death of the previous sibling occurred during the period of observation i.e. between 0 and 60 month of life of the index child. In the present study the fate of the previous sibling was coded as a time varying covariate.

2.3.6 Age of mother at birth

It has been shown in many studies that the relation between maternal age at birth and the risk of child's death follows a "J" curvilinear relationship (Knodel and Hermalin 1984). According to these findings infant mortality is elevated among young and old mothers. This is consistent with the predictions of physiology of pregnancy and gestation. Organisms of both, old and young mothers are not enough selective with respect to malformed foetuses which results in higher rate of still births, hypothrophic births and thus higher infant mortality (Gray et al. 1993, Weinstein et al. 1993, Wood 1994).

2.3.7 Birth cohort of an index child

The mortality in the period of infancy and late childhood exhibit considerable decline in time associated with better health care and improvement in economic conditions. It could be assumed that infant mortality is one of the most sensitive measures of changes associated with modernization. As we have already seen, in Bejsce parish the infant and child survival improved considerably over time (compare FIGURE 4). Therefore all models include a variable indicating the birth cohort of and index child. This categorical variable contains four birth cohorts; earliest period covered by the parish registers (years 1737-1819), period up to the end of IWW (years 1820-1917), period between IWW and IIWW (years 1918-1944) and finally the period after IIWW (years 1945-1968).

2.3.8 Presence of extended family (grandmothers and grandfathers)

Recent studies focused on the improvement in survival of infants due to the presence of extended family, particularly grandparents (Beise and Voland, 2002, Sear et al. 2000, Voland and Beise 2001). These studies explore so-called grandmother hypothesis which states that there is a positive effect of grandmother's presence on the survival of grandsons and granddaughters. This effect is especially important in the light of theoretical consideration of adaptive significance of menopause in humans and so-called inclusive fitness theory (Grafen 1982, Hamilton 1964, Peccei 1995, Shanley and Kirkwood 2001). The positive relation between presence of post-reproductive helpers (grandmothers) and survival of grandchildren, provides an indirect test that phenomenon of menopause might have an adaptive meaning and indirectly increase reproductive success of grandmothers. Moreover, such positive relationship would be in accordance with the prediction of the evolutionary theory of inclusive fitness, which states that individuals might also indirectly contribute to their own reproductive success by enhancing reproduction of relatives (Grafen 1982, Hamilton 1964).

In the present analysis the effect of grandparents (both maternal and paternal) is included as time constant covariate indicating whether an index child experienced death of one of the grandparents during the period of observation (four dummy variables). Thus four variables (maternal grandmother and grandfather, paternal grandmother and grandfather) indicate the effect of death of a grandparent over selected periods i.e. 0-60 months, 0-12 months and 12-60 months.

2.3.9 Presence of parents

The variables indicating presence of parents were constructed in a similar way as the variables indicating presence of grandparents. The presence of the parents is represented by the two dummy variables. The variables equals one when the infant experienced death of the mother or father over selected periods (0-60, 0-12 and 12-60 months) It could be assumed that death of the parents (especially mother) decreases chances of infant's survival due to lack of maternal care and insufficient nutrition (lack of breastfeeding). The effect of father's death should have less impact on the chances of survival.

2.3.10 Season of child's birth

The relation between month of child's birth and mortality has been widely explored in many historical European populations (for an excellent review see: Breschi and Livi Bacci, 1997). Despite the local variation in climate in Europe, two main patterns of mortality with respect to the month of birth could be spotted. In the regions where the winters are particularly strong there is a higher risk of infant death due to respiratory infections. On the other hand in the regions with extremely hot summers the higher infant death rate is associated with higher risk of contracting infection of the digestive tract.

Apart of medical reasons, increase in the infant mortality by month of birth could be associated with social and economic conditions. An excellent example is Russia in the second half of the 19th century where the highest mortality rates were registered for those infants born in the summer, which was in opposition to usual predictions assuming higher mortality for those infants born in the winter (Breschi and Livi Bacci 1997: 161). This might be of course partially explained by good adaptation to severe winters. However much convincing explanation is that in the summer months demand for the labour force was so high (four-fifths of population working in agriculture) that most of females were apart from home, which caused early weaning or irregular breastfeeding and lower degree of protection and care.

The relation between month of birth and risk of death is strongly related to the age of infant. Since first months of life are critical with respect to survival it could be assumed that the effect of birth month would be also stronger in this period. In the present analysis we have included the month of birth as a categorical variable. We have grouped month of birth into four seasons: winter (December-February), spring (March-May), summer (June-August), and autumn (September-November).

3. Results

3.1 The baseline risk of the child's death

The estimated models allow for capturing differential effect of the correlates in the various stages of life, as well as model the risk of death by means of so-called duration splines. The duration splines as implemented in the aML software gives quite handy way of modelling the risk of event over selected intervals called the “nodes”. As defined elsewhere (Lillard and Panis 2000) the splines refer us to the simple piecewise linear model. Here, we also select the intervals (called the nodes) and the only difference is that the risk in not constant over the interval since the software returns the slopes over defined nodes. Hence, the model is also called piecewise linear. The baseline hazard is captured by the component of the equation (1) denoted as $y(t)$ which is simply the effect of duration on the intensity of studied event.

In the present analysis we have estimated three different models. The first one deals with the risk of death over the first five years of life, second one with the risk in the first of death year of life and the third one which, models the risk of death over the period between first and fifth birthday. Therefore it was possible to plot the shape of the baseline risk for each of the model separately. These plots are shown on the FIGURE 5 to 7 (based on the results from the TABLE 2 to 4).

The risk of death for children from Bejsce parish over the first five years of life (FIGURE 5) shows quite standard pattern with high mortality in the first month on life and declining afterwards. As we can see, there is slight excess of male mortality for this model. The sex differences in the mortality pattern are more obvious for the model of infant mortality presented at the FIGURE 6. On this chart we can clearly see the excess of male mortality over the first years of life which is declining as the first birthday approach. The intensity of death is concentrated (for both sexes) in the first months of life. As argued above, the infant mortality might be concentrated even in the first days or weeks of life. On the other hand the model of mortality over the period between 1^{st} and 5^{th} birthday (FIGURE 7) shows quite ambiguous pattern with clearly no differences with respect to sex of the child.

[FIGURE 5-7ABOUT HERE]

[TABLE 2-4 ABOUT HERE]

3.2 Sex of the child

The sex differences in mortality patterns are also apparent on the level of covariates. From the TABLES 2 to 4, we can clearly see that sex differences are due to increased female survival in the first 12 months of life. In this period females have almost 20% higher chances for survival than males. Similarly, over the whole period of first 5 years of life females have 12% higher chances of survival. On the other hand there is no such difference with respect to period between 12^{th} and 60^{th} month of life (TABLE 4).

3.3 Age of mother at birth

According to the hypotheses young and old mothers should experience higher infant mortality due to higher incidence of foetal malformation (compare: Wood 1994). These effects are only partially present in the current analyses. We have shown that especially, children born to young mothers had higher mortality. This is particularly clear in the case of the infant mortality (TABLE 3) where children born to teenage mothers had around 46% higher mortality. This effect is still present, although much weaker, for the early childhood mortality (TABLE 4). Additionally for this period of child's life, there has been observed slightly increased risk of death for individuals born to the mothers who have reached 35 years old (around 20% higher risk).

3.4 Multiple birth

Although it was not possible to include the effect of multiplicity of birth into the model of infant mortality[4], it could be clearly seen that arrival of more than one infant increased the risk of death by 40%. This effect is constant both in the case of the model for the whole period of first five years of life as well as for the period between 12^{th} to 60^{th} months of life.

3.5 Birth rank

The birth rank of the child had a significant effect on the survival chances (compare TABLES 2 and 3). This effect, however, is restricted only to the period before the first birth. Those infants who were born as 4^{th}, 5^{th} or in other words had many older siblings, have almost 20% higher risk of death in the period of first twelve months of life in comparison with firstborn children. This effect is also positive, and even stronger, in the model covering the whole period of first five years of life. There is no effect of birth rank in the period of early childhood (TABLE 4). Interestingly, there is also no effect in the case of birth rank up to 3^{rd} and, as noted, above the effect appears at higher parities.

3.6 Length of the birth intervals

The effect of the length of the birth intervals in the estimated models is limited to the period between 12 and 60 months of life (TABLE 4). In the case of remaining two models there was no

[4] Due to numerical problems with estimation.

effect on the risk survival of the index child. In the case of subsequent birth interval, if the next child was born in the period shorter than 22 months, the survival chances of the index child dropped by 15%[5]. Also, if the index child was born after interval shorter than 24 months the risk of death was elevated by 11%. Although the increase in the risk of event is not particularly big it seems to confirm the prediction that close spacing increases risk of death.

3.7 Fate of the previous sibling

Survival of previous sibling had a significantly negative effect on the survival of the index child[6]. Those children whose previous brother or sister died have almost twice higher risk of death than children whose sibling survived. This effect is present both in the general model and in the model of later childhood mortality. Although it was not possible to estimate effect of death of the previous sibling during the period of the infancy it could be assumed that this covariate reflects rather environmental factors than bio-genetic predisposition.

3.8 Presence of the extended family

The presence of the extended family, which is represented in this case by grandparents, influences survival of the newborn child. This effect is particularly strong in the first year of child's life. As we can see, there is no effect in the case of the model covering the period between 1st and 5th birthday (TABLE 4).

Death of the grandmother over the first year of infant's life decreases survival by around 20% in comparison to the cases where grandmother was present through the whole period (TABLE 2). There is almost no difference between the effect of death of maternal and paternal grandmothers. Both of them seem to enhance infant's survival in this same way. Surprisingly, the magnitude of the effect of grandfathers is greater that the effect of grandmother. Death of maternal grandfather decreases survival chances of the newborn infant by almost 50% and death of the paternal grandfather by 38%. This differential effect of grandmothers and grandfathers is even more apparent in the case of the model covering the mortality over the whole period of first five years of life. Such relationship, which partially stands in opposition to the theoretical predictions, might result from the fact that males in the agricultural populations, like this of Bejsce parish, had very strong economic position as main caretakers and providers of food for the whole household. Therefore, household where the head of family was present could enjoy economic well being

[5] Comparing to the cases where the length of the subsequent birth intervals was longer than 22 months.
[6] This covariate was not included into infant mortality model due to numerical problems during estimation.

which might translate into better conditions for rising children and thus lower mortality. Usually newly married couple moved into the household of the groom (partilocality) which might partially explain stronger effect of paternal grandparents. Moreover, the structure of the peasant family was strictly hierarchical. Therefore death of the head of family could cause some serious problems with inheritance including partition of the land. This in turn might lower economic and social status of the young couple. In fact, couples with more land had more children which might be associated with increased survival compare (Stys 1957, 1959).

3.9 Presence of parents

Not only presence of grandparents might influence survival of the children. More obvious factor should be whether one of the parents died during the period of observation. In the general model of mortality (TABLE 2), death of mother during the first five years of child's life increases risk of death by 66% comparing to the cases where mother did not died. The magnitude of this covariate's influence is similar in the case of the remaining two models. The effect of father's death is more ambiguous. In the model presented in the TABLE 2 there is no effect of father's death on the risk of child's death. In the remaining two models there is slight positive effect although its significance is problematic.

3.10 Season of child's birth

In each of the three presented models, children born in the summer exhibit slightly lower mortality in comparison to children born during the winter season. This patter is particularly strong in the model of infant mortality (TABLE 3). Infants born in the summer have 15% lower risk of death than infants born during winter. There are no changes in the risk of death for the infants born during spring or autumn. The effect of birth season is also significant in the case of early childhood mortality (TABLE 4). In this model children who were not born during the winter show on average 10% lower risk of death.

3.11 Child's birth cohort

As expected, trends in mortality decline with birth cohort of children. In comparison with birth cohort 1737-1819 (reference category) children born in the years 1820-1917 had slightly higher mortality (TABLE 2). The shift in the mortality trends could be spotted from the year 1918 onwards. Children born between the end of IWW and the end of IIWW had 34% lower risk of death over the first 5 years of life than the reference category. Even stronger decline in mortality could be observed for children born after IIWW (1945-1968). For this birth cohort the risk of death over the first five years of life was lower by 46% than in the reference category.

The changes in the infant mortality pattern exhibit even more dramatic changes (TABLE 2). The major shift in the infant mortality occurred after the IIWW. The risk of death for infants born between year 1945 and 1968 was almost 70% lower than the reference category. What's interesting, the decline in the infant mortality in the period between two wars was not so dramatic. Infants born between 1918 and 1944 had only 27% lower mortality than the reference category. Therefore, it seems justified to assume that major changes, which led to decrease in infant mortality, occurred after the year 1945. Although in Poland this date marks establishment of the communist regime but it also marks the fast process of modernization and wider access to professional medical care.

The effect of the birth cohort in the model of early childhood mortality brings results, which are quite difficult for interpretation (TABLE 3). Surprisingly, birth cohort 1945-1968, exhibits mortality decreased by 18% in comparison with reference category whereas earlier cohort exhibits 55% decrease. We would rather expect the reverse pattern.

The present analysis of the effect of birth cohort on the risk of infant mortality could give just a rough approximation of real trends (compare: Piasecki 1990). It is well known that infant mortality was sensitive for short-term changes in the economic situation thus broad cohorts included in the models could reflect only more general trends.

4. Discussion

The presented framework of the determinants of mortality in the young ages discriminates between the endogenous and exogenous causes. The term endogenous is attributable to the causes of death preceding or associated with foetal malformation or birth trauma whereas the term exogenous is attributable to the causes associated with postnatal environment like hygiene, nutrition infections or accidents. However, as shown at the FIGURE 1, the rigid distinction between endogenous and exogenous causes is far from being realistic. In fact many environmental factors (exogenous) influence also the endogenous causes of death. This is, for instance, mother's health as a result of nutritional status, which in turn influences the development of the child during the pregnancy.

Therefore, the investigation of the correlates of mortality in the young ages is always limited since it is not possible to control for any possible determinant of mortality. Usually, many of the

correlates are indirect measures or indicators of endogenous or exogenous causes. The most advanced studies of infant and child mortality rely on biometric variables like birthweight, mother's nutritional status, duration of breastfeeding (Knodel and Kintner 1977, Kuate Defo 1997, Sear 2001). Such analyses give quite accurate picture of infant mortality since mentioned factors are the best predictors of mortality especially during the early stages of life.
Unfortunately, researchers working with data coming from historical or traditional contemporary populations usually do not have detailed biometric information on the newborn child or mother. In fact, it is impossible, to reconstruct such information for historical European populations in order to obtain database for the quantitative analysis. The only exceptions here are the studies of breastfeeding habits, which usually show that early weaning leads to sharp increase in infant mortality (Forste 1994, Knodel and Kintner 1977, Manda 1999, Rosenberg 1989).

Due to these obvious limitations, researchers working with the historical data had to find alternative measures and correlates in order to describe the patterns of infant mortality. These measures, which can be easily calculated on the basis of historical data, indirectly reflect the condition of the index child as well as the mothers' condition.
The present analysis aimed at including all those covariates that could be created on the basis of the parish register reconstitution database. To our knowledge, present study of infant and early childhood mortality is the only one based on historical data using such rich set of covariates. Although these alternative measures are far from being free from many distortions, they show surprisingly constant patterns across populations and time.

The effect of the birth rank and birth interval has been analyzed in many historical and tradition populations bringing quite consistent results (Boerma and Bicego 1992, Cohen 1975, Knodel and Hermalin 1984, Miller et al. 1992, Modin 2002, Palloni and Millman 1986, Pebley et al. 1991, Retel-Laurentin and Benoit 1976). The results of the current study bring quite similar results. Usually short birth intervals (preceding and subsequent to the birth of an index child) decrease the survivorship. This is associated with the fact that closely spaced children usually experience shorter breastfeeding, which in turn influences nutritional status and survival. The effect of birth rank, besides mentioned already increased risk of transmission of infectious disease, lies also in the fact that having many siblings means shorter birth intervals. Thus, as noted by Knodel and Hermalin (1984: 1102), the strong relation between infant and early childhood mortality and the birth rank (or ultimate number of children) might be mediated by the length of birth intervals, breastfeeding patterns, genetic causes and combination of family resources and parental care practices. Moreover, mothers who have experienced many pregnancies might exhibit so-called mother's depletion syndrome, which is typical when a woman do not have time to recover both physically and nutritionally which might result in more frequent pregnancy losses and lower birth weight babies (Jelliffe and Maddocks 1964).

However, not only the impact of so called demographic variables influences the survival at young ages. As shown in the present study presence of the grandparents (both maternal and paternal) might greatly enhance infant's survival. This research direction focuses on investigation of the effect of extended family in the context of infant and early childhood mortality because of its' importance from the perspective of evolutionary approach to human reproductive behaviour (Beise and Voland 2002, Sear et al. 2000, Voland and Beise 2001). From this perspective, increased survival of grandchildren provides a rationale for the evolutionary origins of menopause in humans (Hawkes 2003, Shanley and Kirkwood 2001). If post-reproductive females are able to increase the survivorship of their grandchildren, they are contributing indirectly to their widely understood inclusive fitness.

Apparently, not only purely demographic variables affect the endogenous mortality factors. Other factors like birth season and cohort have well proven effect. In all populations, which underwent demographic transition this process was associated with improvement in infant survival, which subsequently led to changes in reproductive behaviour. Both in historical and traditional populations improvement in infant survival was associated with proliferation of professional medical care and popularization of hygiene (Morel 1991). Therefore most of the studies, which cover the period of demographic transition, show substantial improvement in infant survival in time and the present study is no exception.

All these variables included into model of infant and early childhood mortality allowed accounting for the interactions between endogenous and exogenous causes of morality. Although it is not possible in most of the historical studies to account for the bio-medical factors, the effect of above described variables is surprisingly coherent across many studies, populations and époques. Therefore, it could be assumed that these "proxy" variables accurately describe long term, and possibly universal correlates of mortality at young ages in many historical and traditional populations. It has to be mentioned that besides these mechanisms the levels of infant mortality were greatly influenced by short term shocks like famines or epidemics (Cotts Watkins and Menken 1985, Scott et al. 1995). These short-term shocks had an effect on infant survival, developmental conditions and also on future reproduction and maturation (Lummaa 2003).

The analyses presented in this paper present very simple model of infant and early childhood mortality with the use of wide scope of covariates, which might reflect both endogenous and exogenous causes of mortality. This was done in order to present an overview on the patterns and the correlates of mortality at young ages. From this perspective presented analyzes might be an excellent starting point for more sophisticated investigations of the presented covariates. This includes various interactions between studied covariates which might reveal more detailed patterns of infant mortality. Moreover, presented usefulness of the Bejsce data might provoke further comparative analyses with the data coming from other European historical populations.

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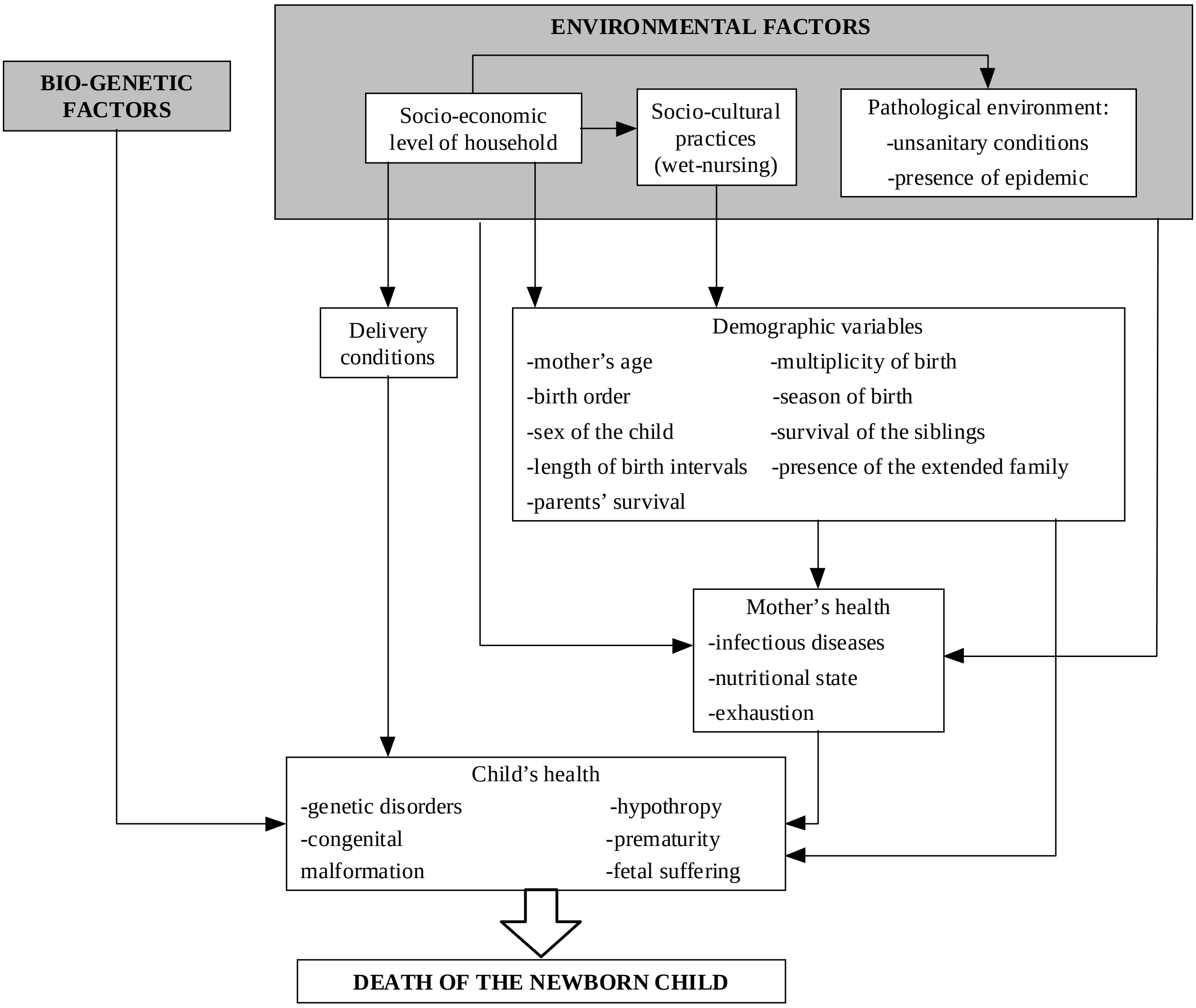
FIGURE 1. Conceptual framework for analyzing the interrelation between endogenous and exogenous determinants of mortality at young ages in historical populations.



Source: Modified from (Lalou, 1997: 206)

FIGURE 2. Probability of dying by sex and age of child over first 5 years of life. Calculated for the total sample from the reconsitution of Bejsce parish registers.

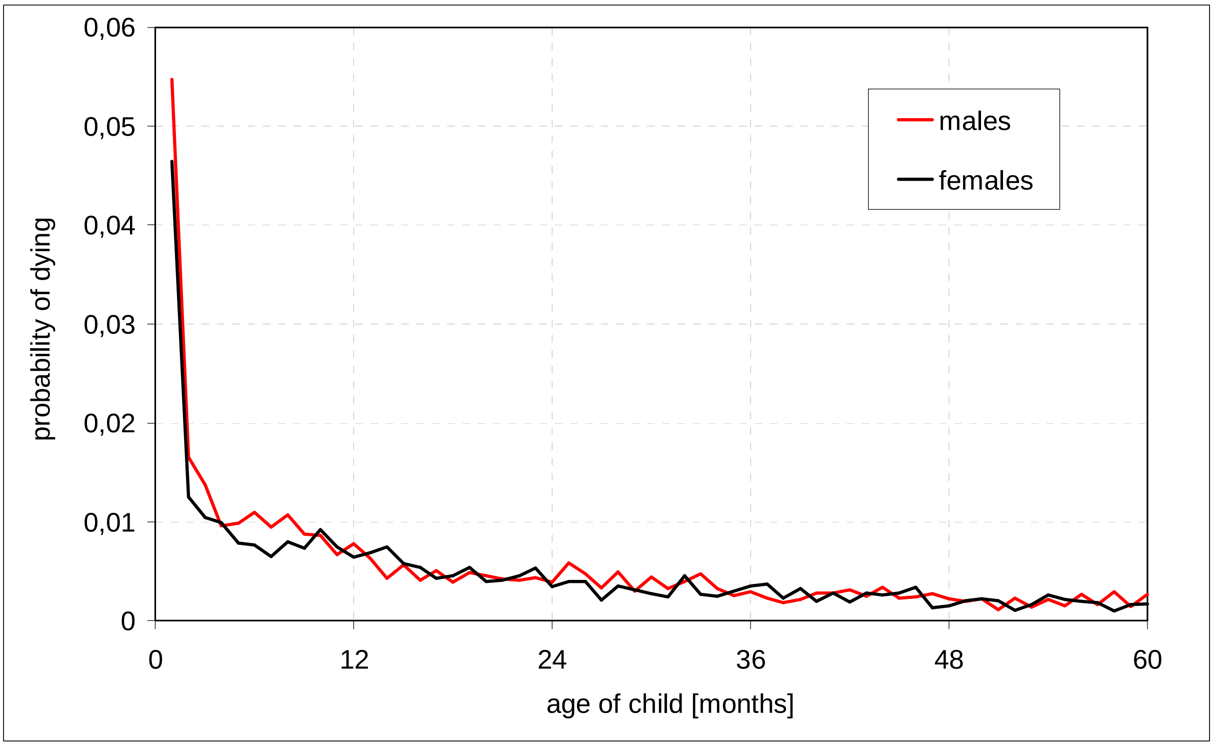


FIGURE 3. Mortality of children in first 60 months of life. Kaplan-Meier estimate of survivor function with respect to sex of child.

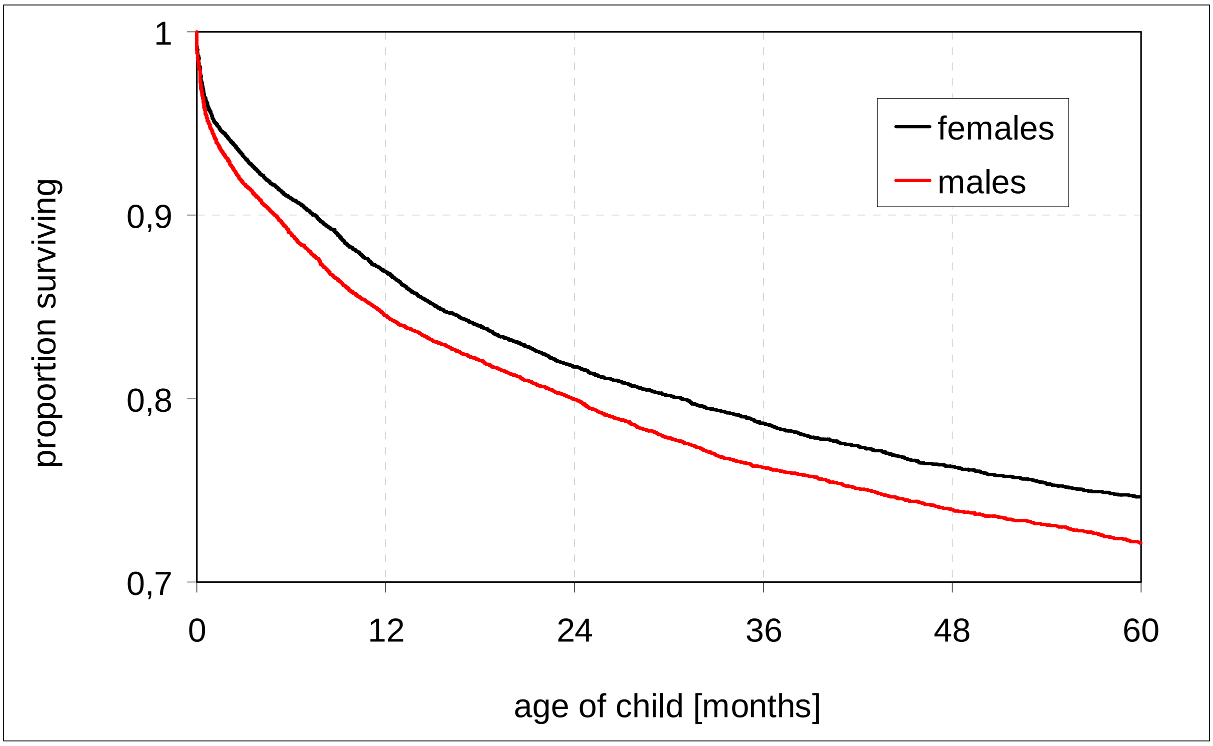


FIGURE 4. Mortality of children in first 60 months of life. Kaplan-Meier estimate of survivor function with respect to birth cohort of child.

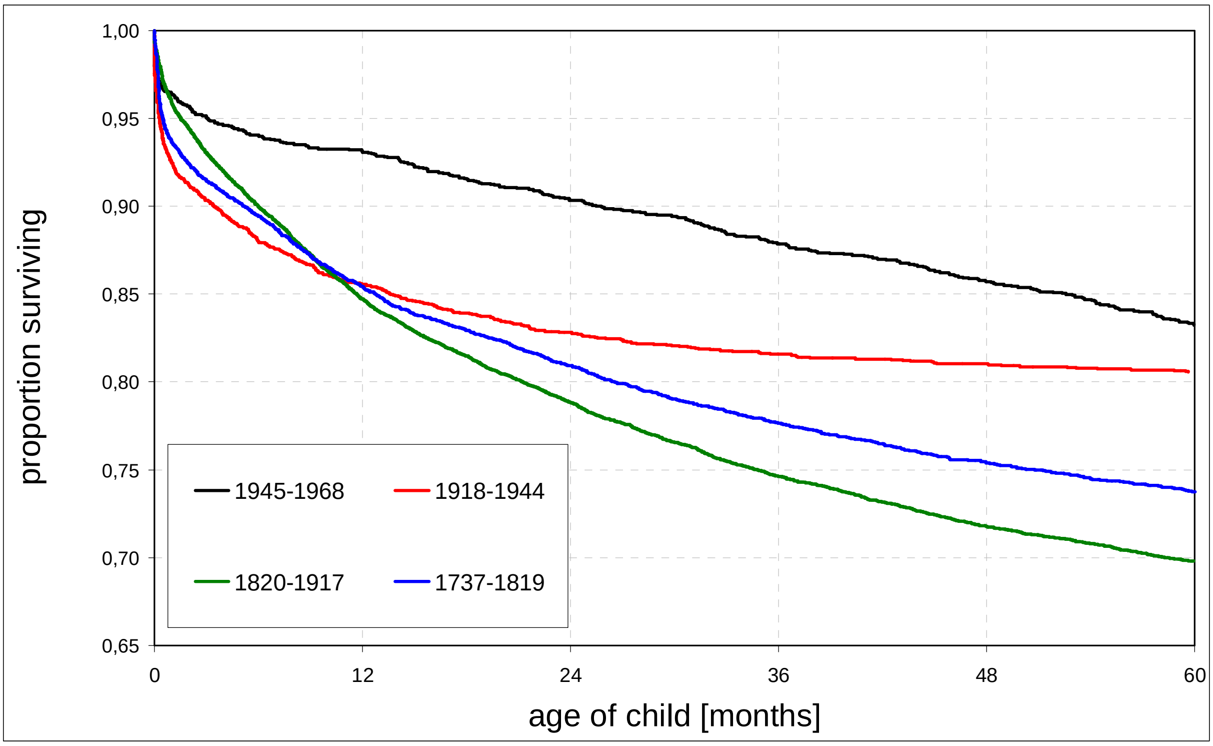


TABLE 1. Statistical description of the sample and the variables on which the following analyses are based.

	Number of cases at risk	*Number of events*
Total	18997	6785
Baseline: age of child (in months)[1]		
0-1	17804	1193
1-6	16503	1301
6-12	15410	1093
12-24	14152	1258
24-36	13267	885
36-60	12212	1055
Sex of the child		
Male	9701	3676
Female	9296	3109
Age of mother at birth		
15-25	3430	1263
26-34	5411	2048
35-50	3141	1351
Missing information	7015	2123
Multiple birth		
Yes	532	257
No	18465	6528
Birth rank		
1	5278	1626
2-3	6716	2193
4≥	7003	2966
Season of birth		
Winter	5273	1851
Spring	4677	1627
Summer	4347	1597
Autumn	4700	1710
Birth cohort of the child		
1737-1819	4844	1725
1820-1917	9577	4108
1918-1944	2819	619
1945-1968	1757	333

	Number of cases at risk	*Number of events*
Length of the subsequent birth interval		
Less than 22 months	2366	2124
More than 22	5270	1686
Missing information	11361	2975
Length of preceding birth interval (months)		
Less than 24	3321	1207
24-48	7907	3109
More than 48	2412	795
Missing information	5357	1674
Survival status of the previous sibling		
Survived	18095	6358
Died	902	427
Presence of the maternal grandmother		
Alive	3753	1341
Died	4600	1771
Missing information	10644	3673
Presence of the maternal grandfather		
Alive	2673	1073
Died	6153	2177
Missing information	10171	3535
Presence of the paternal grandmother		
Alive	2775	987
Died	5698	2094
Missing information	10524	3704
Presence of the paternal grandfather		
Alive	1846	704
Died	7112	2547
Missing information	10039	3534
Presence of mother		
Alive	10434	3702
Died	1548	961
Missing information	7015	2122
Presence of father		
Alive	14270	4931
Died	4259	1583
Missing information	468	271

[1]Age intervals inclusive the left border and exclusive the right border.

FIGURE 5. Baseline risk of mortality over first 60 months of life, by sex.

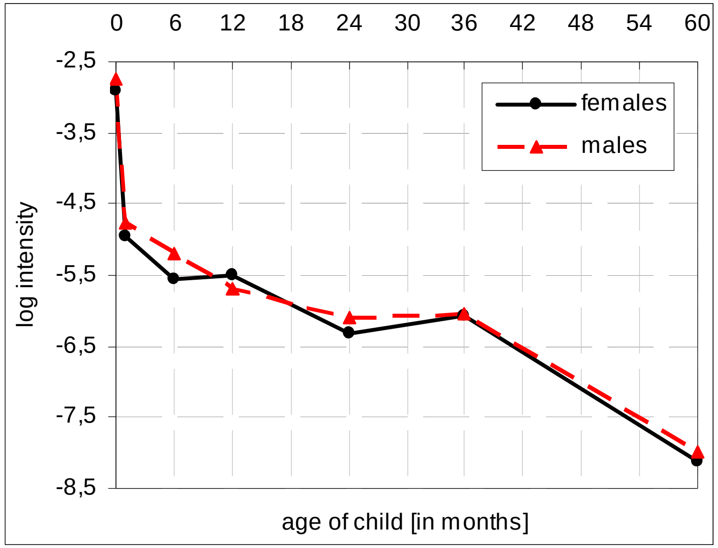


FIGURE 6. Baseline risk of mortality over first 12 months of life, by sex.

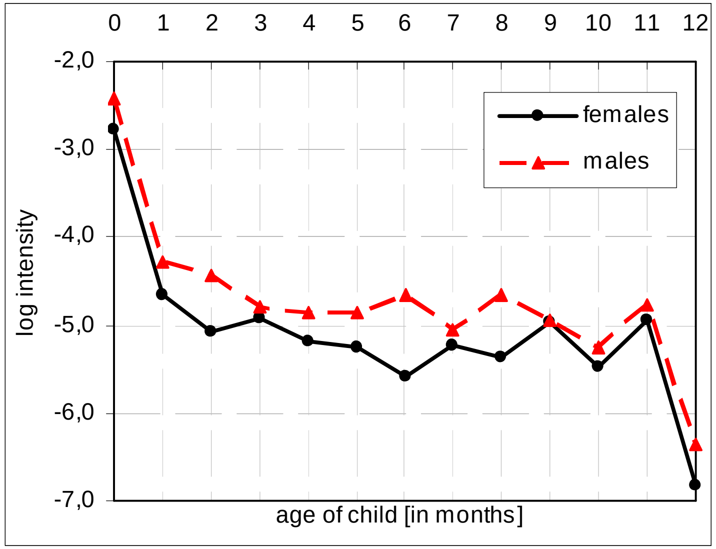


FIGURE 7. Baseline risk of mortality over 12-60 months of life, by sex.

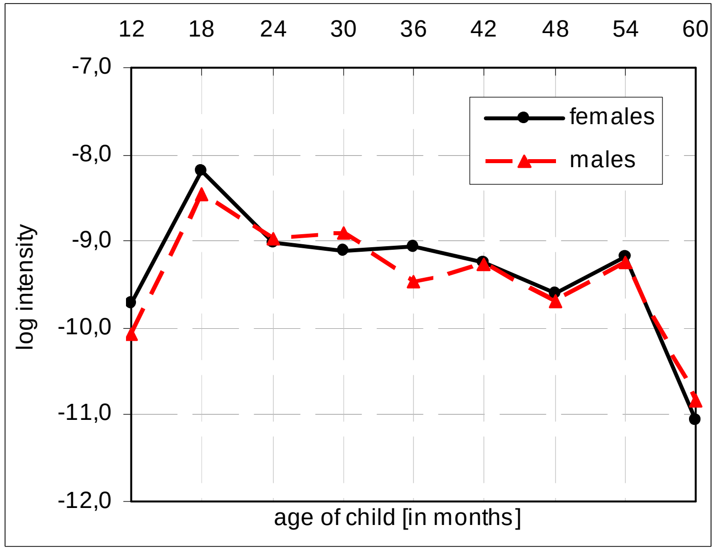


TABLE 2. Multilevel hazard model of mortality over first 60 months of life. All parameters refer to relative risks (exp β) except for baseline and unobserved heterogeneity parameter.

	exp(β)	S.E.
Baseline: age of child (in months)		
Intercept	-2,80***	*0,178*
0-1	-2,04***	*0,062*
1-6	-0,10***	*0,013*
6-12	-0,04***	*0,010*
12-24	-0,05***	*0,005*
24-36	0,01**	*0,006*
36-60	-0,08***	*0,004*
Sex of the child		
Male (ref. cat.)	1	
Female	0,88***	*0,025*
Age of mother at birth		
15-19	1,45 ***	*0,095*
20-25	1,05	*0,041*
26-34 (ref. cat.)	1	
35-50	1,01	*0,040*
missing information	0,77 ***	*0,047*
Multiple birth		
Yes	1,40***	*0,064*
No (ref.cat.)	1	
Birth rank		
1 (ref. cat.)	1	
2-3	1,26	*0,169*
4≥	1,52**	*0,168*
Length of preceding birth interval (months)		
Less than 24	0,96	*0,035*
24-48 (ref. cat.)	1	
More than 48	0,99	*0,041*
missing information	*1,22*	*0,166*
Survival status of the previous sibling		
Survived (ref. cat.)	1	
Died	1,83***	*0,060*

	exp(β)	S.E.
Presence of the maternal grandmother		
Alive (ref. cat.)	1	*0,043*
Died	1,08 *	
missing information	*1,13 ****	*0,047*
Presence of the maternal grandfather		
Alive (ref. cat.)	1	*0,045*
Died	1,31 ***	
missing information	*1,25 ****	*0,046*
Presence of the paternal grandmother		
Alive (ref. cat.)	1	*0,044*
Died	1,14 ***	
missing information	*1,08 **	*0,041*
Presence of the paternal grandfather		
Alive (ref. cat.)	1	*0,048*
Died	1,22 ***	
missing information	*1,07 **	*0,041*
Season of child's birth		
Winter (ref.cat)	1	
Spring	1,01	*0,034*
Summer	0,94 *	*0,034*
Autumn	1,03	*0,035*
Presence of mother		
Alive (ref. cat.)	1	
Died	1,66 ***	
missing information	*1,02*	*0,028*
Presence of father		
Alive (ref. cat.)	1	
Died	1,07	*0,033*
missing information	*1,67*	*0,07*
Birth cohort of the child		
1737-1819 (ref. cat.)	1	
1820-1917	1,17 ***	*0,039*
1918-1944	0,66 ***	*0,054*
1945-1968	0,54 ***	*0,064*
Unobserved heterogeneity	0,424 ***	*0,025*

NOTE: Asymptotic standard errors in the right column; Significance: '*'=10%; '**'=5%; '***'=1%.

TABLE 3. Multilevel hazard model of infant mortality (over first 12 months of life). All parameters refer to relative risks (exp β) except for baseline and unobserved heterogeneity parameter.

	exp(β)		S.E.
Baseline: age of child (in months)			
Intercept	-2,530	***	*0,102*
0-1	-1,866	***	*0,083*
1-2	-0,263	**	*0,106*
2-3	-0,131		*0,127*
3-4	-0,161		*0,133*
4-5	-0,034		*0,141*
5-6	0,001		*0,148*
6-7	-0,105		*0,149*
7-8	0,170		*0,144*
8-9	0,014		*0,144*
9-10	-0,390	**	*0,157*
10-11	0,510	***	*0,169*
11-12	-1,721	***	*0,213*
Sex of the child			
Male (ref. cat.)	1		
Female	0,83	***	*0,035*
Age of mother at birth			
15-19	1,46	***	*0,127*
20-25	0,99		*0,056*
26-34 (ref. cat.)	1		
35-50	1,06		*0,054*
missing information	0,89	*	*0,064*
Birth rank			
1 (ref. cat.)	1		
2-3	0,96		*0,046*
4≥	1,18	***	*0,051*
Length of preceding birth interval (months)			
Less than 24	0,99		*0,039*
24-48 (ref. cat.)	1		
More than 48	0,98		*0,051*
Missing information	*1,03*		*0,033*

	exp(β)		S.E.
Presence of the maternal grandmother			
Alive (ref. cat.)	1		
Died	1,20	***	*0,057*
Missing information	*1,04*		*0,063*
Presence of the maternal grandfather			
Alive (ref. cat.)	1		
Died	1,49	***	*0,059*
Missing information	*1,24*	***	*0,064*
Presence of the paternal grandmother			
Alive (ref. cat.)	1		
Died	1,24	***	*0,060*
Missing information	*1,00*		*0,056*
Presence of the paternal grandfather			
Alive (ref. cat.)	1		
Died	1,38	***	*0,065*
Missing information	*1,10*	*	*0,055*
Season of child's birth			
Winter (ref.cat)	1		
Spring	1,03		*0,047*
Summer	0,85	***	*0,047*
Autumn	1,05		*0,048*
Presence of mother			
Alive (ref. cat.)	1		
Died	1,59	***	*0,056*
Missing information	*0,98*		*0,031*
Presence of father			
Alive (ref. cat.)	1		
Died	1,11	**	*0,033*
Missing information	*1,73*	***	*0,094*
Birth cohort of the child			
1737-1819 (ref. cat.)	1		
1820-1917	0,95		*0,055*
1918-1944	0,77	***	*0,069*
1945-1968	0,33	***	*0,103*
Unobserved heterogeneity	0,558	***	*0,033*

NOTE: Asymptotic standard errors in the right column; Significance: '*'=10%; '**'=5%; '***'=1%.

TABLE 4. Multilevel hazard model of child mortality (between 12 and 60 months of life). All parameters refer to relative risks (exp β) except for baseline and unobserved heterogeneity parameter.

	exp(β)		S.E.
Baseline: age of child (in months)			
Intercept	-10,01	***	*0,266*
12-18	0,260	***	*0,017*
18-24	-0,113	***	*0,015*
24-30	0,001		*0,017*
30-36	-0,047	***	*0,018*
36-42	0,000		*0,019*
42-48	-0,064	***	*0,021*
48-54	0,072	***	*0,023*
54-60	-0,285	***	*0,030*
Sex of the child			
Male (ref. cat.)	1		
Female	0,97		*0,036*
Age of mother at birth			
15-19	1,24	***	*-0,014*
20-25	1,05		*-0,049*
26-34 (ref. cat.)			
35-50	1,13	**	*-0,050*
missing information	0,59	***	*-0,044*
Multiple birth			
Yes	1,44	***	*0,064*
No (ref. cat.)	1		
Birth rank			
1 (ref. cat.)	1		
2-3	0,93		*0,051*
4≥	1,09		*0,055*
Length of preceding birth interval (months)			
Less than 24	1,11	**	*0,044*
24-48 (ref. cat.)	1		
More than 48	0,94		*0,051*
Missing information	*0,77*	***	*0,038*
Length of the subsequent birth interval			
Less than 22 months	1,15	***	*0,024*
more than 22 (ref.cat)	1		
missing information	*1,25*	***	*0,034*

	exp(β)		S.E.
Survival status of the previous sibling			
Survived (ref. Cat.)	1		
Died	1,83	***	*0,060*
Presence of the maternal grandmother			
Alive (ref. cat.)	0,94		*0,057*
Died	1		
Missing information	*1,20*	***	*0,054*
Presence of the maternal grandfather			
Alive (ref. cat.)	1		*0,060*
Died	1,10		
Missing information	*1,24*	***	*0,052*
Presence of the paternal grandmother			
Alive (ref. cat.)	1,02		*0,062*
Died	1		
Missing information	*1,16*	***	*0,054*
Presence of the paternal grandfather			
Alive (ref. cat.)	1,01		*0,070*
Died	1		
Missing information	*1,02*		*0,055*
Season of child's birth			
Winter (ref.cat)	1		
Spring	0,90	***	*0,041*
Summer	0,87	***	*0,043*
Autumn	0,90	**	*0,041*
Presence of mother			
Alive (ref. cat.)	1		
Died	1,56	***	*0,055*
Missing information	*1,00*		*0,042*
Presence of father			
Alive (ref. cat.)	1		
Died	1,21	***	*0,044*
Missing information	*1,37*	***	*0,100*
Birth cohort of the child			
1737-1819 (ref. cat.)	1		
1918-1944	0,45	***	*0,085*
1945-1968	0,82	***	*0,073*
Unobserved heterogeneity	0,415	***	*0,043*

NOTE: Asymptotic standard errors in the right column; Significance: '*'=10%; '**'=5%; '***'=1%.