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Short Birth Intervals and Child Health in India

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ABSTRACT

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The association between close birth spacing and child mortality is well established, especially in developing countries. Although academic research has previously been conducted to quantify and explain the relationship, many uncertainties remain. This thesis explores the pathways through which short birth intervals affect child survival using two main approaches. The first, is to analyse the effects of birth spacing on child nutritional status, using anthropometric assessment of children from the state of Karnataka, India. Two complimentary data sets are used. The 1992-93 NFHS for Karnataka is a large cross-sectional survey providing statistical power across individuals with which to identify correlates and explore the effect of short birth intervals. The maternal and child health survey is longitudinal thus facilitating the analysis of temporal effects. As well as the substantive results this thesis also provides an example of the application of statistical models for the analysis of longitudinal data and contrasts the results with that of the cross-sectional analysis. The second approach used to investigate causal pathways within the relationship between short birth intervals in child survival is to conduct a detailed analysis of mediating factors within the relationship. The 1992-93 NFHS for the whole of India is used to explore the interactions between the effects of short birth intervals and other covariates, on child mortality. Multilevel modelling techniques are used to allow for the hierarchical structure of the data.

The results show that short birth intervals are significantly associated with child weight measurements and that the effect varies with the age of the child. Whilst there is little effect at birth, the nutritional status of children following short birth intervals declines towards the end of the first year of life and during early childhood, increasing the deficit between those following longer intervals. The results support the hypothesis that exogenous factors associated with close birth spacing are unfavourable to the welfare of the child particularly during the vulnerable late post-neonatal period when the child is weaned and becomes more mobile.

Short birth intervals were also found to be significantly associated with infant and early childhood mortality. The effect was strongest in the early post-neonatal period. Significant interactions were identified between short birth intervals and maternal education, the gender or the child and the survival status of the previous sibling. The detrimental effect of short birth intervals is thus exacerbated by the accumulation of adverse circumstances such as maternal illiteracy or female gender (where gender discrimination occurs). Conversely the effects are diluted in favourable circumstances such as high maternal education or where the previous sibling dies removing the need to compete for resources or maternal care and attention. These results again demonstrate the importance of exogenous pathways within the relationship.

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CHAPTER 1

Introduction

1.1 The Health Consequences of Short Birth Intervals

Childbearing patterns, which increase the mortality risk for the infant have been a focus of research for some time. Such patterns are commonly termed "risky reproductive behaviour" and include child bearing at very young ages, close birth spacing and high parity (NFHS India, 1992). In particular, the association between short birth intervals and child mortality has received much attention. Analyses have consistently confirmed this relationship across a number of countries of different socio-economic and cultural setting (Hobcraft et al., 1985; Miller, 1992). Short birth intervals commonly refer to intervals of less than two years between births. However, some authors have analysed shorter intervals and the results generally confirm that the shorter the interval the stronger the relationship. The detrimental effect is most marked for the child succeeding the short interval, although the preceding child also suffers to some extent (Koenig, 1990).

In theory the excess mortality caused by short birth intervals is avoidable and thus reductions in infant and child mortality could be attained through appropriate family planning. Indeed family planning programmes have developed initiatives to increase birth spacing as a method of promoting maternal and child health. However, despite such initiatives, birth intervals of less than 24 months have remained highly prevalent in many countries. Apart from the logistics of making contraceptives freely available to all, social, cultural or other barriers prevent optimum childbearing patterns for maternal and child health. Furthermore, it is likely that short birth intervals will increase in some communities as they develop economically. In the early stages of economic development, changes occur in traditional patterns of behaviour which are not always immediately followed by the adoption of the alternative "modern" way of life. For example, women tend to breast-feed for shorter durations as a result of lifestyle changes accompanying economic development, a time lag may occur, however, before the full acceptance and availability of modern contraceptive methods. As breast-feeding is a natural mechanism which spaces pregnancies women who breast-feed for shorter durations would be more likely to have short birth intervals.

1.2 Competing Theories

If the harm suffered by mothers and their children as a result of short birth intervals is to be minimised it is crucial that knowledge is generated concerning the mechanisms of the relationship so that appropriate health promotion and preventative interventions can be developed. Although academic research over the past two to three decades has sought to quantify and explain the relationship, many uncertainties remain concerning its causal pathways. The main debate at present concerns three main mechanisms:

1) Maternal depletion

According to this hypothesis short birth intervals (less than two years) do not allow the mother sufficient time in a non-pregnant, non-lactating state in order to replete her nutritional status (Winkvist, 1992; Miller et al., 1994). The child succeeding the short interval is thus disadvantaged as a result of foetal malnutrition and a compromised intrauterine environment. This results in failure to thrive during childhood and a greater risk of ill health or death.

2) Sibling rivalry

If there are two or more young children close in age within a family, it is necessary for them to compete for resources and for maternal care and attention. This could impact on the nutritional status, particularly of the younger child, on the incidence of morbidity, and on higher fatality from illness and accidents (Boerma and Bicego, 1992; Alam, 1995). The heavy workload of the mother may reduce her ability to attend health care sessions both during pregnancy and following the birth. She may also be less able to monitor her children effectively and may miss early signs of illness, etc. This could be exacerbated in communities where women suffer low status during the early stages of their marriage when their autonomy is low and they are less able to make decisions concerning childcare.

3) Exposure to infectious disease

This concerns an increased exposure to infectious disease suffered by the younger child. The older sibling of a short birth interval is at an age in which infectious disease is particularly prevalent, i.e. around two years, whilst the younger child is vulnerable because the immunity acquired from the mother declines. At this stage the infant has not yet fully acquired his/her own immunity. Furthermore, secondary cases of disease have frequently been shown to be particularly severe, such as with measles and chicken pox. The younger child of the interval is usually the secondary case of infection (Boerma and Bicego, 1992).

A number of authors have claimed evidence of either maternal depletion or sibling rivalry in their analyses. One method used to identify mechanisms is to examine the strength of the relationship at different periods during infancy (Koenig et al., 1990; Boerma and Bicego, 1992). If the association is stronger in the neonatal period, it is claimed that maternal depletion is the causal mechanism. Conversely, if the association is stronger in the toddler or childhood period, sibling rivalry is thought to be the causal mechanism. This is because neonatal deaths are thought to be related to prenatal factors and post-neonatal or toddler deaths to exogenous factors. However, the results of these analyses have tended to be inconsistent and have failed to provide conclusive evidence.

Another method used to indicate mechanisms is to eliminate causes. If, for example the previous sibling dies, there is no longer a need to compete for resources or for maternal care and attention. So if the relationship is attenuated by the death of the previous sibling then, sibling rivalry is thought to be the causal mechanism. Analyses have generally found evidence that this is the case in later infancy or in childhood but not during the neonatal period (Alam, 1995; Curtis, 1991).

Finally some authors have taken the more direct approach of analysing the association between birth spacing patterns and a measure of the mechanism itself. Miller et al. (1996), for example, looked for evidence of maternal depletion in the weight change of the mother over the reproductive cycle. They found that there was evidence of lower pre-pregnancy weight in women who had short birth intervals. Fikree and Berendes (1994) found short birth to conception intervals to be a significant risk factor of intrauterine growth retardation. Finally, Boerma and Bicego (1992) looked for evidence of changes in a number of different outcomes including infant anthropometric measures, infant morbidity, health care utilisation and breast-feeding behaviour. However, they claimed their results provided little evidence to support the sibling rivalry hypothesis.

Overall, most analyses concerning birth spacing have focused on the relationship between short intervals and infant mortality. Very little research has considered the effects on the health and morbidity of the child. Analyses which have sought to identify causal mechanisms have either looked for mediating factors within the relationship, or have assessed the association between birth spacing and a measure of the mechanism itself. The results of these analyses have to a large extent depended on the approach used, and have claimed evidence of either sibling rivalry or maternal depletion with no real consistency. There is thus a need for more research into the effects of birth spacing, particularly on the health of the child and the potential roles of social, economic and behavioural factors during infancy.

1.3 Objectives of the Study

The main objective of this thesis is to investigate the causal pathways of the relationship between short birth intervals and infant survival. Two approaches are adopted, the first is to analyse the effects of birth spacing on infant health, rather than mortality, and the second is to focus on mediating factors within the relationship.

The analysis of infant health will provide a direct and sensitive indication of circumstances which are disadvantageous to the wellbeing of the child. Anthropometric assessment is a useful health indicator for such analyses. Whilst height or length measurements reflect the long-term nutritional status of the child, weight measurements also reflect more recent influences. Lower than expected values are indicative of failure to thrive usually resulting from inadequate diet and/or incidence of morbidity. Two data sets are used: the 1992-93 National Family Health Survey (NFHS) for Karnataka, India and the Maternal and Child Health Survey for Kanakpura Taluk (collected by the Belaku Trust, Bangalore). The NFHS for Karnataka is a large, cross-sectional survey and includes weight measurements for children between birth and the age of 36 months. This allows the effect of birth intervals to be assessed for children of each successive age group (i.e. age in months). An examination is also undertaken of the role of other factors acting within the relationship between birth intervals and weight measurements. For example, the average weight at different age groups can be compared by the gender of the child. A limitation of using cross-sectional data to analyse the anthropometric status of children, however, is that growth curves are synthetic in nature and thus statements cannot be made concerning change over time without making fundamental assumptions which rule out any cohort effects.

The Maternal and Child Health Survey is longitudinal and consists of weight measurements recorded monthly for infants throughout the first year of life. It thus allows the change in anthropometric status to be examined and provides a more sensitive indicator of circumstances in which a child to thrives less well. The advantage of this approach is that the effects of short birth intervals can be assessed throughout the first year of life and in relation to other covariates. This may answer questions such as "is the average weight gain over the first year of life different for children who follow short birth intervals than for those who follow longer birth intervals?" Also, "at what age does the disadvantage associated with short birth intervals start to take effect?"

The overall aim of these analyses is to investigate the effect of birth spacing on the weight attainment of children in the State of Karnataka, India. The larger, cross-sectional data set provides statistical power across individuals and allows the relationship to be analysed for children of successive age groups between birth and 36 months. The longitudinal data adds a further dimension in that it facilitates the analysis of weight change, but includes fewer children and up to one year of age only. The growth curves attained, however, provide a 'yard stick' with which to assess the impact of omitting cohort effects in the synthetic growth curves attained from the cross-sectional data. The reliability of making statements concerning weight change during the second and third years of life, based upon these synthetic growth curves can thus be assessed.

One problem with analysing infant athropometric status is that the data includes only surviving children and thus the effect of short birth intervals on infants who subsequently die, are lost. An analysis is conducted of neonatal and early childhood mortality, using the 1992-93 NFHS for Karnataka. This demonstrates the relationship between short birth intervals and mortality in the same state as used for the analysis of child anthropometric status. An assessment is then made of the potential bias caused by the self-selective nature of the anthropometric data.

The second approach used in the investigation of causal mechanisms is to conduct a detailed analysis of mediating factors within the relationship between birth spacing and child mortality. The 1992-93 NFHS for the whole of India, is used for this analysis. This extensive data set provides considerable strength of inference across individuals and thus facilitates a detailed examination of interactions between the effect of birth intervals and other covariates. This enables the mediating influence of factors such as maternal education and socio-economic status to be assessed within the relationship between short birth intervals and infant mortality.

The main focus of the thesis concerns the empirical results, however, an additional objective includes the practical application of statistical models for the analysis of longitudinal data. Although considerable work has been conducted to develop statistical methodology that allows for the particular characteristics and structure of longitudinally collected data, it has not yet been widely used. This analysis, therefore, provides a practical example of the application of such methods in the assessment of child anthropometric status. The selection of the most appropriate model is discussed with a practical demonstration of how alternative models apply to the data. Also, by making a direct comparison between the cross-sectional and longitudinal analyses, specific information is provided concerning the use of each approach, as well as their advantages and disadvantages.

1.4 India as a Setting for the Analysis of Birth Intervals and Child Health

India provides an interesting setting in which to conduct this research. It has demonstrated creditable economic growth over recent decades and its achievements have included the emergence of a large scientific community. The Gross Domestic Produce (GDP) for India compares well with that of other countries in South Asia and has demonstrated a 3% average annual increase between 1975 and 1998 (Human Development Report, 2000). India has also demonstrated substantial progress in terms of social welfare, with declines in age specific mortality rates and an increase in the expectation of life at birth. Life expectancy at birth increased from 50.3 years in 1970-1975 to 62.6 years in 1995-2000 (Human Development Report, 2000). Nevertheless social policies relating to the expansion of basic education and health care have been less progressive. India demonstrates particularly high levels of illiteracy in comparison to other developing or newly developed countries. The literacy rate of adults, aged 15 or over, was 56% in 1998, whilst the average for all countries classified as having attained medium levels of human development was considerably higher at 77%. Furthermore, considerable gender differences remain with the literacy rate of women, aged 15 or over, being only 44%, whilst that for males is 67%. These relatively low rates are reflected in the human development index (HDI), which is used to measure the average achievements in basic human development in different countries; India ranks 128 of 174 countries. The ranking of the HDI is less favourable than that of the GDP indicating lower than expected social development given the level economic development (Human Development Report 2000).

Indicators of infant and child welfare have also fallen behind those of other developing countries. The infant mortality rate for 1998 was 69 deaths per 1,000 births and the under 5 mortality rate 105 per 1,000 births. Although these are half that of the rates for 1978, reflecting admirable improvements in infant and child welfare, they are above the average rates for all developing countries, 64 and 93 deaths per 1,000 live births respectively (Human Development Report 2000). Even more marked, are the particularly high rates of underweight children within India. Thirty three percent of infants were classified as having low birth weight and 53% of children under 5 years of age were classified as being underweight. These rates are high even compared with countries classified as being of low human development, for which the average rates are 16% and 39% respectively (Human Development Report, 2000).

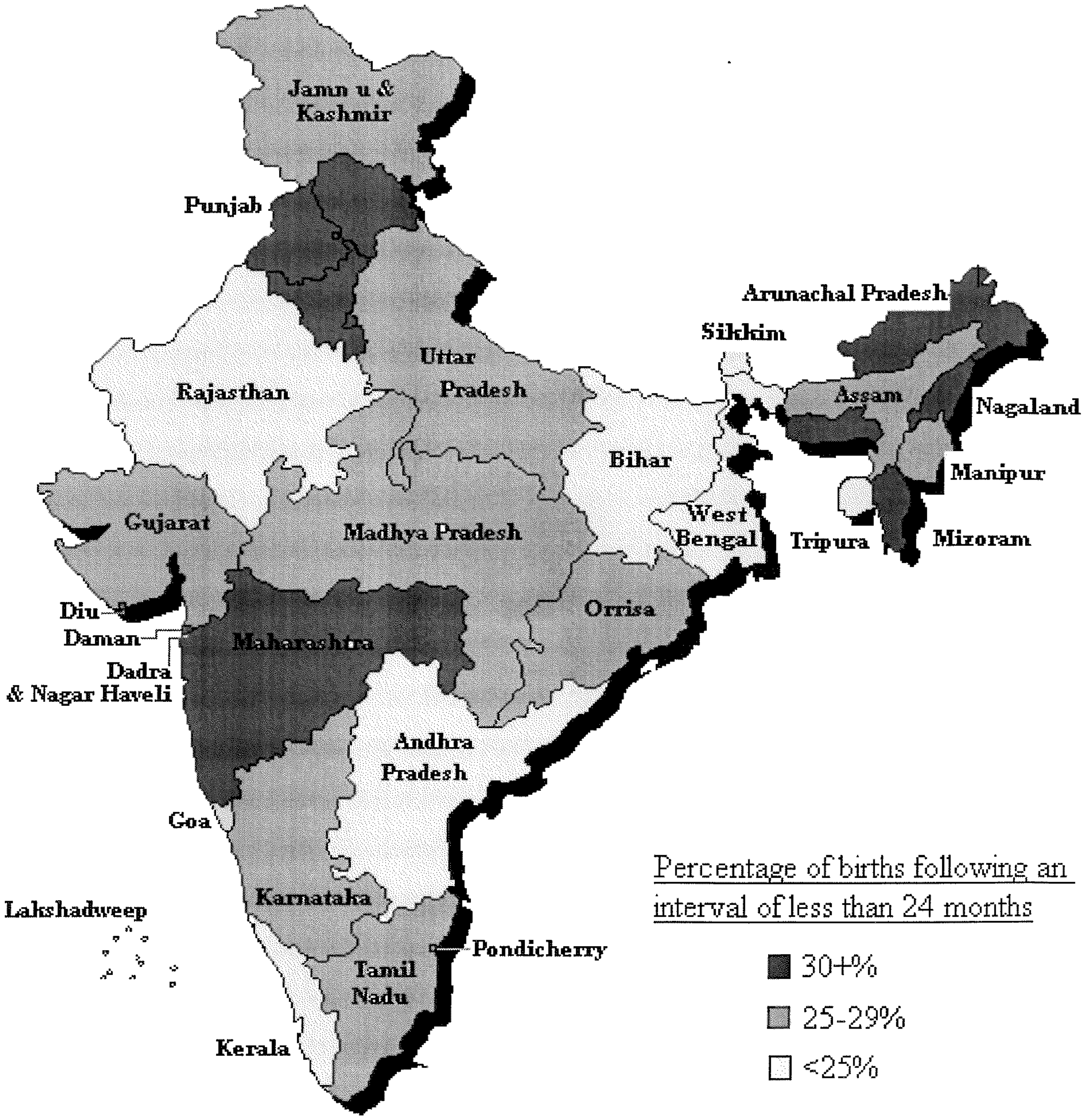
India has demonstrated a fairly sharp decline in fertility from 5.4 births per woman in 1970-75 to 3.1 in 1995-2000 (Human Development Report, 2000). The NFHS for India (1992-93) showed that forty one percent of currently married women, aged 15-49 years were using a method of contraception and that the most widely used method was female sterilisation, which was accepted by 67% of current users. Government family planning programmes actively promoted sterilisation during the 1970's as part of an initiative to stem rapid population growth and promote economic development. The termination of the reproductive life span has thus been the main focus of family planning activities with little attention given to the use of modern methods for spacing births. Furthermore, sterilisation has been conducted at early ages; 36% of sterilised women underwent the operation before the age of 25 years and a further 36% between the ages of 25 and 29 years (NFHS India 1992-93). Child bearing has been concentrated into the early years following marriage with close and frequent birth spacing. Overall 27% of second or higher order births follow an interval of less than 24 months and 12% follow very short intervals of less than 18 months.

Short birth intervals are thus highly prevalent in India. Not only this, but the wider socio-economic circumstances leave many children particularly vulnerable. Underlying levels of child malnutrition are particularly high and social conditions, such as low levels of maternal education, are unfavourable for child survival. Such circumstances are likely to exacerbate any disadvantage caused by close birth spacing. India, therefore, provides a setting which not only facilitates detailed research into the relationship between short birth intervals and child health, but also in which considerable benefits could be gained from a greater understanding of the mechanisms within the relationship. India has demonstrated progressive achievements in economic and welfare developments over recent decades and has potential for promoting child health further.

This study focuses on the State of Karnataka for the analysis of anthropometric status. Because of its geographical location, Karnataka became the meeting place of the northern and the southern cultural currents, resulting in their synthesis (NFHS for Karnataka, 1992-93). Karnataka is economically diverse generating income from both agricultural production, and industry. The industrial sector is progressive and has been particularly successful in electronics accounting for nearly 20% of the total output for the country. Karnataka demonstrates fairly average indicators in terms of demographic and social welfare. The female literacy rate is 54% for Karnataka compared with 57% for India as a whole (NFHS for India 1992-93). Infant and child mortality rates are below average but not unusually low (65 and 24 per 1,000 live births, respectively in Karnataka and 79 and 33 in India). Figure 1.1 demonstrates the prevalence of short birth intervals within the states of India. Karnataka falls within the medium range of 25-29% of second or higher order births.

Karnataka thus provides a fairly average representation of India. An understanding of factors associated with child nutrition could help to unravel the contrasts in child welfare evident between other Indian States (NFHS for India 1992-93). Although

Figure 1.1 Map of India Showing the Prevalence of Short Birth Intervals by State



NB Prevalence rates apply to non-first births only

Karnataka includes rural poor and deprived populations, it is also economically progressive. It thus has potential to benefit from research findings and to focus policy initiatives effectively. Finally the longitudinal survey conducted by the Belaku trust in the villages of Kanakapura, Karnataka, provide an invaluable opportunity to facilitate analyses in temporal effects associated with child nutrition.

1.5 Organisation of the Thesis

This chapter has provided an introduction to the subject area and the overall objectives of the thesis. Chapter 2 provides a detailed literature review, consisting of two main sections. The first, and major part of the review, concerns the relationship between short birth intervals and infant survival. This includes a brief summary of the general progress of the research over time, an examination of literature, which has sought to identify mechanisms within the relationship, and an investigation of literature concerning the mechanisms themselves. The final section of the review provides a discussion of the use of anthropometric assessment for research concerning infant and child health.

Chapter 3 describes the population of Karnataka and the data sets used for the analyses. First a portrait of the state of Karnataka and its population is described, providing to broader context within which the analyses can be interpreted. The overall nutritional status of the children within the state is also considered, as well as mortality rates during the neonatal, post-neonatal and early childhood periods. This is followed by a description of the survey design for the 1992-93 National Family Health Survey for Karnataka and a preliminary investigation of child nutritional status and mortality by a number explanatory variables. The second half of the chapter describes the Maternal and Child health survey. As well as a description of the survey design, a "snapshot" summary of life in the rural villages of Kanakpura, is provided. The final section of Chapter 3 contrasts the use of cross-sectional and longitudinal data, highlighting the advantages and disadvantages of each approach.

Chapter 4 presents the cross-sectional approach to the analysis of weight measurements of children in the State of Karnataka. This includes a description of the hierarchical structure of the data and the motivation for using multilevel models, as well as a description of the models themselves. Chapter 5 presents the longitudinal approach to the analysis of weight measurements. The methodology for the analysis of longitudinal data is discussed together with a review of appropriate modelling techniques. Chapter 6 presents an analysis of the correlates of infant mortality using the 1992-93 NFHS for Karnataka. Specifically the relationship between birth spacing and mortality during the neonatal and post-neonatal or early childhood period is investigated. Effects of mortality on the anthropometric analysis are thus assessed.

Finally the relationship between short birth intervals and infant mortality is analysed further, in Chapter 7, using data for the whole of India. The main focus of the analysis is to explore interactions within the relationship thus identifying mediating effects. A comparison of the cross-sectional and longitudinal analyses of child anthropometric status is presented in Chapter 8, together with an overall summary of the research results and the conclusions.

CHAPTER 2

Literature Review

2.1 Introduction

The health consequences of frequent and close birth spacing have been a focus of research concerning reproductive and child health for much of this century. The methodology used for this research has evolved over this period, especially as a result of the huge developments in technology that have taken place. This chapter provides an overview of the literature in this area. In the first section a brief summary is given of the progression of research over time. This is followed by a more extensive examination of literature, which has sought to identify the causal mechanisms of the relationship.

The focus of this thesis includes the effect of birth spacing patterns on the health status of the infant, as well as mortality risk. The final section of the review, therefore, discusses the use of anthropometric assessment for research in health issues. This concerns the use of anthropometric data as an indicator of malnutrition, and more generally, as an indicator of poor health and mortality risk.

2.2 Short Birth Intervals and Child Mortality

A considerable body of research has been undertaken since the earliest analyses in 1923. Particularly over the last two to three decades researchers have sought to investigate and explain many different aspects of the relationship between birth spacing and infant mortality. Some of this research has included reviews of the pertinent literature at different points in time. This section briefly outlines the focus and progression of research on this subject.

The early studies sought to establish the relationship between birth spacing and infant mortality using small scale studies (Hughes, 1923; Woodbury, 1925). Bivariate tabulations demonstrated an association between birth spacing and child survival, including both the previous and succeeding birth intervals. Woodbury (1925) quantified the effect, claiming that if a subsequent conception occurred within one year, the infant suffered two and a half times the mortality risk. The relationship has been confirmed repeatedly by the literature since these early analyses, leaving little doubt of the true existence of an association (Yerushalmy, 1956; Wyon et al., 1962; Palloni, 1986; Miller et al., 1992). Indeed it has been found to persist across many populations of different socio-economic characteristics and cultural settings. Hobcraft et al. (1983, 1985), for example, gained strength of inference across thirty nine different countries. They found consistently that short preceding intervals were associated with increased child mortality and that short succeeding intervals were associated with increased toddler or child mortality.

Cleland and Sathar (1984) went a step further by analysing the second preceding interval but found little effect after allowing for the previous interval. They claimed, therefore, that spacing effects were transient in nature. An alternative focus of research has been to assess the relationship between birth spacing and infant mortality at different periods during childhood, comparing the relative strength of the association and raising questions as to the effect of environmental and cultural factors (Omran, 1976; Spiers and Wang, 1970; Alam, 1995). Attempts have also been made to confirm the magnitude of effect (De Sweemer, 1986; Palloni, 1986; Miller, 1989; Miller, 1992). This has proved to be difficult, however, owing to the unknown effect of potential confounding factors within the relationship.

Indeed the question of confounding factors was raised early in the course of the literature. Eastman (1944), for example, claimed that short birth intervals were likely to contain a high proportion of premature births and thus the relationship may merely reflect the association between premature births and mortality. Fredrich and Adelstein (1973) considered the confounding effect of the death of the previous sibling, arguing that the relationship may reflect the high concentration of short birth intervals following the early death of the previous sibling and the correlated mortality risk within families.

The review by Winikoff (1983), however, criticised this literature for failing to control adequately for the multiplicity of confounding factors. Since this time, therefore, many authors have focused their research has more extensively on confounding factors and many have sought to assess the extent to which they attenuate the relationship

(Palloni, 1989; Potter, 1988; Millman et al., 1987; Rethorford et al., 1989 and Miller, 1989).

Curtis (1992) summarised the results of such analyses in an in-depth review of literature. Overall, she concluded that the relationship between short birth intervals and infant mortality was extremely robust. She identified gestation as the being strongest mediating variable resulting in an overestimation of the relationship. Premature births are positively associated with both mortality risk and short birth intervals and thus inflate the relationship. The effect did not, however, completely attenuate the relationship, however.

Issues concerning data quality have also been a subject of debate and are argued potentially to cause a spurious relationship. One problem acknowledged by authors concerns mis-reporting which is inherent within retrospectively collected data. Errors typically include dates of events such as births or deaths and the omission of children who have died. Such errors tend to be more acute the greater the recall period. Millman et al. (1987) assessed the impact of data limitations on analyses which have used the World Fertility Survey. They claimed that the effects were likely to be minimal and thus promoted the validity of previous research findings. Potter (1986), however, argued that data mis-reporting should not be dismissed too lightly and that one cannot be sure how much of the association between birth spacing and mortality is due to reporting errors, or to other unmeasured confounding factors. Curtis (1992) also assessed the effect of data issues and concluded that the relationship was robust to the various study designs and methods used. In addition she reported that studies using longitudinal data, which do not suffer the data quality issues, have still identified a significant relationship although it tended to be weaker.

The focus of Curtis's own work was on solving a methodological problem. The modelling techniques commonly used to identify the correlates of infant mortality assume that observations are independent. In reality, however, they are often correlated. This occurs if individuals share common circumstances that may influence their chances of survival, for example, if more than one child per family is included in a sample. The result of this violation of assumption is that standard errors will be underestimated and significant associations may be artificially identified. Using multilevel modelling techniques, recently developed at that time, Curtis found that the relationship between birth spacing and infant mortality is preserved despite the highly significant family effects.

A focus, particularly of more recent research has been to investigate the mechanisms underlying the relationship between birth spacing and child survival. Three main mechanisms have been hypothesised in the literature: maternal depletion, sibling rivalry and exposure to infectious disease (see Chapter 1 for description of mechanisms). Authors have generally sought evidence of one more of these mechanisms in their analyses. Curtis (1991) examined the evidence exhibited by these analyses and assessed the extent to which they support or refute the roles of maternal depletion and sibling rivalry within the relationship. Overall she finds the literature to be "inconclusive and contradictory" and claims the causal mechanisms have yet to be established.

Summary

A large body of literature has been conducted over the past seventy years which has aimed to establish and explain the relationship between short birth intervals and infant mortality. The earlier work, which first identified the relationship, consisted of small-scale medical studies. The results of these studies were later confirmed by analyses using larger, nationally representative surveys and more sophisticated statistical techniques. Much discussion in the subsequent literature has concerned the possibility of a spurious association owing to various confounding factors. The concentration of premature births in the shortest birth interval groups was found to be the biggest confounding factor, but did not completely attenuate the relationship. More recently research has included an investigation of the causal pathways within the relationship. Debate has mostly evolved around the relative roles of three main mechanisms, maternal depletion, sibling rivalry and increased exposure to infectious disease. The literature has been generally contradictory, however, and the mechanisms of the relationship have yet to be fully established.

The following sections focus on these three mechanisms, and provide a detailed review of the analyses undertaken to identify causal pathways. The aim of the review is to clarify the definition of the mechanisms and explain why previous research has been inconclusive. This will enable future research to be focused more effectively.

2.3 The Debate Concerning Causal Mechanisms

Although there has been a considerable body of literature which has sought to identify the causal mechanisms of the relationship between short birth intervals and infant mortality, it has met with limited success and has suffered criticism. Curtis (1991) for example, states that "many authors seem to come down in favour of one mechanism or the other, even when there is no real evidence to support either hypothesis in their work". Part of the problem is that the mechanisms are subjective in nature and thus not easily defined or measured. Much of the evidence stated by researchers has thus tended to be indirect and can appear inconclusive.

This section provides a review of literature related to the mechanisms. First, the different approaches adopted by authors who claim to have found evidence of causal mechanisms are outlined, together with a discussion of the strengths and weaknesses of each approach. In these analyses, mortality is the outcome variable and the focus is on identifying factors which mediate the relationship between short birth intervals and infant mortality. In the following section the potential role of each mechanism is examined by reviewing literature which takes the mechanism itself as the outcome variable and analyses the extent to which it is associated with birth spacing patterns. Each mechanism is thus reviewed in turn. Although quite extensive research has been undertaken to assess the impact of maternal nutritional status on the fetus, very little research has been undertaken to assess the adverse effects of two or more young children close in age within a family.

2.3.1 Identifying Mechanisms

Some analyses look for evidence of causal mechanisms by comparing the strength of the relationship between the birth interval and the risk of mortality at different periods during infancy and childhood. In these analyses the death of a child is categorised into a combination of two or more of the following periods: postnatal (following birth), perinatal (the first week of life), neonatal (the first four weeks of life), and post-neonatal. Where the relationship between short birth intervals and mortality risk is found to be strongest in the postnatal, perinatal and neonatal period, it is usually concluded that maternal depletion is the causal factor. Conversely where the relationship is found to be strongest in the post-neonatal period or in childhood, sibling rivalry, infectious disease or other social and behavioural factors are thought to be the causal mechanism. This is in accordance with literature, which relates early deaths to biological causes and toddler or childhood deaths to socio-economic and physical environmental causes (Bhatia, 1989, cited in Stevenson, 1998).

Boerma and Bicego (1992), for example, find that preceding birth intervals of less than two years increase the mortality risk in the neonatal period by 98%. They claim that the results present evidence of the importance of prenatal causal factors, possibly including maternal depletion. Similarly, Miller (1989) finds a significant relationship between birth intervals and perinatal mortality. Having made the statement that exogenous, environmental factors are not relevant in determining the cause of perinatal deaths she concludes that maternal depletion is feasible as a causal mechanism. Conversely, Madise (1991) finds that the impact of birth intervals are strongest in both the postnatal and childhood periods and not significant in the neonatal period. She, therefore, suggests that the relationship could function through both endogenous factors and through competition for food and maternal care between siblings.

Koenig et al. (1990) analysed the effects of both preceding and succeeding short birth intervals. They found that, whilst both were significantly associated with mortality, the timing of mortality was different. Short preceding intervals resulted in an increased risk of mortality in the neonatal period and short succeeding intervals resulted in an increased risk of mortality in early childhood. It was, therefore, suggested that preceding and succeeding intervals affect mortality through different mechanisms; the former through maternal depletion whilst the latter through sibling rivalry.

Another method of identifying causal mechanisms is by a process of elimination. For example, the death of the older sibling removes the need to compete for resources and maternal care. Alam (1995), for example, found that if the older sibling survived infancy, a short preceding interval was associated with a greater risk of mortality in the post-neonatal period; however if the older sibling died in infancy no association remained. Alam suggests, therefore, that sibling rivalry is the most likely mechanism.

Curtis (1991) focused on this attenuation of effect, in her review of literature on the causal mechanisms. DeSweemer (1984), Hobcraft et al. (1994), and Cleland & Sathar (1983) are cited as examples of analyses that have investigated the effect of the death of the previous sibling on the mortality risk of the index child. Although only DeSweemer claimed evidence of sibling rivalry, all three analyses found that, for children over one year of age, a decrease in mortality risk occurred if the previous sibling died. On further investigation Curtis claims that the tables shown by DeSweemer provide evidence that this attenuation of effect is stronger for those children who follow short birth intervals, than those who follow longer birth intervals. This strongly supports the hypothesis that sibling rivalry is a disadvantage for the younger child of a short birth interval in the second year of life.

The effect of the death of a sibling is complicated, however, by the correlated risk of mortality between siblings. Members within families are exposed to similar biological, genetic and environmental factors, which influence the risk of mortality (Curtis, 1991; Zenger, 1993). DeSweemer, Hobcraft et al. and Cleland and Sathar did not find an attenuation of excess mortality risk for infants of younger age groups and indeed Majumder (1990) found that risk of mortality during infancy, i.e. less than one year of age, actually increased with the death of the preceding sibling. However, Curtis argues that although the index child is exposed to a greater risk of mortality during infancy as a result of familial characteristics, the advantages of the reduction in competition have a stronger positive effect during childhood.

Zenger (1993) points out that the death of the previous sibling has a number of consequences for the index child other than reducing competition. For example, the increased exposure to infectious disease suffered by the younger sibling of a short birth interval is eliminated in addition to sibling competition. It cannot be assumed, therefore that sibling rivalry is the causal mechanism, even if the relationship is attenuated by the death of the previous sibling.

Summary

There have been two main approaches adopted by authors who have sought to identify causal mechanisms within the relationship between short birth intervals and child mortality. One approach has been to analyse of the strength of the relationship by the age at death. Authors using this method have generally claimed evidence of maternal depletion as a causal mechanism for children succeeding a short birth interval and sibling rivalry for those preceding a short birth interval.

Other authors have analysed the relationship by the survival status of the previous sibling. If the previous sibling dies, then competition between siblings is eliminated. A number of analyses have been consistent in finding that although the death of the previous sibling is associated with an increased mortality risk for younger infants the effect becomes negative for children over one year of age. It has been hypothesised that familial correlation of mortality risk is evident for infants aged less than one year, but the elimination of sibling competition more than compensates for this in the second year of life. A closer investigation has suggested that this effect is stronger for infants following short birth intervals. A critic of the research, however, may question whether other factors are also responsible for the change in mortality risk with the death of the previous sibling; for example, exposure to infectious disease would also be eliminated.

The main problem with the approach used in these analyses, and perhaps the reason why they appear contradictory or inconclusive, is that the methods used are very indirect and rely on broad assumptions concerning the mechanisms. Unfortunately, there is no one variable which can adequately represent a mechanism and thus be used for a more direct analysis of a mediating effect within the relationship. In the following section, each mechanism is examined in turn and their potential role within the relationship is explored by considering how birth spacing patterns are related to the mechanism itself. Although each mechanism is considered of equal importance in the review, very little literature was identified concerning the association between reproductive cycles, competition between siblings (or exposure to infectious disease) and infant health outcomes.

2.4 Maternal Depletion as an Outcome

In order to assess the relationship between birth intervals and maternal depletion it is necessary to provide a clear definition and to identify an appropriate unit of measurement for maternal depletion. The first part of this section, therefore, discusses what maternal depletion actually means, and how it can be distinguished from malnutrition. Following this a review of literature concerning the relationship between reproductive cycles and maternal depletion is provided. This includes the role of confounding factors, interactions which exacerbate the effect, and mechanisms that the body adopts to cope with the extra demands of pregnancy when undernourished. In the final section the effects of malnutrition on the fetus are discussed as well as the longer term implications.

2.4.1 Depletive Reproductive Cycles

Close and frequent birth spacing patterns, together with full and lengthy breast-feeding behaviour, are thought to deplete the nutritional status of the mother. A poorly nourished mother is more likely to have an adverse outcome of pregnancy or an infant who is undernourished, underdeveloped or growth retarded. Consequently, the infant may fail to thrive in early childhood and suffer greater risk of morbidity and mortality. If the infant dies, breast-feeding will obviously terminate, and the length of time the woman is in a depletive state will be reduced. However, postpartum amenorrhoea will be shorter and the likelihood of a second short birth interval will be increased. Also the woman may deliberately choose to replace the dead child. Thus a depletive reproductive cycle is completed. Conversely, the nutritional and metabolic stress of two pregnancies in close succession may have a negative impact on the future pace of child bearing. Postpartum amenorrhoea may be lengthened owing to the depleted state of the mother.

The definition of the maternal depletion hypothesis may seem intuitive, but to gain an understanding of the mechanism it is necessary to consider the exact definition. The Oxford English Dictionary defines depletion as "reducing the fullness of, emptying out or exhaustion". The introductory paragraphs of the pertinent literature typically describe maternal depletion as a syndrome attributed to the nutritional stresses of frequent and successive pregnancies and lactation (Winkvist, 1992; Miller et al., 1994). Most fail, however, to provide a full definition of maternal depletion.

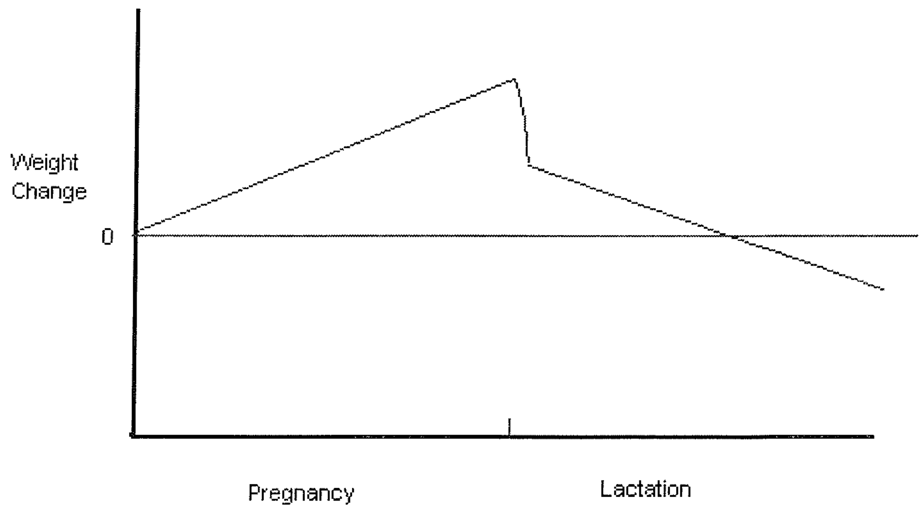
Perhaps the best way to define maternal depletion is by considering appropriate units of measurement. The next section discusses the use of anthropometric measurements, in their effectiveness of capturing the nutritional status of the women and thus maternal depletion syndrome.

2.4.2 Defining Maternal Depletion by Weight Change

Figure 2.1 represents the typical weight change over one reproductive cycle as described by Miller (1994). A woman who is adequately nourished is likely to experience a rapid increase in weight during pregnancy as a result of foetal and placental growth, the expansion of the uterus and the deposition of fat reserves. Upon delivery weight is immediately reduced owing to the loss of the foetus, the placenta and fluids. Weight continues to reduce during lactation and may actually fall below the pre-pregnant level. Repletion of energy stores begins upon weaning. Maternal depletion, therefore, concerns the low energy stores of the woman when pregnancy occurs before the process of replenishment has been completed (Miller 1994).

Figure 2.1

A Typical Pattern of Weight Change Over the Reproductive Cycle



In addition to weight change, depletion can be measured in terms of energy balance or energy reserves. When an energy deficit occurs, fat is mobilised to meet the energy requirements. If the fat reserves become depleted muscle stores are mobilised. Examples of measurements of energy reserves, therefore, include:

- Body mass index (wt/ht^2) - *Indicator of total body fat.*
- Skin-fold thickness of the triceps or thigh - *Percent body fat.*
- Arm muscle area (arm circumference minus skin-fold thickness) - *Measures muscle and protein stores.*

Defining maternal depletion in terms of weight change or energy balance has the advantage that the data is fairly easy to collect, it has specific units of measurement, is non-invasive and is not time intensive. The disadvantage is that it assesses only one of many nutritional components, micro-nutrients may, for example, become depleted as a result of short birth intervals

2.4.3 Defining Maternal Depletion by Micro-nutrient Deficiencies

The high prevalence of micro-nutrient deficiencies in many developing countries has been a focus of concern for humanitarian and international organisations for some time and has been well documented (UNICEF, 1998). Pregnancy is accompanied by an increased demand for micro-nutrients, it follows, therefore, that where frequent and successive pregnancies occur and are accompanied by full and prolonged breast-feeding, women would have insufficient time to replenish these nutrients.

Anaemia is probably the most obvious example. This is a reduction in number of red blood cells or in the haemoglobin content. It results from iron deficiency or from haemorrhage. There is an increased demand for iron during pregnancy and blood loss may occur during childbirth. A short interval before the increased demands of the second pregnancy may well be insufficient for haemoglobin levels to be restored.

Goiter is another example of a specific micro-nutrient deficiency. Enlargement of the thyroid gland occurs as a result of iodine deficiency. Again pregnancy increases the predisposition to this owing to the associated increase in urinary excretion and the additional demands of the fetus.

Measuring micro-nutrient deficiency is a very specific method of measuring maternal depletion, but virtually no studies have attempted to do this. The main disadvantage is that it is a very invasive procedure requiring blood samples and sophisticated equipment for analysis. It is, therefore, not feasible for research carried out in rural areas of developing countries.

2.4.4 Distinguishing Maternal Depletion from Malnutrition

Maternal depletion is complicated by its relationship with nutritional intake. Short birth intervals or lengthy breast-feeding may well have different consequences for a woman who has a barely adequate diet than for one who has a plentiful diet. It is important, therefore, to distinguish between depletion caused by malnutrition and depletion caused by reproductive patterns. Winkvist et al. (1992) does this by looking at energy balance throughout the reproductive cycle for different scenarios of energy intake and expenditure. They hypothesise that maternal depletion occurs in those who receive a moderately inadequate diet and have closely spaced births. Energy deficiency occurs during pregnancy and lactation as the woman is unable to meet the additional nutritional requirements. The short 'non pregnant, non lactating period' before conception of the following child is insufficient for energy stores to be replenished. In the longer term, the primary cause of depletion is thus the childbearing pattern. This is distinguished from depletion caused by malnutrition, in which a severely inadequate diet is the primary cause, and energy stores would not be replenished despite a longer reproductive cycle.

This could explain why adverse effects of short birth intervals have been identified in different communities despite different socio-economic circumstances. Miller (1992), for example, finds that the estimated reduction in neonatal mortality, if short conception intervals could be avoided are very similar for Bangladesh, Hungary, Sweden and the United States. She concludes that this does not support the maternal depletion hypothesis as one would expect a greater reduction in mortality to be attained by lengthening birth intervals in those countries which have a higher prevalence of malnutrition. Winkvist et al. (1992) argue, however, that if the primary cause of depletion is malnutrition and not birth spacing, lengthening birth intervals would not reduce mortality.

Although this distinction is valuable in that it clarifies the term "maternal depletion", it is perhaps too simplistic and does not consider the effect of mediating factors which may influence energy balance. The following section highlights some of these factors in a review of literature, which has investigated the association between birth spacing and the maternal nutritional status.

2.4.5 Looking for Evidence of Maternal Depletion

Miller and Huss-Ashmore (1989) investigated the relationship between reproduction and maternal nutrition from both a short and long-term perspective. The short-term perspective aims to capture recent exposure to a depletive state and thus investigates the effect of current pregnancy status, length of open interval and length of last closed interval on maternal weight measurements. The length of open interval indicates the time since the birth of the youngest child, thus if this is short, it is likely that the woman is still breast-feeding. The length of last closed interval indicates recent birth spacing patterns. Long-term effects are excluded from this section so age and parity are included only as controls.

The long-term perspective aims to capture the cumulative effect of the reproductive history and thus investigates the effect of parity and median birth interval. The median birth interval represents the typical spacing pattern for a woman throughout her reproductive life.

Results of the analysis confirm that short-term reproductive spacing and breast-feeding behaviour are important determinants of nutritional status, assessed by maternal weight measurements. A temporary worsening of nutritional status was found in relation to spacing of recent pregnancies and lactation. However, complete recovery was usually gained by the third year after the birth. No evidence was found of cumulative depletion in relation to long-term reproductive patterns. Indeed maternal nutritional status was actually found to increase with parity. The cross-sectional nature of this analysis, however, limits its explanatory power, as the data does not reflect the experience of women over time. The results are thus based upon synthetic patterns of weight change, constructed from data for many individuals at one point in time only. It cannot be assumed, therefore, that women at earlier time points will demonstrate similar patterns to those at later time points unless it is also assumed that there are no cohort effects.

In their subsequent paper, Miller et al. (1994) used longitudinal data from rural Bangladesh, collected monthly over a period of thirty months, to investigate the effects of reproductive patterns, lactation and seasonality on maternal weight change. Seasonality was included as energy balance is likely to be affected during the rainy season when food availability is poor and the pre-harvest activities involve a heavy workload. The results confirmed that both birth spacing and breast-feeding are important determinants of maternal weight change. Birth intervals of less than 18 months and, surprisingly, high parity, were shown to be associated with a decrease in weight at conception. Weight loss following the birth of the index child was greater in lactating than non-lactating women and was found to persist for approximately 18 months, peaking at around 5 to 9 months duration of breast-feeding. A rebound effect was identified upon weaning, whereby the woman underwent a rapid weight recovery. As expected, season was found to influence weight change whereby the winter months and the rainy season resulted in weight loss. An interaction was also evident between season and duration of breast-feeding, such that a greater weight loss occurred if the most demanding period of breast-feeding coincided with a season when food availability was poor.

Miller (1994) also identified compensatory mechanisms whereby weight gain during pregnancy was greater among women with low weight at conception, e.g. those with short inter-pregnancy intervals. This did not completely compensate for the pre-pregnancy deficit in weight, however. Similarly, postpartum weight loss was found to be slower among women with low initial postpartum weight. Miller claims that these findings support other research, which has found evidence of metabolic adaptations to restricted nutritional intake during pregnancy and lactation.

Prentice and Prentice (1988) explain why many populations suffering widespread malnutrition maintain growth rates as high as 4%. They attribute this to the high fat deposits in the body composition of women and to the slow growth and development of the human foetus (and infant), which spreads the cost of reproduction over a long period. They estimate that in order to meet the additional requirements of reproduction it is necessary to increase the dietary intake by 14 % during pregnancy and 24% during lactation. If this increase is not available, the energy costs of pregnancy and lactation can be met through the adoption of a number of physiological and behavioural strategies. Fat reserves, for example, can be mobilised and the metabolic rate decreased, thus compensating for the additional requirements of pregnancy.

The ability to reproduce in times of nutritional stress does not guarantee the survival of the child, however. Prentice and Prentice (1988) point out that child mortality is high in many countries with widespread malnutrition and high fertility rates. Indeed, Baquil (1994) found maternal weight to be negatively correlated with number of child deaths.

Very few studies have been undertaken to determine whether specific micro-nutrient deficiencies are more prevalent in women who have closely spaced births. Ronsmans & Campbell (1998) conducted a fairly comprehensive review of literature concerning the effect of birth spacing on maternal complications and mortality. They concluded, however, that "the literature does not provide compelling evidence favouring a biologically plausible effect of the length of the birth interval on maternal mortality." They suggest that "the most plausible mechanism appears to be unreplaced gross blood loss or anaemia. No consensus was found, however, as to whether anaemia is increased with short birth intervals."

Frederick and Adelstein (1973, cited in Curtis 1992) did find a slightly higher prevalence of low haemoglobin levels and higher incidence of severe toxaemia than expected in mothers with short conception intervals. Winikoff (1983), however, failed to find any evidence to support the maternal depletion hypothesis in her analysis of haemoglobin levels by age and parity. Again this could just reflect the transient nature of maternal depletion.

Summary

One method of defining maternal depletion is in terms of weight measurements or energy balance. Using weight change as a unit of measurement for energy balance, Winkvist et al. (1992) distinguishes depletion caused by short reproductive cycles from that caused by malnutrition. This may help to explain why the effect of birth spacing has been found to be consistent in different countries regardless of economic status as, according to Winkvist et al. it is the reproductive cycles responsible for maternal depletion and not malnutrition.

Recent analyses have confirmed that, in the short-term, close birth spacing and full breast-feeding depletes the nutritional reserves of the mother in terms of weight. They have also demonstrated, however, the complexity of energy balance and the need to account for mediating factors such as the season. In addition to this, the body appears to be capable of compensatory mechanisms in times of nutritional stress.

It is possible that maternal depletion could also involve deficiencies of specific micro-nutrients and electrolytes. Few studies have investigated this aspect of depletion. This probably reflects the invasive nature of obtaining measurements and the need for fairly advanced technology. Ronsmans and Cambell (1998) have undertaken a literature review of the relationship between birth intervals and maternal complications, but have failed to find any evidence of significant associations. They suggest that the most likely micro-nutrient deficiency caused by short birth intervals is anaemia.

2.4.6 Maternal Depletion and Fetal Growth

Other studies look for evidence of maternal depletion as a causal mechanism within the relationship between birth intervals and infant mortality, by analysing the association between reproductive patterns and the anthropometric status of the baby at birth. If the nutritional status of the mother during pregnancy is compromised the growth and development of the foetus may well become disrupted. Matsuda et al. (1998), for example, found that the mean birth weight was significantly correlated with the nutritional status, measured by the body mass index, of women in Japan. They concluded that the mean birth weight in a community thus represents the long and short-term nutritional condition of the mothers.

Low birth weight can be classified by its relationship to gestation; those who are born before the normal human gestational period of 37 weeks (premature births), those who have completed 37 weeks gestation but have a weight for gestational age below the 10th percentile for gender (intrauterine growth retardation), and those whose birth weight is below the 10th percentile for gestational age regardless of length of gestation (small for gestational age) (WHO 1991b, cited in Hutter, 1994).

Small for gestational age or intrauterine growth retarded babies may be further subdivided into those who are wasted, and those who are growth stunted. The former is characterised by low weight, but normal length, and results from "short-term utero-placental vascular insufficiency". These babies suffer higher risk of neonatal mortality, but have higher propensity for 'catch up growth'. The latter is characterised by proportionate weight for length, and results from "long-term utero-placental vascular insufficiency". Although these babies are less likely to die in early life they are more likely to die in infancy than babies suffering from wasting (WHO 1991b, cited in Hutter 1994).

2.4.7 Looking for Evidence of Impaired Fetal Growth

A number of studies have examined the effect of reproductive patterns on the prevalence of growth retardation, small for gestational age infants, prematurity and termination or loss of pregnancy. Although results have shown some consistency in finding a positive association between short birth intervals and growth retardation or small for gestational age babies, uncertainty remains concerning the extent to which they explain the relationship between birth spacing and infant mortality. There are also mixed results concerning the association between reproductive patterns and premature births.

Fikree and Berendes (1994) carried out an assessment of the incidence of, and risk factors for, intrauterine growth retardation in urban squatter settlements in Karachi. They found that 24.4% of the 738 babies were growth retarded and that short birth to conception intervals were a major risk factor. Other important risk factors identified were low levels of maternal education, paternal unemployment, consanguinity, short maternal stature, and low maternal weight.

Using data on Swedish infants in 1973 collected by the World Health Organisation, Miller (1989) analysed the relationship between length of preceding birth interval and weight for gestational age of the baby at birth. She found that infants born after birth intervals of a year or less were 30% more likely to be small for gestational age than infants born after longer intervals. She claims, however, that the results do not support maternal depletion as there is no evidence of an attenuation of the risk with increasing length of interval in the under 18 month birth interval range.

In keeping with the compensatory mechanisms discussed above Merchant, Martorell and Haas (1990) claim evidence of a "buffer mechanism" whereby the fetus is protected in times of nutritional stress. The focus of their analysis is the nutritional stress caused by overlap of lactation with pregnancy, which tends to be more prevalent in short reproductive cycles. The study based on women in Guatemala found that although maternal fat stores where reduced, birth weight (accounting for gestation) was unaffected. They hypothesised that the mother buffers the foetus at times of nutritional stress. They point out, however, that the women in their study had access to freely available primary health care including nutritional supplements; it is likely that in populations where this is not available the negative effects on both maternal fat stores and foetal growth would be greater.

The relationship between birth intervals and premature births is even less clear. Kallan (1992) examined the effect of inter-pregnancy interval (birth to conception) on low birth weight caused by pre-term births and by intrauterine growth retardation as well as on pregnancy loss. Using data from the US National Survey of Family Growth, 1988, he found that both short and long inter-pregnancy intervals, i.e. less than 7 months or greater than 60 months, raise the risk of intrauterine growth retardation and pregnancy loss net of socio-economic, demographic and behavioural variables. The effect of birth spacing on pre-term births was less clear. Conversely however, his later analysis based upon "1991, US Linked Birth / Infant Death Files" (1997) found that the risk of both pre-term birth and intrauterine growth retardation was increased following short inter-pregnancy intervals.

Miller (1989) using data from Sweden and Hungary examined the role of prematurity in the relationship between birth interval and perinatal mortality from two aspects. First, the extent to which it acts as a confounding factor within the relationship, and second, whether the risk of prematurity differs by the length of conception interval. This difference in role is consequential in the interpretation of results, as on the one hand it is necessary to control for prematurity to avoid overstatement of the relationship, whilst on the other the indirect effect of prematurity as a mechanism should be taken into account. Although she was able to quantify the extent to which length of gestation attenuates the relationship, she was only able to set approximate bounds for the true risk of perinatal mortality attributable to short conception intervals as she was unable to determine the indirect effect of prematurity as a mechanism.

2.4.8 Intrauterine Malnutrition and Fetal Development

As with maternal nutritional status, maternal depletion may manifest itself in specific micro-nutrient deficiencies or the consequent diseases, rather than just in infant anthropometric status. A considerable amount of research has been undertaken, in recent decades, to investigate the consequences of the foetal environment for the risk of disease later in life. Although this has primarily focused on the identification of causal mechanisms for degenerative diseases, it does provide some specific reference to the biological mechanisms through which the nutritional environment influences foetal development. This gives an indication of the types of conditions that infants may suffer if maternal depletion is a pathway through which short birth intervals effect infant health.

Hales (1997) describes the "thrifty phenotype hypothesis" in which a restricted nutritional environment during pregnancy alters the development and metabolic function of organs in the foetus. These changes are thought to prepare the individual for later life and are beneficial to survival when nutritional intake is poor. However, the changes are detrimental, if the nutritional intake, later in life, is good.

Tests on rats, for example, have shown that protein restrictions during pregnancy result in abnormal liver enzyme activity of the offspring at the time of weaning (Hales, 1997). This persisted for up to 10 months after weaning. If protein deficiency was evident during lactation this adverse effect did not occur. An application for this hypothesis in human disease can be demonstrated with diabetes mellitus. If the intrauterine environment is low in carbohydrates or glucose, development of the pancreas may be geared to low levels of insulin production. If the individual then has a diet high in carbohydrates later in life it follows that the body may be ill equipped deal with it and disease may occur. According to this hypothesis then short birth intervals would be disadvantageous to those with good nutritional intake as the metabolic changes resulting from maternal depletion do not reflect the external environment to which they would be exposed.

Barker (1997) states that "The growth trajectory of the fetus is set in the earliest stages of pregnancy and may be reset downwards in response to low concentrations of nutrients because it will reduce the demand for nutrients in late gestation". The fetus thus adapts to the limited supply of nutrients available during early pregnancy, which results in permanent changes to their physiology and metabolism.

A specific response to maternal malnutrition during early pregnancy is a slowing of the rate of cell division, especially in organs which are undergoing rapid cell division (a critical period of their development). Even after brief periods of under-nutrition the number of cells in organs can be permanently reduced as growth after birth mainly consists of the development and enlargement of existing cells rather than the addition of new ones. This may determine disease in later life (Barker 1997).

Some organ development is be prioritised over others; for example, the brain is protected in preference to the muscles. Under-nutrition in late pregnancy has been found to result in disproportion of body length to head size, although the babies may present normal birth weight for gestation. The disproportionate growth occurs when blood is diverted away from the trunk in favour of the brain. Barker concludes, therefore, that birth weight is an inadequate summary measure of fetal growth.

Development of the liver is also impaired by the lack of nutrients and oxygen, and results in metabolic reprogramming. Functions of the liver include cholesterol metabolism and blood clotting so the consequent disturbance can have lasting effects on the individuals health.

Summary

Whilst a number of analyses concerning the relationship between birth intervals and intrauterine growth retardation (or small for gestational age infants) have attributed maternal depletion as the causal mechanism, others have been more doubtful. Miller

(1989), for example, found that the relationship did not attenuate with increasing birth interval as would be expected. Merchant (1990) found no association of weight for gestation with the nutritional stress of the mother and suggested buffer mechanisms protect fetal growth at the expense of the mother. It is possible, however, that there is a threshold of maternal nutritional status below which the mother is prioritised over the fetus.

Analyses concerning the effect of birth intervals on prematurity have also demonstrated mixed results. There is uncertainty in the extent to which prematurity acts as a confounding factor or as an indirect mechanism through which the relationship functions. Establishing the exact role of these opposing functions is crucial in determining the excess risk of mortality caused by birth intervals.

Research has recently been conducted to assess the effects of the intrauterine environment on the development of the foetus and on disease later in life. This research is relevant to the investigation of the role of maternal depletion as it identifies specific changes that occur during foetal development as a result of malnutrition. Results suggest that the development and growth trajectory is set in early pregnancy and can be reset downwards by fetal malnutrition. In addition, metabolic changes may occur which present in disease patterns later in life. This indicates that the consequences of maternal depletion may not necessarily be limited to infancy or early childhood.

2.5 Sibling Rivalry as an Outcome

Very little research has been undertaken to investigate the effect of birth spacing on the necessity for siblings to compete for resources or for maternal care and attention. This section outlines the analysis by Boerma and Bicego (1992) which directly assesses the association between birth spacing and outcomes related to sibling rivalry. It then goes on to provide a more general review of literature which has focused on resource allocation within the household and considers how this may apply to infants who follow short birth intervals.

Boerma and Bicego (1992) used Demographic & Health Survey data from 17 countries to investigate possible links between birth spacing and infant survival. Their approach was to use a series of different outcomes to indicate the relative importance of the pathways. As well as mortality and anthropometric measurements, the outcomes included immunisation, health service utilisation and whether the child was breast-fed. They found that in many of the countries short birth intervals were associated with a slightly higher risk of non-attendance of antenatal care (throughout pregnancy) and of not breast-feeding the baby, but the effect was minimal. The effects of birth spacing on medical service utilisation during the post-natal period, and on child immunisation were also very small or non-existent. Boerma and Bicego conclude, therefore, that the analysis gives little support to the sibling competition hypothesis.

However, the lack of association between birth spacing and the outcome variables could result from the format of the variables used, and from poor data quality. The variable representing breast-feeding behaviour, for example, was constructed as a dichotomous variable where those never breast-fed were compared with those who were breast-fed. In many developing countries it is practically universal to breast-feed, and thus a more detailed description of breast-feeding behaviour is necessary, such as the frequency and duration of feeds. Also, Boerma and Bicego comment on the poor quality of the breast-feeding data used.

Some authors have analysed behaviour in resource allocation within households and the distribution strategies adopted by parents. Particularly in relation to food allocation, economists have argued that when resources are scarce parents adopt an investment strategy, whereby preference is given to children who provide the greatest returns. Behrman (1988), for example, assessed behaviour in the intra-household allocation of essential nutrients amongst the poor in rural India. Using 24 hour recall data on nutritional intake, Behrman showed that a pure investment strategy was adopted when resources were scarce and that earlier born children, i.e. those of lower birth order, were favoured. There was a significant reduction in effect, however, as the age differential between children increased. Also the bias was less acute for landholding or higher-caste households and for households with more educated heads.

Using data from rural West Java, Ralston (1997) found evidence that food allocation responds to differences in the children's labour contribution within the household. Also male children were found to be valued more highly in the villages surveyed, than female children, even after the controlling for the effect of labour contributions. Miller (1997) investigated variations in the strength of gender bias between different regions in South Asia, and found that women's social status within the community influenced such behaviour.

Farmer (1995), however, argues that analyses may incorrectly identify biased behaviour in intra-household food distribution because the definition of equality is often too narrow. The paper thus questions the definition of equality and suggests that the fairness of food allocation should be considered in relation to a child's needs. Children may, therefore, be treated equally even though they receive different quantities of food, providing that their needs are met. The results of the analysis showed that equity could not be ruled out as a strategy and that different concepts of fairness should be considered.

Other authors have considered similar investment strategies but have analysed child health or survival rather than food distribution. Pradip (1997), for example, considers the long term effects of short birth intervals for older siblings. In this case the younger sibling is no longer new born and the older sibling is beyond weaning. Pradip argues that the effects of short birth intervals on the longer term mortality risk would thus work through the ability of the child to gain resources. Using data from Matlab, Bangladesh, Pradip finds that resource allocation depends on the existing family composition. For example, when resources are scarce, preferential treatment is given to the first girl and the first two boys within the family. Overall, Pradip finds that although an increased risk of mortality exists for children succeeding a short birth interval up until the age of 4 years, the long-term effects are much smaller than the short-term effects. Competition with the younger sibling, therefore, appears to occur primarily at earlier stages, before the younger child can be considered a competitor for food other than breast-milk. This could indicate that it is competition for maternal care and attention that is the problem rather than for food resources.

Desai (1991) measures resource availability using the height-for age z scores (HAZ) of children (see section 2.8 for description of HAZ scores). Using Demographic and Health Surveys in Northeast Brazil, Colombia and the Dominican Republic in Latin America and in Ghana, Senegal and Mali in West Africa, the paper examines the consequences of family size for nutrition and resource availability to children. While the presence of other siblings, particularly those under 5 years of age, had a statistically significant negative impact on the nutritional status of the index child in Latin America, the effect in West Africa was weaker, and was statistically significant in Gahna but not in Mali or Senegal. This is consistent with literature which suggests that the institution of child fosterage spreads the cost of children across a larger group than just the parents and weakens the trade-off between number of children and resources available to each child.

Summary

One approach to assessing the potential role of sibling rivalry has been to use different outcome variables to investigate the importance of health related factors in relation to birth spacing. The analysis did not show, however, evidence to support the sibling rivalry hypothesis, although this could reflect the format of the outcome variables used and poor data quality. Authors who have analysed the food allocation within households have found evidence that parents adopt an investment strategy whereby preference is given to children who provide the greatest returns. This has been found to result in a bias towards earlier born children especially where births are closely spaced. Gender differences in resource allocation have also been identified where boys tend to be given preferential treatment to girls. Similar strategies have been suggested as explanations for analyses which have found family composition to be an important correlate of mortality risk. For example a child is considered to receive less preferential treatment if they have older siblings of the same gender. According to the theory of investment strategy then, a child following a short birth interval would be disadvantaged in resource allocation, as they would provide least returns to the household. This would be particularly acute as the older sibling would be close in age, and a girl following a short birth interval would suffer more than a boy.

Critics of the investment strategy hypothesis argue that bias may be artificially identified owing to the incorrect definitions of equality and that the needs of the child should be taken into consideration. Also the effects of household composition on resource allocation may differ in communities where child care extends outside the immediate household for example where extended kin and non-kin support systems exist.

2.6 Infectious Disease as an Outcome

Infectious diseases are caused by viruses, bacteria and parasites and are spread via four main methods:

- Direct contact, i.e. touching infected skin or body fluid
- Respiratory transmission, i.e. from the lungs, throat or nose, through the air via droplets
- Fecal - oral transmission, i.e. touching faeces or contaminated objects and then touching the mouth and
- Blood transmission

Such diseases spread very easily among children as they have habits that promote the spread of germs such as putting fingers or objects in their mouths. In addition, infants and toddlers are highly susceptible as they have not yet been exposed to many of the most common germs and thus have little resistance or immunity to them. Also some diseases such as measles tend to be more severe in very young children. It is thus easy to visualise the increased exposure that a younger child of closely spaced siblings would suffer as well as the increased severity of the disease. The question is whether infants who follow short birth intervals are at a greater risk than infants following longer birth intervals. Children of less than two years are vulnerable to disease and tend to behave in ways which increase their exposure such as sucking fingers. Children of 2 to 3 years of age, however, are still likely to have immature immune systems and low resistance to disease. Also, it is questionable how much their behaviour would change at this early age to reduce exposure to contaminated objects. Children in early childhood may actually suffer greater exposure than under 2 year olds as they may be more likely to attend schools or nursery schools. Exposure to infectious disease is particuarly high in such an environment. Very little research has been undertaken to investigate the relationship between short birth intervals and the transmission of disease between siblings. Boerma and Bicego (1992) included recent incidence of diarrhoea as an outcome in their analyses, but found that the preceding interval had little influence. It is possible that there is little difference between birth intervals of less than and greater than two years but a comparison of birth intervals of much longer intervals may show significantly less disease transmission.

2.7 An Evaluation of Current Knowledge Concerning Birth Spacing and Child Survival

The relationship between short birth intervals and child mortality has been confirmed repeatedly by academic literature since the early analyses in 1923. It has been shown to exist across populations of diverse socio-economic characteristics and cultural settings. It has also proved to be robust to a number of potential confounding factors such as socio-economic status, breast-feeding behaviour and premature births. There is thus little doubt left as to the true existence of the relationship.

Three main causal mechanisms have been hypothesised to function within the relationship. These include maternal depletion, sibling rivalry and exposure to infectious disease. Research has provided evidence to support both the maternal depletion and sibling rivalry hypotheses, although rather indirectly. There has been no real evidence to date, however, to support the infectious disease hypothesis. It is thus doubtful whether exposure is significantly different for infants following short birth intervals than for those following longer intervals.

Research investigating mechanisms within the relationship between short birth intervals and child mortality, has tended to use maternal depletion and sibling rivalry as concepts, which are rather subjective in nature and not easily defined or measured. This, together with the indirect methods used to identify the mechanisms, render the existing evidence rather inconclusive. The methods used to identify causal pathways have included, the elimination of causes (such as the death of the previous sibling), and the timing of the associated increase in mortality risk. Some researchers have also contributed to the knowledge on this subject, through the investigation of proxy measures of the mechanisms itself. This mostly relates to maternal depletion however, whereby the effect of reproductive cycles on the nutritional status of the mother have been examined. Very little work has been conducted on the effect of birth spacing on child care or resource allocation.

The main thrust of the research has focused on infant or child mortality as the outcome, with little attention afforded to the effect of reproductive patterns on the health of surviving children. Not only would such knowledge make a substantial contribution to the understanding how short birth intervals effect child welfare and ultimately their survival chances, but it would also have important policy implications in that welfare initiatives could be targeted to minimise the disadvantage suffered by these children.

Finally, whilst a substantial body of literature has been concerned with controlling for potential confounding factors within their analyses, authors have failed to consider the mediating role of such covariates. A understanding of interactions between short birth intervals and other associates of child mortality would be crucial in understanding how the relationship functions, as well as identifying those at greatest risk.

2.8 Anthropometric Assessment as a Health Indicator

The first approach adopted in this analysis uses anthropometric assessment to investigate the effect of birth spacing patterns on the health status of children. This section, therefore, provides a review of literature concerning the use of anthropometric assessment as an indicator of malnutrition and its potential for capturing the general health status of the child.

Anthropometric measurements commonly used as an indicator of child health include weight, height (or length), head circumference, mid upper arm circumference, skin-fold thickness and body mass index. In order to standardise the measurements weight and height can be expressed as z scores, which account for the age of the child. This is the difference between the observed measurement and the median for children at that age, given as a proportion of the standard deviation. The standardised measurements are thus termed weight-for-age z scores (WAZ), height-for-age z scores (HAZ) and weight-for-height z scores (WHZ). Each of these standardised measurements indicate different aspects of child nutrition. HAZ scores, for example, reflect the nutritional history of the child. Thus a child who is growth stunted is likely to have suffered long term, chronic malnutrition. Conversely WHZ scores indicate the current nutritional status and a child who is wasted is likely to have suffered acute, short-term malnutrition. WAZ scores may indicate that a child is underweight, but used alone, it does not allow a distinction to be made between long and short-term nutritional effects.

However, the prevalence of under-nutrition or malnutrition cannot be fully captured by these anthropometric indicies. This section, therefore, examines their effectiveness in predicting the health status of children and associated mortality risk. In addition, the method of standardising the measurements by expressing them in terms of a reference population is discussed. Although it is valuable to analyse the data in this wider context, it raises concerns as to the validity or appropriateness of the comparison. These concerns are outlined together with the current consensus of opinion.

A number of factors can influence the height and weight measurements of children. As well as nutritional intake, these include: the genetic potential of the individual, incidence of infectious disease (especially diarrhoea), levels of exercise, stress and conditions such as dwarfism or hormone deficiency. Anthropometric measurements, therefore, vary considerably between children of the same age and may be determined by factors other than their health status. However, as stated by McMurray (1996) "all healthy children are expected to increase progressively in dimensions and weight until they reach adulthood". Anthropometric assessment can, therefore, be considered in terms of growth attainment, and "expected norms" of child development can be identified by providing a range of measurements for height and weight that most healthy children would reach at a given age.

As conditions such as dwarfism are rare, a child's failure to thrive, or to reach full growth potential, usually reflects poor nutritional intake and unfavourable environmental circumstances, which increases susceptibility to infection. It is widely recognised, therefore, that anthropometric assessment is an effective indicator of child health and ultimately, of potential mortality risk (McMurray, 1996; Behrens, 1991). Poor growth attainment is thus a manifestation of socio-economic deprivation, which results in poor health prospects and survival chances for the child.

Although the relationship between poor anthropometric attainment and mortality is well established (McMurray, 1996; Behrens, 1991), considerable debate remains as to which of the anthropometric measures are most sensitive in predicting the health status of children. In addition, the use of "cut-off points" to identify children who are considered to be at increased risk of mortality has been questioned (Behrens, 1991). Chen et al. (1980) cited in Behrens (1991), for example, found WAZ scores to be the strongest variable in their analysis of Bangladeshi children over 2 years of age. He identified a "cut-off point" of 62% of the median weight for the National Center for Health Statistics reference population, thus children with a WAZ score below this point were found to suffer increased mortality risk.

Briend and Zimicki (1986), cited in Behrens (1991), on the other hand, found mid-upper-arm circumference to be more accurate than WAZ scores in predicting mortality risk. This could result from the correlation between WAZ scores and HAZ scores, i.e. children that have a low HAZ score will also have a low WAZ score. Kielmann and McCord (1978), cited in Behrens (1991), argue that the variance in HAZ scores may account for as much as two thirds of the variance in WAZ scores, but only 9.6% of the variance in mid-upper-arm circumference. This suggests that whilst stature has a considerable influence on WAZ scores it is much less so for mid-upper-arm circumference.

WHZ scores overcome this problem and is argued by McMurray (1996) to be the best method for identifying present malnutrition. However, it is transient in nature, i.e. individuals either recover fairly quickly or deteriorate and die. For this reason prevalence of wasting at any one time tends to be low, and hence analyses looking for correlates would require large samples. Alternatively, Behrens (1991) suggests that birth weight, being of "low genetic penetration" and closely associated with maternal nutrition, is a successful predictor of both morbidity and mortality risk.

Having found the recommendations of the literature rather contradictory and confusing, Pelletier (1991) states that there is no "best indicator" and that selection should be made to suit the purpose of the analysis. Selection should take into consideration the use of the indicator, i.e. for prevalence estimation and monitoring within a population, for screening and monitoring of individuals, for identifying causal effects or for program evaluation. Other considerations may include the effect of measurement error (i.e. WHZ scores are least affected by errors in age), and whether the primary interest is on long or short-term nutritional status.

2.8.1 The Use of a Reference Population for Standardisation

The interpretation of anthropometric analysis can sometimes be enhanced by the use of a standard reference population for comparison. It is likely that children from the same community are exposed to common environmental circumstances, which influence their growth attainment. For this reason it is often necessary to compare their measurements to those of healthy, well nourished children in order to assess the extent to which they are realising their true genetic growth potential.

A commonly used reference data recommended for this purpose was prepared by the World Health Organisation / National Center for Health Statistics / Center for Disease Control (WHO/NCHS/CDC). The reference population used for this data consists of well-nourished American children during the 1970s.

Using age-standardised growth curves, weight and height measurements can be expressed as:
1) centiles of the reference distribution
2) percentages of the reference median
3) standard deviations from the reference median (z-scores) (Behrens, 1991; McMurray, 1996).

Whilst percent of median and percentiles have been used frequently in the past, z-scores have now become the more commonly used method (Pelletier, 1991).

Cut-off points are often used to identify children whose measurements are outside the range that accounts for the normal variation expected between children which would result from differences in genetic potential. For example, those who are more than 2 standard deviations below the reference median (if z scores are used), and below 80% of the reference median weight-for-age or below 90% of the reference median height-for-age (if percentages are used), are often described as malnourished. The proportion of children of a particular age range who are malnourished is often used as a comparative statistic.

Much discussion has taken place concerning the use of such reference data in developing countries, and mainly concerns the following points.

1) The existence of ethnic differences in genetic growth potential.
   It is a commonly held belief that there are ethnic differences in growth potential and it is, therefore, inappropriate to use an "alien" reference population for comparison. Research has established, however, that although there are racial differences in adult stature, there is no difference in growth potential before puberty (Pelletier, 1991; McMurray, 1996). Indeed a number of studies have confirmed that nutritional and environmental factors account for a considerably greater amount of variation in anthropometric assessment and that the role of ethnicity is minimal (Eveleth and Tanner, 1976; Habicht et al., 1974, cited in McMurray, 1996). Pelletier (1991) confirmed this in a comparison of the mean heights of 7 year-old boys, from different regions, with percentiles from the reference population. Groups were compared from both socio-economically privileged and less privileged backgrounds and results demonstrated that whilst most of the more privileged samples had means "hovering" around the 50th percentile, those of less privileged status have means well below the 25th percentile. Differences associated with socio-economic status are thus far greater than differences across populations.

2) It is inappropriate to compare children from developing countries to "well off" American children.
   Clearly comparison to an "alien" population with a different environmental setting and lifestyle is conducive to misinterpretation of results and the development of unrealistic objectives. Also some may find it unacceptable for children of developing countries to be compared "unfavourably" in this manner. The general consensus, however, is that in the absence of a more local reference population, it is acceptable to use the NCHS, provided that interpretation of analyses, any recommendations made, and targets set for health intervention are appropriate to the local population (McMurray, 1996).

3) Growth attainment recommendations set by the WHO are lower than those exhibited by the standard reference population.
   The WHO growth recommendations are relevant to infants fed according to their current recommended schedule. This includes exclusive breast-feeding for the first four to six months, followed by a combination of breast-feeding and weaning to appropriate foods. The American children in the reference population, however, were mostly bottle-fed. The WHO working group on infant growth has thus recommended a revised reference population reflecting their feeding recommendations. However, it should be noted that the effect of the different methods of feeding are considered to be small (McMurray, 1996).

4) Weight and height values below the 10th centile or above the 90th centile in the NCHS reference population were estimated and hence not derived from true population means. In some developing countries the measurements of children are quite concentrated in these extremes (McMurray, 1996). It is far from ideal to draw conclusions about the nutritional status of a population when comparisons are so heavily based upon these estimated values.

Despite these problems the overall consensus is that in the absence of a more local reference population it is appropriate to use the WHO reference data provided it is used with these factors in mind. For example, values should be used as a yardstick and not a target (Waterlow, 1977, cited in McMurray, 1996). Alternatively, norms could be set to reflect the characteristics of the local population, for example 95% of the reference population instead of 100% (WHO).

2.8.2 Use of Cut-off Points as Indicators of Malnutrition

Cut-off points are useful for identifying prevalence of malnutrition and as a guide when making decisions about the condition of individuals for intervention programmes. They also have the advantage of being easy to interpret and focus attention on sectors of the population most in need (McMurray, 1996; Pelletier, 1991). However, there is doubt as to the reliability and specificity of this method, indeed a number of authors argue against its use for analyses concerning the correlates of malnutrition. Specifically it is argued that results derived from relative risk analysis are highly sensitive to the choice of cut-off, and that it is unreliable to make classifications when it is unclear whether there is a real difference between the categories (Pelletier, 1991).

This point is articulated by Ray and Scanlon (1994), cited in McMurray (1996)' " the risk of undesirable outcomes including mortality does not change drastically when crossing the magic cut-off point. The only certain part of risk prediction in using the distribution of specific health or nutrition parameters as a guide, such as weight-for-age, is that the further away from the central part of a distribution the greater the likelihood of true disease or poor outcomes".

One solution is to use three or more categories, as an outcome so that the prevalence of milder cases of malnutrition can be assessed. However, this would require larger sample numbers in order to test for significant correlates, especially if analysing weight-for-height which is usually collected less frequently. Statistical tests based on means offer greater power and versatility (Pelletier, 1991).

To further complicate the use of cut-off points, those derived across the three methods of standardisation do not correspond and the deficit found in analyses tend to vary with age. It is important, therefore, to use the same standard uniformly throughout the analysis (Pelletier, 1991).

McMurray (1996) and Pelletier (1991) recommend the use of anthropometric measurements as a continuous outcome, with a focus on covariation, rather than the use of cut-off points to transform measurements into dichotomous variables. McMurray (1996) demonstrates the difference between results from logistic and linear regression models in the analysis of HAZ scores, and WAZ scores of Burundi children. For the logistic regression model, z score cut-off points were used at plus and minus two standard deviations from the reference median. She found consistently that a wider range of factors remained significantly associated with growth attainment in the linear models than in logistic ones. She, therefore, concludes that the ease of interpretation of odds ratios derived from logistic regression models involve costs in terms of a compromised analysis.

Summary

Although anthropometric measurements, such as weight and height, vary considerably between children of the same age, most healthy children can be expected to fall within a given range of measurements appropriate for a given age. Failure to reach full growth potential usually reflects poor nutritional intake and unfavourable environmental circumstances. Anthropometric assessment is thus been found in previous literature to be an effective indicator of child health and mortality risk. There have, however, been contradictory findings as to the most sensitive measurement. It is important, therefore, that overall selection reflects the specific objectives of the analysis.

The use of the WHO reference population for comparison adds a wider perspective to the analysis, but invites criticism as to the appropriateness of its use. The general consensus is that in the absence of a more localised reference population the WHO population can be used but caution should be adopted when interpreting results.

The use of cut-off points has enabled the identification of children whose measurements fall outside of the expected range, accounting for normal variation between children. This method has also received criticism in terms of its reliability as it has been found to be highly sensitive to the choice of cut-off point used. Authors have argued against its use for analyses concerning the correlates of malnutrition owing to the consequential loss of statistical power.

CHAPTER 3

Two Study Designs: Data Collection and Preliminary Analysis

3.1 Introduction

Two data sets are used in this project to analyse the effect of birth spacing patterns on infant anthropometric measurements in the state of Karnataka, India. The National Family Health Survey (NFHS) for Karnataka was part of the larger, national survey, covering the whole of India. This survey was cross-sectional, consisting of a measurement for each individual at one point in time. The relatively large sample size provides considerable statistical power with which to identify the correlates nutritional status. The analysis of infant mortality in chapter 6 is also conducted using this data.

The Maternal and Child Health Survey was conducted in the Kanakapura villages of Karnataka, India. This was a longitudinal survey, consisting of a series of repeated measurements taken for each child over the period of one year. Although smaller in size, this data provides greater scope, in that it facilitates the investigation of temporal effects within the analysis of infant nutritional status. Each survey thus provides a different, but complimentary, approach to the analysis.

This chapter first describes of the state and people of Karnataka in order to portray the broader socio-economic and demographic background of the populations studied. The overall nutritional status of children within the state is also considered, as well as mortality rates during the neonatal, post-neonatal and early childhood periods. Trends over five year periods prior to the survey are examined. The cross-sectional and longitudinal survey designs are then presented together with a preliminary analysis. This includes the distribution of child nutritional status and mortality by a number explanatory variables, as well as an investigation of birth spacing behavour. For the Longitudinal data, frequency distributions are explored to provide a more detailed profile of 'life within the villages'. In the final section of the chapter, the advantages and disadvantages of analysing data from cross-sectional and longitudinal designs are contrasted and discussed.

3.2 The State and People of Karnataka

The state of Karnataka is located on the west coast of southern India. Formerly known as Mysore, Karnataka suffered a turbulent history under control of a number of different Indian dynasties such as the Cholas, Gangas Hoysalas and Chaludyans. Many left vivid evidence of their presence with intricate and detailed sculptures built within their temples and architecture. During the 19th Century under British power, a succession of progressive rulers where installed. The Maharaja was perhaps the most popular amongst the Indian people and became first governor of state.

Geographically Karnataka forms two well defined regions of India: the Deccan Plateau and the Coastal Plains and Islands. The Deccan Plateau is of high elevation and is bordered on either side by ranges of hills which parallel the coast to the east and the west. The Western Ghats are the higher of the two ranges and separate the Deccan Plateau from the wide coastal plains. This range runs north-north west to south-south east through Karnataka for a distance of about 320 km. It provides the origin of a number of east and west flowing rivers and thus may be thought of as the "life-line" of the state. On the basis of the regional physiological and graphic characteristics the state can be divided into the following four regions: the northern plateau which is an extensive plateau sloping towards the east and is characterised by its treeless landscape, the central plateau again sloping towards the east, the southern plateau and the coastal region which extends to the Arabian sea and has a diverse terrain with rivers, creeks and hill ranges (1992-93 NFHS for Karnataka).

Climatic conditions are determined largely by the states geographical proximity to the sea, by the monsoons and the physio-geographic characteristics. The west coast and the hilly regions receive the heaviest rainfall and the eastern regions are prone to drought. The year is divided into four seasons: the winter (January and February), the summer (March and May), the Southwest monsoon (June to September) and the Northeast monsoon (October to December). Much of the year thus falls into the monsoon seasons, although the heaviest precipitation occurs during the Southwest monsoon only. Temperatures tend to be lowest in January at around 33°C and highest in May, when temperatures may reach as high as 43°C.

The population of Karnataka is approximately 45 million, and contains 5% of the total population of India as a whole. The land area is 191,773 square km comprising 6% of the total land area of India. Population density is therefore comparatively low at 235 persons per squared km (compared with 273). Over one third of the population live in urban areas, which is a higher concentration than characteristic of India as a whole (31% compared with 26% (Indian census, 1991)). The majority of people nevertheless rely on agriculture for subsistence (63% of workers) and a comparatively high share of the states income is attributable to agricultural activities (39% compared to 35% for India in 1988-89). The rate of increase in food production was slower than population growth in Karnataka between 1970 and 1990, and thus per capita grain food production has declined. Rice, ragi and jowar are the main cereal crops grown, although nearly 34% of agricultural lands are under non-food crops. This is higher than the all India average which is 28% (Centre for Monitoring Indian Economy, 1991, cited in 1992-93 NFHS for Karnataka). Mulberry plantations are one example of a non-food crop, being used primarily as food for silk worms. Sericulture is an important industry in Karnataka, providing income generation for many people and 60% of the country's raw silk production. The industry involves diverse activities from growing mulberry plants to rearing silk worms and reeling the silk in industrial plants.

The industrial structure of the state is diversified and includes the production of machine tools, aircraft, electronics and computers. The capital city of Bangalore is the major industrial centre, attracting buisness opportunists worldwide (1992-93 NFHS for Karnataka). Karnataka is, however, a state of strong contrasts with the modern industrialised city of Bangalore at one extreme and expanses of rural farming areas at the other. Despite the commercial activity of Bangalore about one third of the states population is reported to live below the poverty line[1]. This is a slightly higher level than for India as a whole (Centre for Monitoring Indian Economy, 1991, cited in 1992-93 NFHS for Karnataka), but does not appear to have an impact on the demographic indicators, which generally fare better. Fertility rates were lower, for example, in

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[1] Poverty line defined by the Task Force on "Minimum Needs and Effective Consumption Demand" constituted by the Planning Commission in 1979. It is based upon per capita monthly expenditure, relative to prices corresponding to the per capita daily calorie requirements (for further definition see 1992-93 NFHS for Karnataka).

Karnataka: the crude birth rate for 1992 was 26.2 compared with 29 for India, and the total fertility rate was calculated at 3.1 births per woman, in 1991, compared with 3.6. Infant mortality was shown to be lower in Karnataka at 73 per 1,000 live births, compared with 79 for India. Life expectancy at birth was considerably higher in Karnataka, and gender differences were evident whereby females demonstrated a higher life expectancy than males. This gender differential is consistent in many countries around the world, but is a recent phenomenon in India. Indeed many states still demonstrate higher life expectancy for men. This reflects the lower status and subservient position occupied by many women within Indian society.

The literacy rate of the population aged seven years or more is slightly higher in Karnataka than in India as a whole (56% compared with 52%). Again there is, a large gender difference, whilst 67% of males are literate only 44% of females are (Inidan census, 1991). This difference is only marginally different to that found for the rest of India (1992-93 NFHS for Karnataka).

The National Family Planning Programme, implemented in India in 1951, aimed to provide for both reproductive and more general health care needs, with a particular focus on mothers and children. Services were provided through a network of sub-centres, primary health centres, community health centres, postpartum centres, voluntary organisations, and other facilities. In 1983, The National Health Policy was established, through parliament, to focus health care activities. With the overall objective of ensuring primary health care for all by the year 2000, the government placed high priority on the development of health care infrastructure in rural areas, which had previously been neglected. In addition the following issues were identified for special attention.

- the nutrition of the population
- the immunisation programme
- maternal and child health care
- the prevention of food adulteration and the maintenance of quality of drugs
- water supply and sanitation
- environmental protection
- school health programmes

- occupational health services
- prevention and control of locally endemic diseases
- infant and child mortality

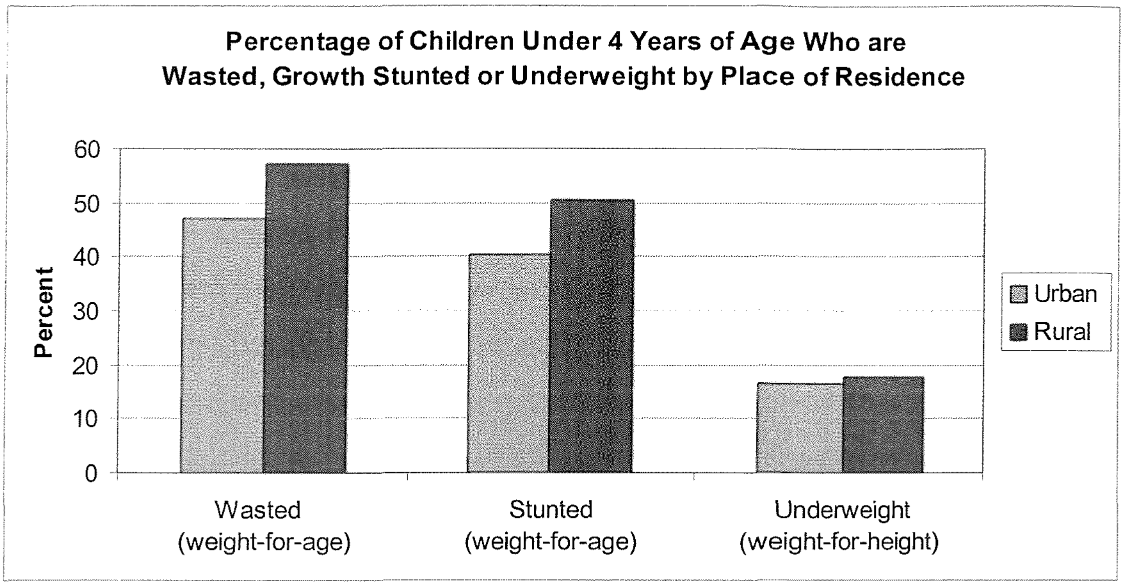
(1992-93 NFHS for Karnataka)

As part of these initiatives various benefits have been made available to the poor in both rural and urban Karnataka. One such scheme involves the issue of ration cards, to poor families. These cards may be used to purchase essential commodities such as rice, wheat, sugar, kerosene and cloth, at subsidised prices through a number of retail outlets or fair price shops. Data from the NFHS survery (1992-93) show that although the percentage of households with cards was lower than expected they were owned by more disadvantaged households, for example those headed by illiterates. Other benefits have included government assistance in housing, loans, assets, wages and training. Overall the utilisation of these benefits has been found to be very low (NFHS 1992-93). Studies to set up monitor and evaluate such programmes have yet to provide full evidence of their effectiveness. Whilst there have clearly been some improvements in welfare, many people remain poor and suffer ill-health.

3.2.1 Infant and Child Nutrition

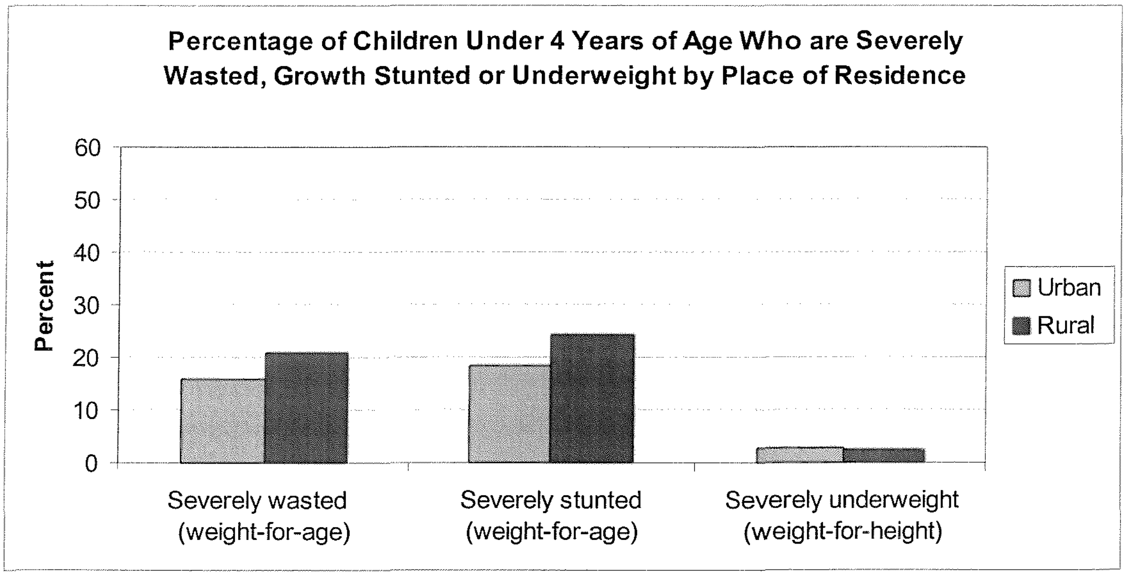
Figure 3.1 shows the percentage of rural and urban children, under four years of age, that were wasted, growth stunted or underweight, by place of residence at the time of the survey. Wasted is defined as a WAZ score of -2 or less, growth stunted as a HAZ score (height-for-age z score) of –2 or less and underweight as a WHZ score (weight-for-height z score) of –2 or less. The graphs show that very high percentages of children are wasted and/or growth stunted, and that the percentages may well be higher for children of rural areas than urban areas. These very high percentages are likely, in part, to reflect differences in the lifestyle of the children of rural Karnataka and the reference population. The average weight for healthy children of Karnataka may well be below that of the reference population and thus true levels of wasting or stunting caused through under or malnutrition may be lower (see Chapter 2 for discussion of the use of cut-off points in anthrompometric assessment). The percentage of children with low WHZ scores is much smaller than the other two indicators at around 15-18%, for both rural and urban areas. This lower level reflects the transient nature of low WHZ's, whereby children either recover or die (McMurray, 1996).

Figure 3.1



Number of children - 477 (Urban), 1200 (Rural). Source: NFHS for Karnataka 1992-93.

Figure 3.2



Number of children - 477 (Urban), 1200 (Rural). Source: NFHS for Karnataka 1992-93.

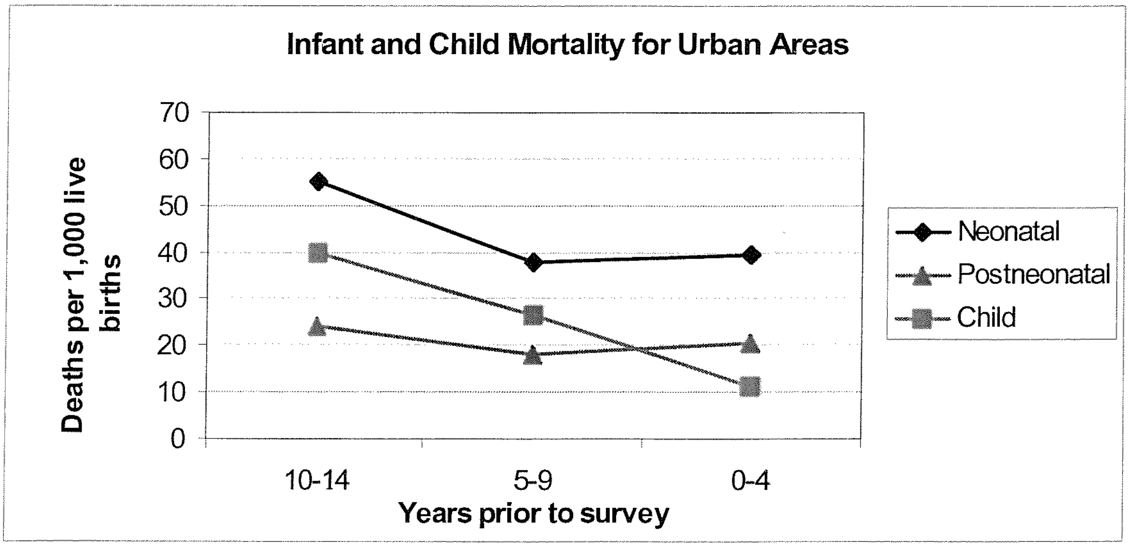
Figure 3.2 shows the percentage of children, who are severely wasted, stunted and underweight. This is defined as z scores of –3 or less. Around 20% of children are shown to be severely wasted and /or stunted and again there appears to be an urban /

rural differential whereby rural children fare worse. It is likely these children have been malnourished and suffer a greater risk of ill health or mortality.

3.2.2 Infant and Child Mortality

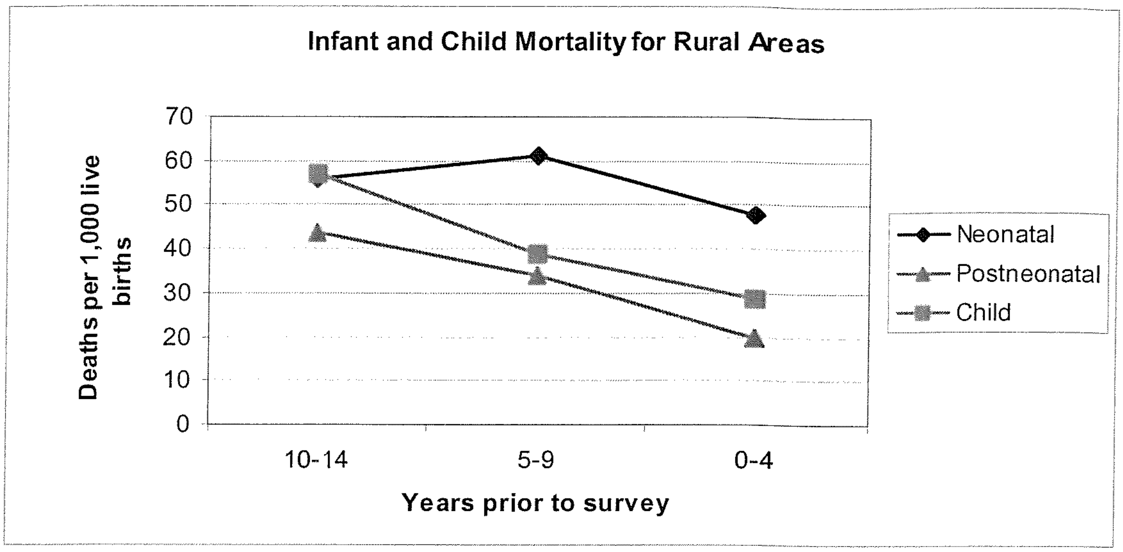
Figures 3.3 and 3.4 show rural and urban mortality rates for the neonatal (aged 0-1 month), post-neonatal (aged 2-12 months) and childhood (aged 13-60 months) periods, for 0-4 years, 5-9 years and 10-14 years prior to the survey. Overall the graphs show that mortality rates have decline over the 15 year period prior to the survey, for all mortality periods. The pattern of decline has varied, however, by the period of mortality and the place of residence. For neonatal mortality the decline was greatest in urban areas, where a steep decline in occurred during the earlier period. In rural areas there was an initial increase in mortality, before the subsequent decline in the more recent time period. For post-neonatal the decline has been fairly sharp and consistent in rural areas, throughout the 15 year period, but has been much smaller in urban areas. However mortality rates were initially much higher in rural than urban areas. For child mortality there has been a steep and consistent decline in both rural and urban areas, although the rates are considerably higher in rural areas. Overall, although mortality rates have declined over time they remain high especially in rural areas. Neonatal mortality for rural Karnataka was nearly 50 per 1,000 live births between 1998 –92, that is one death for every twenty live births.

Figure 3.3



Source: NFHS for Karnataka 1992-93.

Figure 3.4



Source: NFHS for Karnataka 1992-93.

3.3 National Family Health Survey for Karnataka

The 1992 NFHS for Karnataka provides valuable data with which to conduct the cross-sectional analysis of child anthropometric status. The survey is part of a much wider survey, which aimed to provide national and state level data on demographic and health issues in India. The survey included information on fertility, nuptuality, family planning, child health and mortality, as well as the socio-economic setting in which the respondent resided. The data thus provides a wide range of information appropriate for the analysis of child nutrition and welfare. The NFHS for the whole of India is nationally representative and consists of 89,777 ever-married women, aged 13-49, interviewed from 24 states and the National Capital Territory of Delhi. The NFHS for the state of Karnataka was conducted between November 1992 and February 1993. This consisted of 4,413 women from 4,269 households and included health related information on 2,344 of their children born during the previous four years. The survey design was conducted to ensure the sample was representative at the state level. It was self-weighted for place of residence in that the sampling rate (fraction) is the same for urban and rural areas.

3.3.1 Study Design in Rural Areas

Three Level Stratification

Level 1 - Geographic, with six regions consisting of districts of similar characteristic.

Level 2 - 6 strata, consisting of villages with similar population size and distance to an urban centre.

Level 3 - the villages were ordered within each stratum by level of female literacy.

Two Stage Sample Design

- First stage - consisted of the selection of villages

84 Primary Sampling Units (PSU) were selected systemically with probability proportional to size (PPS).

- Second stage - selection of households.

Households to be interviewed were selected from the household lists using systematic sampling with equal probability.

Sampling Frame

First sampling stage - villages from the 1981 census list.

Second sampling stage - list of households and mappings in each Primary Sampling Unit (PSU). This was carried out as part of the survey.

3.3.2 Study Design in Urban Areas

Two Level Stratification

Level 1 - 3 strata of cities and towns. These are: self-selecting cities, district headquarter towns and other towns.

Level 2 - Geographic strata as for rural areas.

Sample Design

1) Self-selecting cities - two stage sample design

- First stage - census enumeration blocks selected with PPS.
- Second stage - selection of households.

2) District headquarters and other towns - three stage sample design .

- First stage - towns selected with PPS.
- Second stage - selection of two census blocks per town with PPS.
- Third stage - selection of households.

Sampling Frame

Census Enumeration Blocks – from the 1981 census list.

3.3.3 Non-response

Completed interviews were attained from 93% of the 4,607 households, selected using the above process. The main reason for non-response was either that the household was vacant (3% of households) or that the respondent was absent from the household (3.5% of households).

3.3.4 The Questionnaires

Although broadly based upon the DHS Model B questionnaire, designed for countries with low contraceptive prevalence, the overall content of the questionnaires was determined in a questionnaire design workshop held in Pune 1991. Modifications were made to suit the specific socio-cultural characteristics of the Indian population and the specific aims of the NFHS in India. In addition, "state-specific" questions were included which concerned the provision of ration cards and anti-poverty programme benefits.

Three types of questionnaire were used:

1) Household questionnaire - this included a list of household members together with information concerning their age, education and occupation as well as household ownership details. This was used to identify potential respondents.

2) Woman's questionnaire - included seven sections: Respondents background, Reproduction, Contraception, Health of Children, Fertility Preferences, Husbands Background and Woman's Work, and Woman's Height and Weight.

3) Village questionnaire - included information in amenities available within the village.

The interviews were conducted by trained, female investigators under the direction of a field supervisor. Editors were employed to detect errors in the completed forms and to resolve problems in editing.

3.4 Preliminary analysis of the NFHS Data

The analyses of the NFHS for Karnataka focus on the correlates of infant and child health outcomes. Chapter 4 is concerned with nutritional status as an outcome and thus assesses the effect of explanatory variables on the WAZ scores. Chapter 6 is concerned with mortality as an outcome and assesses the effect of explanatory covariates on both neonatal and post-neonatal or early childhood deaths. Of particular interest is the relationship between short birth intervals and these health outcomes. This preliminary analysis investigates the distribution of WAZ scores and mortality rates by the explanatory covariates. Also, in order to provide an understanding of reproductive behaviour and factors relating to short birth intervals the final section describes the distribution of birth spacing, first births and multiple births.

Table 3.1 shows the average WAZ score by the explanatory covariates. The average WAZ score for infants following short birth intervals is shown to be lower than those following longer birth intervals indicating that there may well be an association between short birth intervals and nutritional status. Breast-feeding behaviour was also associated with noticeable differentials in nutritional status, the average WAZ score was lower if the cholostrum was squeezed out prior to feeding. This is a common practise amongst women in these villages as cholestrum is often considered dirty.

The average WAZ score was also lower if the infant was not fed according to the United Nations recommendations, i.e. breast-feeding should be exclusive for 4 to 6 months then solids foods gradually introduced. Other groups with low WAZ scores were as expected; those with premature birth, small size at birth, lack of prenatal care, incidence of diarrhoea or fever within the previous two weeks, maternal illiteracy, house construction of poor materials (i.e, katcha), public water source or river and lack of toilet facilities.

Table 3.2 shows the distribution of neonatal and post-neonatal mortality by a number of explanatory covariates. A relatively high proportion of neonatal deaths occur amongst children who follow short birth intervals, i.e. 6.5% compared with 2.4% for children who follow longer birth intervals. For post-neonatal deaths, however, there is little difference by the preceding birth interval (3.7% compared with 3.5%).

Table 3.1 Percent Distribution of Childhood Anthropometric Measurements by Demographic and Background Characteristics

Characteristic	Mean WAZ Score	Standard Deviation	Number
Previous birth interval			
<24 months	-2.2	1.2	171
24-47months	-1.9	1.2	396
48+ months	-2.0	1.1	113
First birth	-2.1	1.2	941
Still breast feeding			
Yes	-1.9	1.2	659
No	-2.2	1.1	282
Squeezed milk from breast			
Yes	-2.1	1.2	392
No	-1.9	1.2	549
Fed as recommended by the United Nations			
Yes	-1.7	1.2	377
No	-2.3	1.1	564
Size at birth			
Small	-2.3	1.1	285
Average /Large	-1.9	1.2	656
Gestation at Birth			
Full term	-2.0	1.2	927
Premature birth	-2.4	1.1	14
Gender			
Boy	-2.0	1.2	489
Girl	-2.0	1.2	452
Mother received prenatal care			
Yes	-2.0	1.2	811
No	-2.5	1.1	130
Survival of previous child			
Survived	-2.0	1.2	884
Died	-1.9	1.2	57
Diarrhoea in previous 2 weeks			
Yes	-2.3	1.2	122
No	-2.0	1.2	819
Fever in previous 2 weeks			
Yes	-2.2	1.2	189
No	-2.0	1.2	752
Death of previous siblings			
None dead	-2.0	1.1	735
1 dead	-2.1	1.2	149
2+ dead	-2.2	1.4	57
Maternal education			
Illiterate	-2.2	1.2	660
Primary	-1.8	1.1	180
Middle / high	-1.5	1.1	101
Maternal occupation			
Household	-1.9	1.2	503
Non manual	-1.7	1.5	14
Manual	-2.2	1.1	424

Table 3.1 Continued

Characteristic	Mean WAZ Score	Standard Deviation	Number
Paternal occupation			
Non manual	-1.9	1.2	137
Manual	-2.1	1.2	804
Religion			
Hindu	-2.1	1.2	798
Muslim	-2.0	1.1	121
Other	-1.3	1.3	22
Household construction			
Kacha	-2.2	1.1	352
Pucca	-2.0	1.2	57
Semi-pucca	-1.9	1.2	532
Number of household items owned			
None	-2.2	1.2	295
One	-2.2	1.1	171
Two plus	-1.9	1.1	475
Water source			
Own	-1.8	1.1	143
Public	-2.1	1.2	702
Pond/river	-2.0	1.2	65
Toilet facilities			
None	-2.1	1.1	845
Pit/bucket	-1.6	1.3	62
Flush	-1.6	1.2	34

Table 3.2 Percent Distribution of Childhood Mortality by Demographic and Background Characteristics

	Neonatal mortality			Childhood mortality		
Characteristic	Survived	Died	Number	Survived	Died	Number
Previous Birth Interval						
<24 months	93.5	6.5	551	96.3	3.7	323
24+ months	97.6	2.4	1390	96.5	3.5	774
First birth	95.3	4.7	826	96.9	3.1	455
Multiple birth	72.1	27.9	43	85.0	15.0	20
Breast Feeding						
Breast-fed	99.0	1.0	2683	96.4	3.6	1548
Never breast-fed	26.8	73.2	127	95.8	4.2	24
Size at birth						
Small	93.0	7.0	784	95.0	5.0	398
Average	97.0	3.0	981	96.6	3.4	554
Large	96.6	3.4	1045	97.3	2.7	620
Gestation at Birth						
Full term	96.8	3.2	2719	96.5	3.5	1544
Premature birth	63.7	36.3	91	92.9	7.1	28
Gender						
Boy	94.9	5.1	1442	97.0	3.0	801
Girl	96.6	3.4	1368	95.8	4.2	771
Prenatal iron supplement						
Yes	96.1	3.9	2076	97.1	2.9	1137
No	94.6	5.4	764	94.7	5.3	435
Prenatal tetanus injection						
Yes	96.0	4.0	2118	97.0	3.0	1144
No	94.9	5.1	692	94.9	5.1	428
Survival of previous child						
Survived	96.6	3.4	2576	96.5	3.5	1445
Died	86.3	13.7	234	96.1	3.9	127
Maternal age						
<15	91.0	9.0	78	87.2	12.8	47
15-19	94.0	0.1	923	96.0	4.0	499
20-24	97.5	2.5	995	97.1	2.9	561
25+	95.9	4.1	814	97.0	3.0	4654
Maternal Education						
Illiterate	95.5	4.5	1809	95.1	4.9	1026
Primary	96.4	3.6	496	98.2	1.8	275
Middle	95.4	4.6	174	99.0	1.0	96
High	96.1	3.9	331	100.0	0.0	175
Maternal Occupation						
Housework	95.4	4.6	1628	97.1	2.9	855
Professional	96.9	3.1	32	100.0	0.0	18
Administrative	97.1	2.9	35	100.0	0.0	25
Service/ Agriculture	96.1	3.9	1115	95.4	4.6	674
Religion						
Hindu	95.5	4.5	2305	96.8	3.2	1279
Muslim	96.9	3.1	425	94.2	5.8	243
Other	96.3	3.8	80	98	2.0	50

Table 3.2 Continued

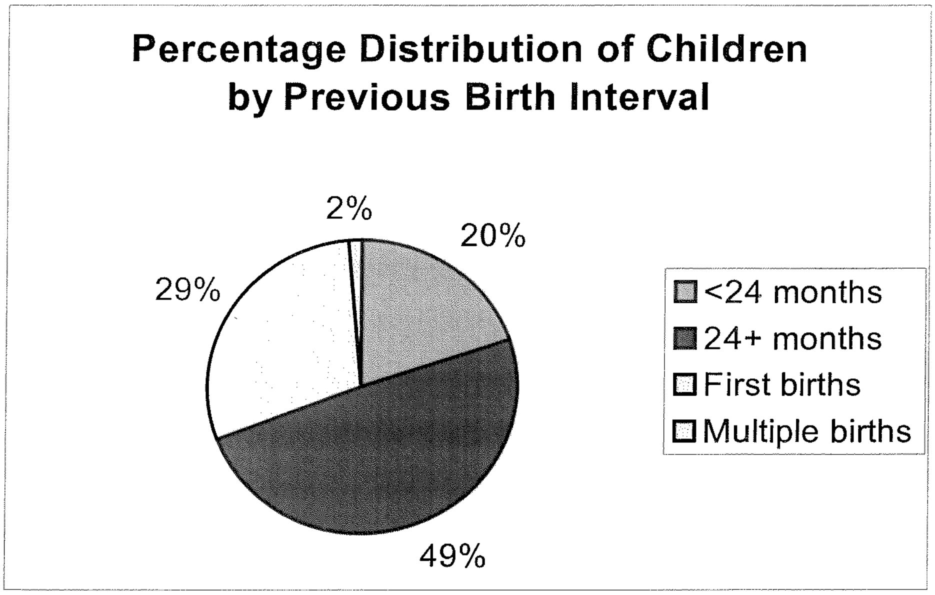
Characteristic	Neonatal mortality			Childhood mortality		
	Survived	Died	Number	Survived	Died	Number
Husbands Education						
None	94.4	5.6	1193	95.2	4.8	618
Attended school	96.7	3.3	1617	97.4	2.6	891
Place of Residence						
Urban	96.5	3.5	820	96.3	3.7	481
Rural	95.4	4.6	1990	96.7	3.3	1091
Standard of Living Index						
Poor	94.9	5.1	437	94.1	5.9	238
Lower middle	95.1	4.9	1560	95.8	4.2	867
Middle	97.3	2.7	563	98.4	1.6	309
Upper middle	98.2	1.8	72	99.0	1.0	103
Rich	96.2	3.8	57	100.0	0.0	28
Household Construction						
Kacha	95.1	4.9	978	95.6	4.4	542
Pucca	96.5	3.5	370	99.5	0.5	217
Semi-pucca	96.0	4.0	1462	6.2	3.8	813
Water source						
Own	97.3	2.7	695	98.3	1.7	409
Public	95.2	4.8	2115	95.8	4.2	1163
Toilet facilities						
None	95.4	4.6	2067	95.9	4.1	1132
Pit/bucket	95.7	4.3	345	96.6	3.4	205
Shared flush	96.0	4.0	99	98.1	1.9	53
Own flush	98.0	2.0	299	98.9	1.1	182

These results indicate that the disadvantage suffered by an infant following a short birth interval increases the health risks very early in infancy but has little effect during early childhood. Similar results were also shown for the distribution of deaths amongst children from multiple births, whereby neonatal mortality was extremely high at 30%. There is also, however, a relatively high proportion of post-neonatal deaths amongst multiple births although less marked than that of neonatal mortality (15%).

Seventy three percent of infants who were never breast-fed died during the neonatal period. This compares with 1% of those who were breast-fed. As mentioned previously it is highly likely that most of these infants failed to breast-feed because they died rather than vice versa. As expected a very high proportion of infants born prematurely died during the neonatal period and to a lesser extent during the post-neonatal or childhood period. Other factors demonstrating higher proportions of neonatal deaths included male gender, if the mother did not receive prenatal iron or tetanus injections, death of the previous sibling, young maternal age, uneducated fathers, residence in rural areas, low or very high socio-economic status, public water source and no toilet facilities. For post-neonatal or child mortality girls rather boys demonstrated higher proportions of post-neonatal mortality, and factors such as socio-economic status, maternal age and maternal education demonstrate more marked effects. Also the proportions of post-neonatal deaths amongst children whose previous sibling died were only marginally different from those whose previous sibling survived.

This project concerns the relationship between short birth intervals and child health and mortality. Figure 3.5 shows the percentage distribution of children by the previous birth interval. Twenty percent of children are born within 2 years of the previous sibling and 2% of children are from a multiple births.

Figure 3.5



Total = 2810.

Table 3.3 shows that the distribution of short birth intervals varies by a number of covariates, particularly the survival of the previous sibling and breast-feeding behaviour. Whilst 17.4% of infants whose previous sibling survived, followed short birth intervals, 44% of those whose previous sibling died followed short birth intervals.

Table 3.3 Percent Distribution of Previous Birth Interval by Demographic and Background Characteristics

	Previous Birth Interval				
Characteristic	<24mths	24+mths	First birth	Multiple birth	Number
Breast Feeding					
Breast-fed	19.2	50.5	29.2	1.2	2683
Never breast-fed	29.1	28.3	33.9	8.7	127
Gestation at Birth					
Full term	19.6	50.4	28.7	1.3	2719
Premature birth	19.8	22.0	50.5	7.7	91
Gender					
Boy	19.7	48.8	29.3	2.3	1442
Girl	19.5	50.2	29.5	0.7	1368
Survival of previous child					
Survived	17.4	49.3	32.1	1.2	2576
Died	44.0	51.3	0.0	4.7	234
Maternal age					
<15	3.8	2.6	91.0	2.6	78
15-19	19.5	27.2	51.9	1.4	923
20-24	20.4	58.2	20.6	0.8	995
25+	20.3	68.6	8.7	2.5	814
Maternal Education					
Illiterate	21.1	54.0	23.8	1.2	1809
Primary	17.3	45.6	34.5	2.6	496
Middle	21.3	39.7	37.9	1.1	174
High	14.2	35.6	48.0	2.1	331
Maternal Occupation					
Housework	19.8	44.3	34.3	1.5	1628
Professional	3.1	37.5	59.4	0.0	32
Administrative	20.0	51.4	28.6	0.0	35
Service/ Agriculture	19.7	57.3	21.3	1.6	1115
Religion					
Hindu	18.4	49.9	30.5	1.3	2305
Muslim	24.5	49.2	23.3	3.1	425
Other	28.8	38.8	31.3	1.3	80
Standard of Living Index					
Poor	19.9	55.3	24.8	0.0	432
Lower middle	20.9	50.5	26.8	1.7	1554
Middle	17.6	45.8	34.8	2.2	557
Upper middle	14.3	37.5	47.0	1.2	168
Rich	9.6	53.8	32.7	2.0	52
Household density					
Low	14.6	43.3	39.5	2.5	157
Average	18.7	47.9	31.7	1.7	1930
High	23.1	54.9	21.2	0.8	723

This large difference indicates that pregnancy occurs soon after the death of a child either through the early return to fecundity or as a result of deliberate action by the parents to replace the child. A greater proportion of infants who have never been breast-fed follow short birth intervals (29%) in comparison to those who have been breast-fed (19%). This could reflect a difference in breast-feeding behaviour amongst women who have closely spaced births. Perhaps a more likely explanation, however, is that a higher mortality or morbidity rate occurs amongst infants who follow short birth intervals. If infants are ill or die soon after birth they may never be breast-fed.

Other factors worthy of note are the low proportion of short birth intervals amongst women with high school education, of professional occupation and of high socio-economic status. This could indicate that these women deliberately space pregnancies either because they have a greater awareness of the risks of short birth intervals or because they make rational decisions concerning reproduction to maximise their life style.

Multiple births are shown to be concentrated amongst infants who have never been breast-fed. As with short birth intervals it is likely that such infants suffer a higher mortality risk and thus are less likely to breast-feed. Multiple births are also shown to be highly concentrated amongst prematurely born infants in comparison to infants born at 40 weeks gestation or greater. This possibly indicates that the intrauterine environment is less competent in supporting more than one fetus, and that the heavy demands of the third trimester of a multiple pregnancy are likely to become untenable.

Summary

The preliminary analysis has shown that the average WAZ score was lower for those following short birth intervals than for those following longer birth intervals. The distribution of deaths by the explanatory covariates also showed that a high proportion of neonatal deaths occur amongst children who follow short birth intervals. This could indicate that the fetus suffers a disadvantage during the prenatal period increasing the risk of mortality in early infancy. There is little difference, however, between the proportions of post-neonatal or early childhood deaths by the previous birth interval.

Approximately 20% of children follow intervals of less than two years. This is a substantial proportion if short birth intervals are associated with adverse health outcomes. The distribution of short birth intervals was found to vary by a number of explanatory covariates. Of particular interest, however, was the high proportion of children whose previous sibling died who follow short birth intervals. Also a high proportion of children who were never breast-fed followed birth intervals or less than two years. It is likely that the breast-feeding effect reflects a reverse causality whereby children were not breast-fed because they died rather than vice versa.

3.5 The Maternal and Child Health Survey, Kanakapura Taluk

The data used for the longitudinal analysis of infant anthropometric status was part of an in-depth survey on maternal and infant health carried out by the Belaku Trust in Bangalore, India. The repeated weight measurements, provide a rich source of data with which to assess the correlates of infant nutritional status and facilitates the analysis of temporal effects within such relationships. A disadvantage of the data, however, is that the sample size is relatively small and localised. This reflects the greater financial and logistical requirements of collecting repeated observations over a period of time. Nevertheless the data provides valuable information concerning change in infant nutritional status, and thus adds a further dimension to the research that would not be possible with use of the cross-sectional survey alone.

The Maternal and Child Health Survey consisted of two parts: the 'Obstetric Health Survey', funded by the World Health Organisation, and the 'Maternal and Infant Follow-up Survey', funded by UNICEF (United Nations Children's Fund). The obstetric survey was commenced in August 1996, the infant follow up survey soon after. Data collection is expected to be completed by December 2001.

Eleven villages were selected near the Taluk headquarters town of Kanakpura, which is approximately 60 kilometers from Bangalore City in Karnataka. The villages are between 8 and 25 km from Kanakpura Taluk. All pregnant women in the villages were enrolled, as well as those who became pregnant during the study period, providing a total of 471. Approximately 25% were unable to complete the survey as they moved back to their natal home for delivery of the infant. Some respondents rejoined the survey following delivery, when they returned to their marital household.

Non-response for reasons other than moving between the natal and marital household was very low.

3.5.1 Obstetric Health Survey

Titled - "Exploration of Socio-Cultural Determinants of Obstetric Care and Maternity Outcomes in the Kanakapura Villages"

Primary objectives

- To describe the prevalence of obstetric morbidities among women.
- To explore the current use of health services and factors which prevent women from seeking care during pregnancy, delivery and postpartum.
- To study traditional beliefs and their interaction with the above.

Questionnaires

A series of eight questionnaires were completed throughout the pregnancy and during the postpartum period. These included:

- An initial questionnaire consisting of socio-economic and demographic background information, completed at enrolment.
- Health and morbidity questionnaires - covering experience of morbidity and health care provision / utilisation.
- Antenatal nutrition and activity - covering diet and energy expenditure.

These were carried out twice during the antenatal period, once during the first week post-delivery and once during the post-natal period at approximately 3 months. The post-delivery and post-natal questionnaires included details of the delivery, breast-feeding and infant health.

The interviews were conducted by a team of trained fieldworkers under the supervision of the principal investigator who is an obstetrician.

3.5.2 Maternal and Infant Follow-up Survey

Primary objectives

- Evaluate the incidence of malnutrition in children under two years of age.

- To determine the underlying causes of malnutrition

Questionnaires
Infant care and follow up questionnaires were completed monthly until the infant reached two years of age. This included information on breast-feeding, dietary intake of the infant, child care, morbidity and health care utilisation. Anthropometric assessment of both the mother and infant was also recorded. As the survey is not yet complete, a sub-sample of 156 women were selected for this analysis. This was on the basis that they had completed 9 months of the infant care component of the study.

3.6 Life in the Villages of Kanakpura

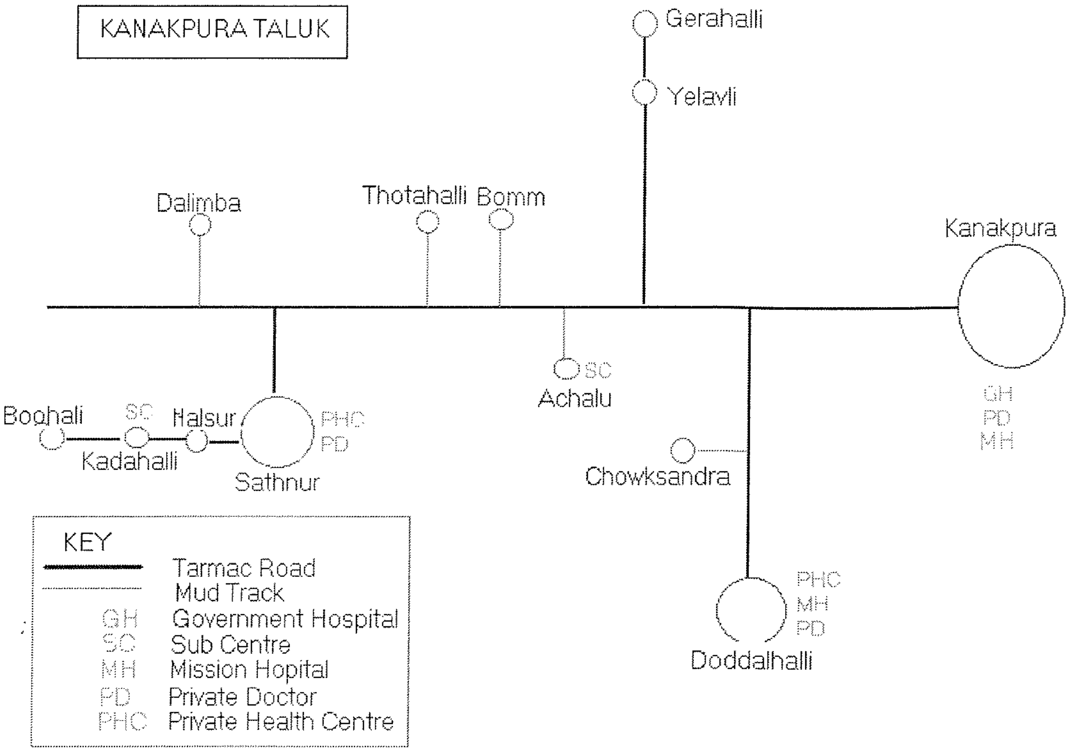
This section provides a "snapshot" summary of life in the rural villages surrounding Kanakpura Taluk. Women were selected for the survey if they were pregnant at the time of its inception or if they became pregnant in the earlier period in which it was conducted. The profile thus reflects the characteristics of women who became pregnant between 1996 and 1998.

3.6.1 Socio-economic Profile

The villages are located between 8 and 25 kilometers from the town of Kanakpura and 60 kilometers from the city of Bangalore. Figure 3.6 shows a diagrammatic map of the villages. Seven villages have access via tarmac roads, the remaining 5 via mud tracks. Bus routes are available on the tarmac roads with a regular daily service from Kanakpura to Bangalore. Kanakpura supports a range of shops, a daily market, schools, a college and a range of health care facilities. Bangalore is a large city, with a high profile for technology, commonly known as the silicon centre of southern India.

The nearest government hospital is located in the town of Kanakpura, where private doctors also practice (Figure 3.6). The largest of the villages, Doddalhali, is more isolated from the others, has a primary health care centre, a mission house and a private doctor where health care is available. Seven of the smaller villages are located in close proximity to a town which also has a primary health care centre and a private doctor, two of these villages have their own sub-centre which provide basic facilities.

Figure 3.6



Nearly a third of the houses (in which the women live) are constructed of pucca, a high quality material, and 13.2% are constructed of kachha, mud, bamboo or low quality materials (Table 3.4). The majority (58.3%), however, are constructed of semi-pucca which is a mixture of both high and low quality materials. This is rather better than average for rural areas in Karnataka shown in the NFHS, in which 39% are Kachha, 55% semi-pucca and only 6% pucca.

Being a community predominantly of agricultural subsistence most own at least some land; only 14% of households included in the sample were land-less. Two thirds owned plots of up to 5 acres, although this was mostly un-irrigated. A sizeable proportion 17% owned plots of 10 acres or more (Table 3.4). Working the land was carried out mostly by traditional methods, with very little use of modern machinery. Only 1% of households owned a tractor. Three quarters, however, owned livestock, 60% to the values of at least 5000 rupees.

Ownership of other possessions was limited to the necessities of life, with little extra luxury. Transport was mostly via foot or bicycle, although 9% owned a motorcycle.

There was some exposure to media: approximately half owned a radio and 20% a television. Very few villagers owned items such as fridges, sofas or sewing machines, although 10% owned a bull cart and 14% a water pump. Perhaps surprisingly the most commonly owned item was a clock (Table 3.4).

Table 3.4 Socio-economic Status and Ownership

	%		%
Household construction (n = 144)		**Value of possessions** (n = 145)	
Pucca (brick)	28.5	Rs.0 - 1,000	46.9
Kachha (mud/ bamboo)	13.2	Rs.1,001 - Rs.5,000	32.4
Semi-pucca	58.3	Rs.5,001 - Rs. 15,000	11.0
		Rs. 15,001+	9.7
Acres of land owned* (n = 145)			
None	14.5	**Possessions owned**	
0.1 - 2.5	35.2	Bicycle	42.1
2.6 - 5	23.4	Motor bike	9.0
5.1 - 10	10.3	Clock	74.5
10+	16.6	Radio	48.5
		Television	18.6
		Fan	14.5
Value of livestock owned (n = 145)		Sewing machine	2.1
None	26.9	Sofa	2.1
Rs 0 - 5,001	11.7	Fridge	1.4
Rs 5,001 - 10,000	17.9	Water pump	14.5
Rs 10,001 - 25,000	28.3	Bull cart	9.7
Rs 25001+	15.2	Tractor	1.4

* includes irrigated and unirrigated

Most of the women live in their husband's family household after they get married; only 4.2% live in the woman's natal household (Table 3.5). Approximately 25% of the households in which the women live are nuclear, whereby the woman lives only with her husband and children. The remaining 75% are of the more traditional, extended structure. The size of household thus ranges from 2 to 26 members, with a median of 5 members. It is likely that those stating very large household sizes are referring to family members living close by, but not necessarily under the same roof. Similarly, it could be, that those living in a nuclear household have other family members living in close proximity who influence decision making. Household size and family type are therefore, not easily defined.

Table 3.5 The Household and Women's Occupation

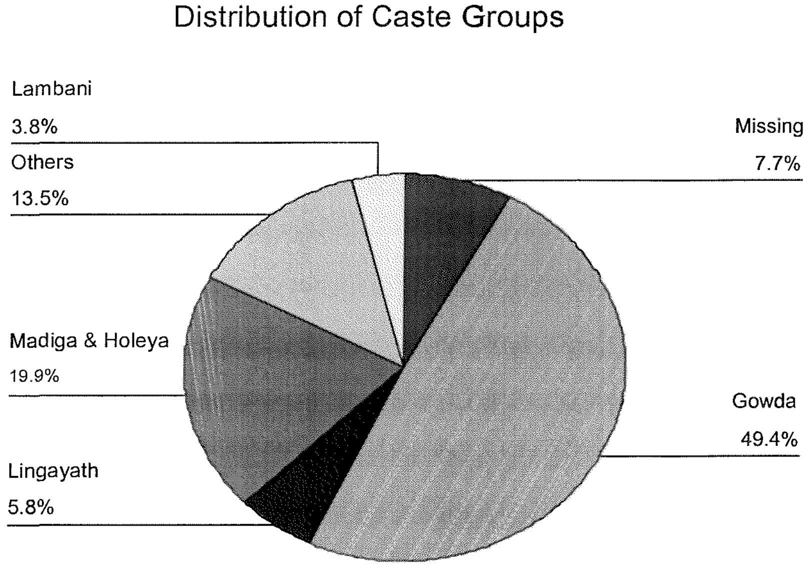
	%		%
Place of Residence (n = 144)		**Secondary Occupation*** (n = 121)	
Marital household	95.8	None	28.9
Natal household	4.2	Agriculture / livestock	42.1
		Sericulture / Family enterprise	14.9
Type of Household (n = 145)		Wage Labour	13.2
Nuclear	24.8	Household work	0.8
Extended	75.2		
		Secondary Occupation** (n = 23)	
Primary Occupation of Woman (n = 144)		None	0
Agriculture / livestock	9	Agriculture / livestock	8.7
Sericulture / Family enterprise	2.1	Sericulture / Family enterprise	8.7
Wage Labour	3.5	Wage Labour	8.7
Salaried employee	0.7	Household work	73.9
Household work	84		
Other	0.7		

* Of Woman whose primary occupation is household work

** Of Woman whose primary occupation is not household work

Figure 3.7 shows the distribution of women within each caste group. Nearly half belong to the Gowda caste, 19.9% to the Madiga and Holeya caste groups, 5.8% to the Lingayath, 3.8% to the Lambani and the remainder to other unspecified caste groups. The Lingayath caste is of higher status, whilst the Lambani, Madija and Holeya are of lower status.

Figure 3.7



Total number 156

Household work is the primary occupation for most women (Table 3.5). However, 70% of those who state household work as their primary occupation also have a secondary occupation: 42% undertake agricultural work and care for livestock, 15% are engaged in sericulture or help with a family enterprise and 13% are wage labourers. Of those women who state a primary occupation other than household work most do household work, as a secondary occupation. Very few women have both a primary and secondary occupation outside of the home (Table 3.5).

There is a noticeable difference in the secondary occupations of women who have previously had children as compared to those nulliparous (Figures 3.8 & 3.9). A considerably higher percentage of first time mothers do not have a secondary occupation whilst women who have previously had children do agricultural work, livestock, sericulture, family enterprise or even wage labour in addition to their household work. This reflects the cultural and socio-economic needs of the study population, for example, the sharing of child-care between family members, the status of newly married women and meeting needs in deprived circumstances.

The most common primary occupation (42%) for the husbands is agricultural work (on their own land) and caring for livestock. Other occupations commonly undertaken include wage labour (20%), work in a family enterprise or sericulture (16%) and salaried employees (16%) (Figure 3.10). Half of the husbands state that they also have a secondary occupation. Those working on their own land and looking after livestock commonly carry out additional work in a family enterprise or do sericulture. Some, however, do waged labour as the secondary occupation. Salaried employees are the least likely to have a secondary occupation.

There is quite a diverse pattern shown in the educational level of the women. Figure 3.11 shows the percentage of women who gained at least some education at primary, middle/high, and college or postgraduate level. Whilst 42% of the women received no education at all, 5.6% received college or postgraduate education. Also a substantially greater proportion received education to middle or high school level than just primary. It seems then that whilst quite a large proportion of the women are uneducated, most of those who do receive education obtain at least an intermediate level. This pattern is

Figure 3.8

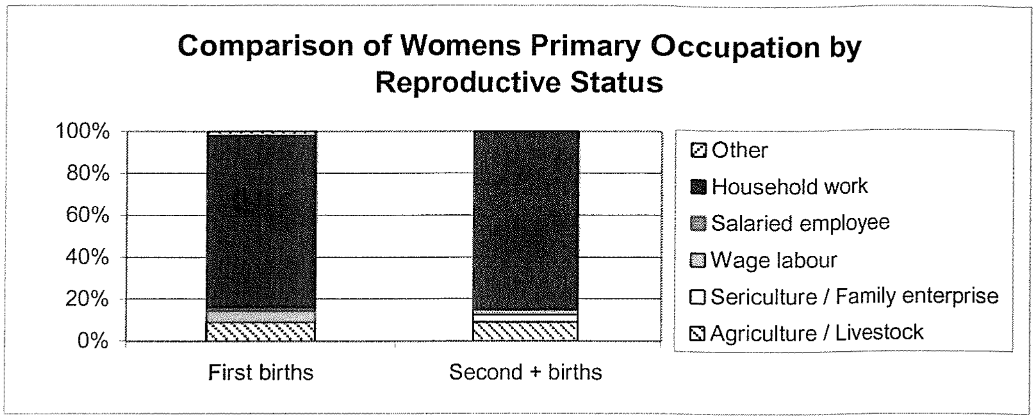


Figure 3.9

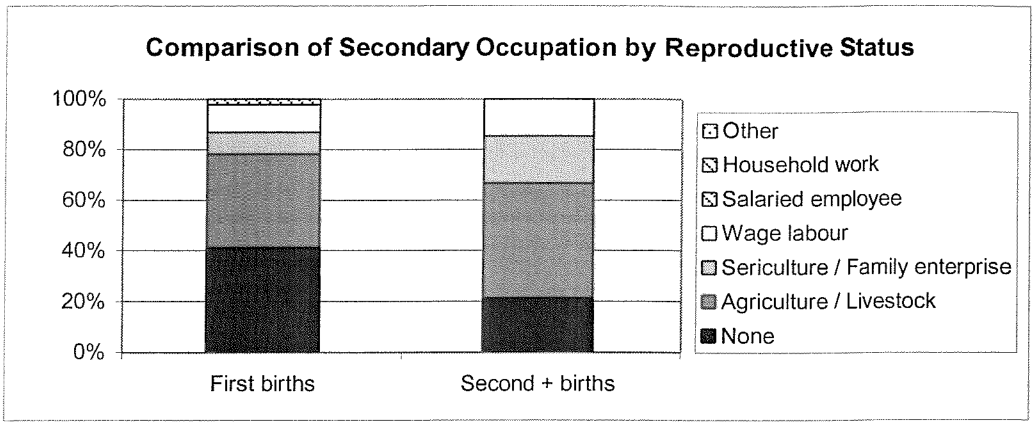


Figure 3.10

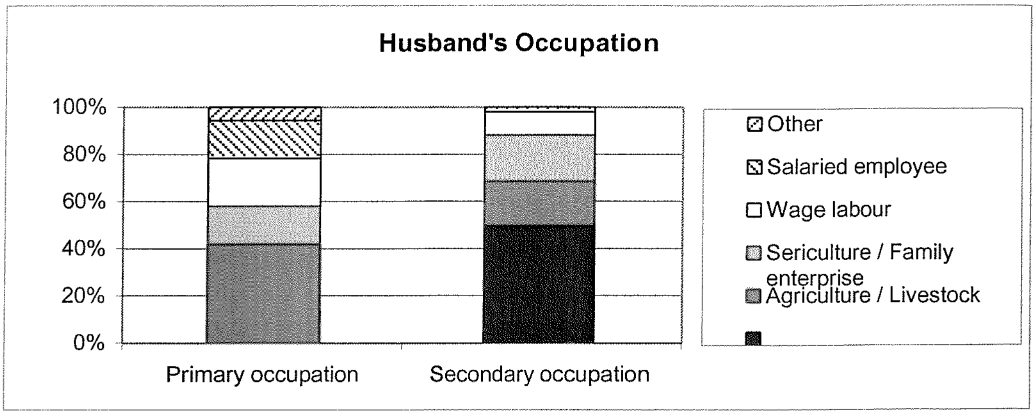
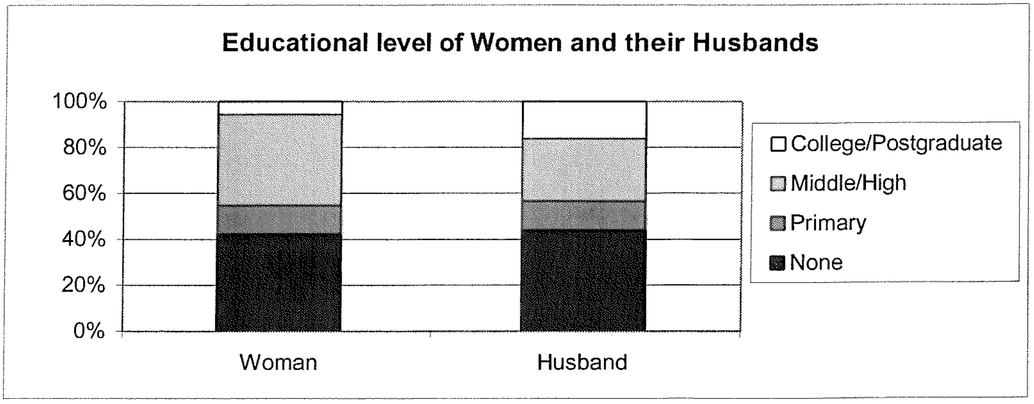


Figure 3.11



even more marked for the women's husbands. Whilst 44% received no schooling 16% went to college or received postgraduate education.

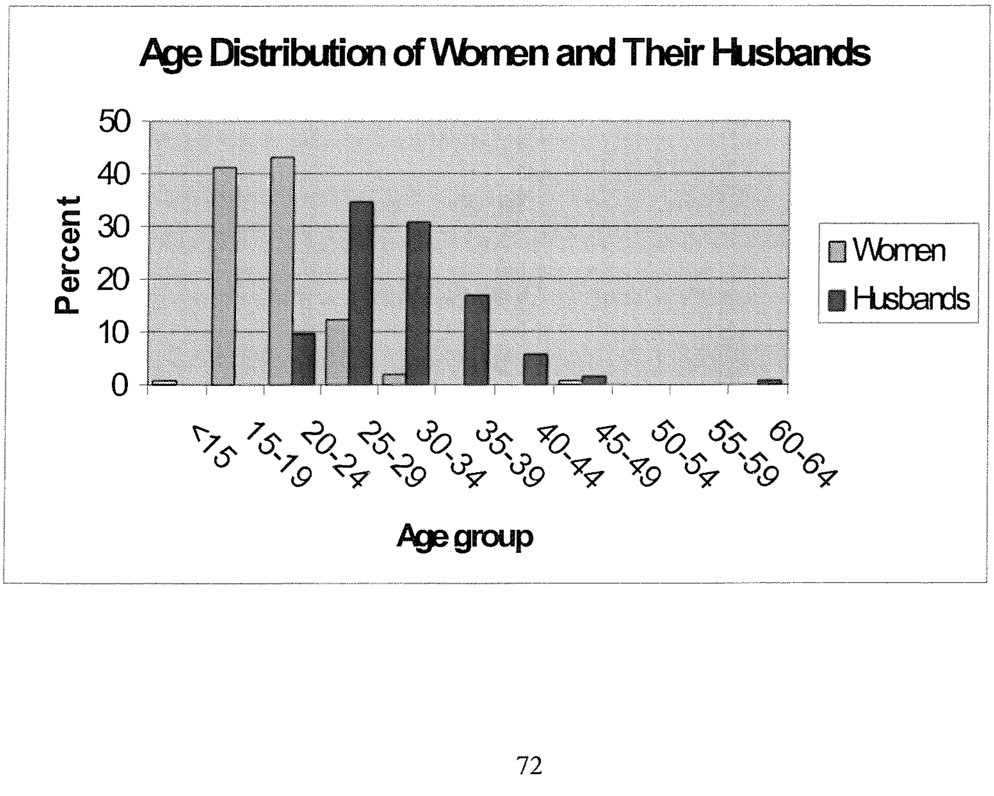
In many rural areas of India it is considered more important that boys are educated than girls. Figure 3.11 demonstrates that in this sample, as many women actually received education as did their husbands. However, their husbands tended to continue education to a higher level, i.e. college or postgraduate level education.

As may be expected women tended to be married to husbands of a similar educational level. Where there was a difference, however, the women were just as likely to be better educated in comparison to their husbands. However, Ganapathy et al. (1998) commented that the level of a woman's education in comparison to her husband appears to have very little effect on her status.

3.6.2 Demographic Profile

The age range of the women in the sample is between 14 and 45 years, although the majority are concentrated in the 15 to 24 year age band, which accounts for 84% of the sample (Figure 3.12). Over 40% of the women are less than 20 years of age and thus the prevalence of teenage pregnancy is high in these rural villages.

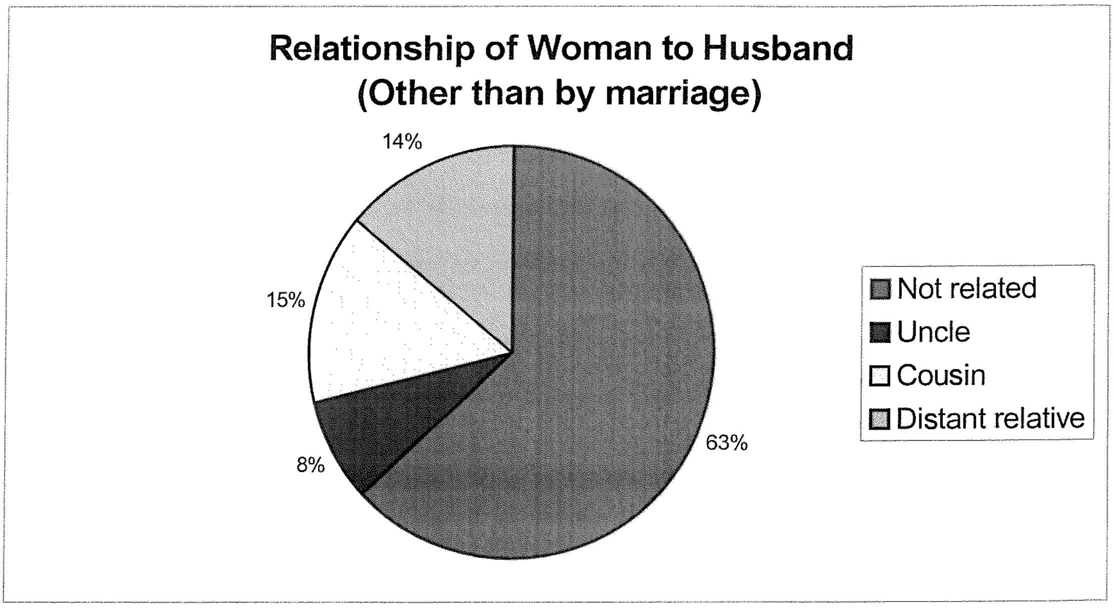
Figure 3.12



The husbands are generally older, with ages ranging between 21 and 60 years. The ages tend to be more widely distributed, although 82% are between the ages of 25 and 40 years (Figure 3.12). The mean age difference between the women and their husbands is 9.4 years, but a few women have an age gap of as much as 20 years.

One reason for the age difference is that women sometimes marry their maternal uncle. A considerable motivation for consanguinity quoted by people within the village, is that families prefer to keep any wealth or assets within the family, thus marrying their daughters to a relative ensures that the dowry or any other belongings remain within the family. Figure 3.13 shows that 37% of the women are married to a relative: 8% to an uncle, 15% to a cousin and 14% to a more distant relative.

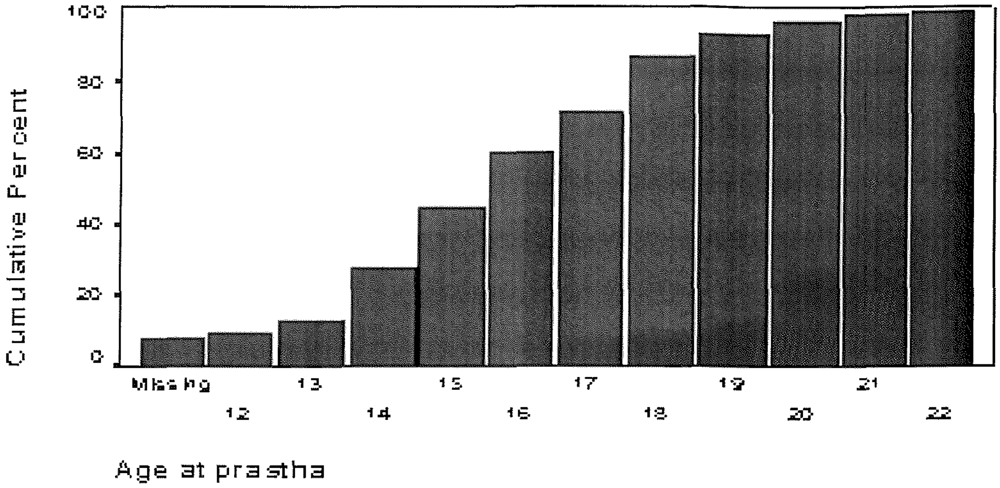
Figure 3.13



Total cases = 156

The mean age at prastha is 16.3 years. Prastha is the age at which the girl or woman is sent to the marital household and at which consummation of the marriage begins. Figure 3.14 shows the cumulative frequency distribution for age at prastha. The youngest age reported by the women in the study was 12 years. Over 40% were living in their marital home before the age of 16 years, and over 70% before the age of 18 years.

Figure 3.14 Age at Prastha



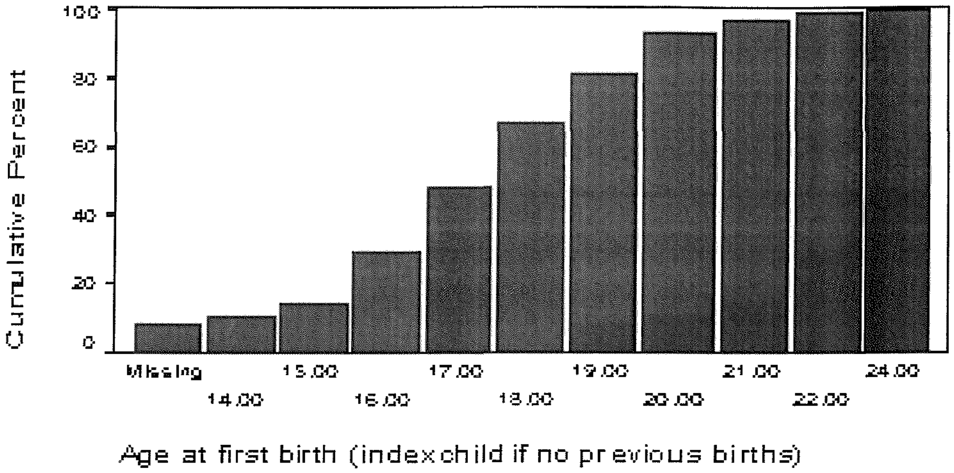
In India the minimum legal age at marriage is 18 years for women, as stipulated by the Child Marriage Restraint Act of 1978. Awareness of this legislation is low in Karnataka, however; only 41% of ever-married women demonstrated accurate knowledge of the legislation, during the NFHS survey. This percentage is for Karnataka as a state and thus includes urban areas. The percentage with knowledge of the legislation in the rural villages is likely to be lower and it is common for women to be married at younger ages. The singulate mean age at marriage for women in rural areas in Karnataka was found to be 19 years in the NFHS, and males were found to marry, on average, 6.5 years later.

The difference between age at marriage and at prastha varies, but in Karnataka cohabitation was found to follow formal marriage almost immediately, in almost all cases. Prastha was postponed by a few at very young ages but by age 15 this proportion was very small (NFHS).

The women in these rural villages, then, tend to get married and live with their husbands at very early ages even in comparison with rural Karnataka as a whole (as described by the NFHS). The majority are married well before the legal age of marriage, as required by the Child Marriage Restraint Act. There is also a large age difference between women and their husbands in the study population, which may partly result from the high proportions of marriages within families.

The mean age at first birth in the study population is 18 years. Three women reported having their first birth as early as 14 years of age and 6% had given birth before the age of 16 years. Between ages 16 to 20 years the cumulative frequency shown in Figure 3.15 becomes much steeper and most women (80%) have begun child-bearing whilst still a teenager. The incidence of complications tends to be higher for teenage births thus increasing the risk of morbidity and even mortality for both the mother and infant.

Figure 3.15 Age at First Birth



Thirty nine percent of the women in the study are pregnant for the first time, 34% for the second time and 27% have had 2 or more previous pregnancies (Table 3.6). One woman has had as many as 7 pregnancies. The total number of pregnancies includes abortions and stillbirths, so does not necessarily relate to the number of children a woman has. Abortion (mostly spontaneous) and stillbirths are quite common in these rural villages. Of the women who have had at least one previous pregnancy 10% have experience of at least one stillbirth and 9% of at least one abortion. Only one abortion was induced.

Child mortality is also high; 23% of women, who have had a previous pregnancy, have experienced the death of a child (Table 3.6). Although most women (95%) have not experienced more than one death, one woman has experienced the death of 3 children and one the death of as many as 5. This is in keeping with the argument that the risk of infant or child mortality is correlated within families, owing to shared biological and social characteristics (Curtis 1992).

Table 3.6 also shows the total number of surviving children of the women who have had a previous pregnancy. Sadly, 9% do not have any surviving children. Most however, have either 1 or 2 surviving children (84%), and a few have 3 or 4. The average number of surviving children per woman is 1.29. This is lower than may be expected in rural villages where the incentive to have children must be considerable, but perhaps reflects the young age structure of the sample.

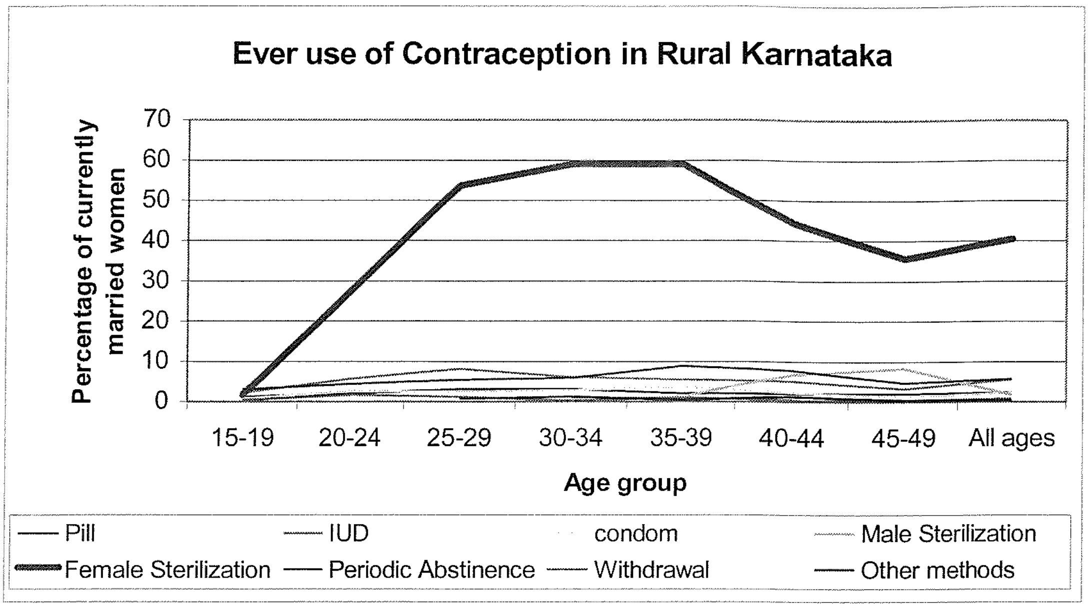
Table 3.6 Reproductive History

	%		%
Total Pregnancies* (n = 144)		**Live births subsequently died** **	
1	39	0	76
2	34	1	19
3	14	2	2
4	7	3	1
5	4	4	0
6	1	5	1
7	1		
Reproductive Experience** (n = 87)		**Surviving children**	
Stillbirth	10	0	9
Abortion	9	1	62
Live birth died	23	2	22
Live birth survived	57	3	5
		4	2

* Includes current pregnancy
**Excludes current pregnancy

Very few women in rural Karnataka use either modern or traditional contraceptive methods to space pregnancies. Female sterilisation, however, is common. The NFHS survey of Karnataka identified that in rural areas over 55% of women in the age group 25 -29 years had already been sterilised (Figure 3.16). Childbearing is thus concentrated in the earlier years of marriage and this together with the high incidence of child mortality means that frequent pregnancies sometimes occur at very young ages.

Figure 3.16



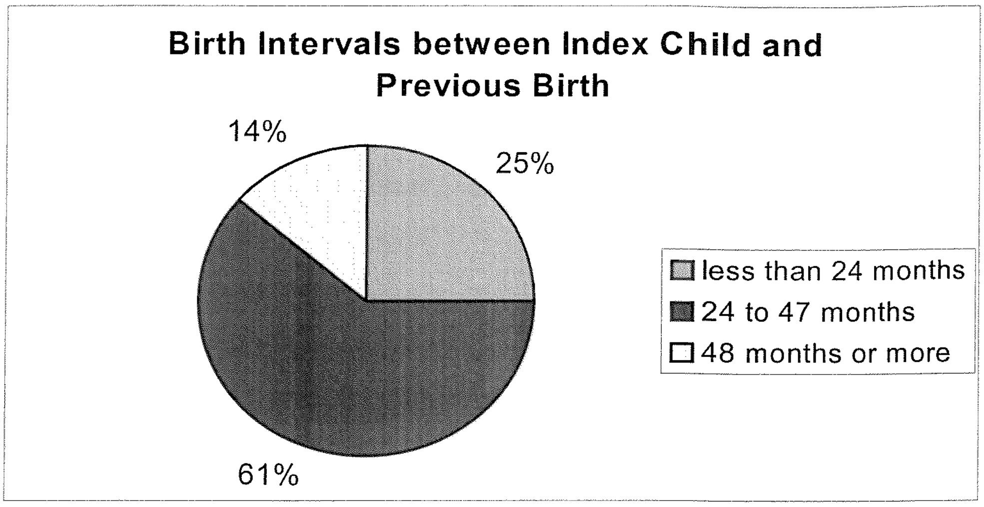
Source 1992 –93 NFHS for Karnataka

3.6.3 Birth Spacing Patterns

Birth intervals of less than two years have been found to increase the risk of infant mortality. Debate concerning the mechanisms of the relationship, centre around the role of biological factors such as maternal depletion and social factors such as competition between siblings (see literature review). Figure 3.17 shows that of the women who have had a previous birth, 25% (of the index births) follow an interval of less than 2 years. Conversely 13.6% followed an interval of 4 years or more. Long birth intervals are also negatively associated with infant survival, but to a lesser extent. It has been hypothesised that the age of the mother is a causal factor for the long birth interval and increased risk of complications.

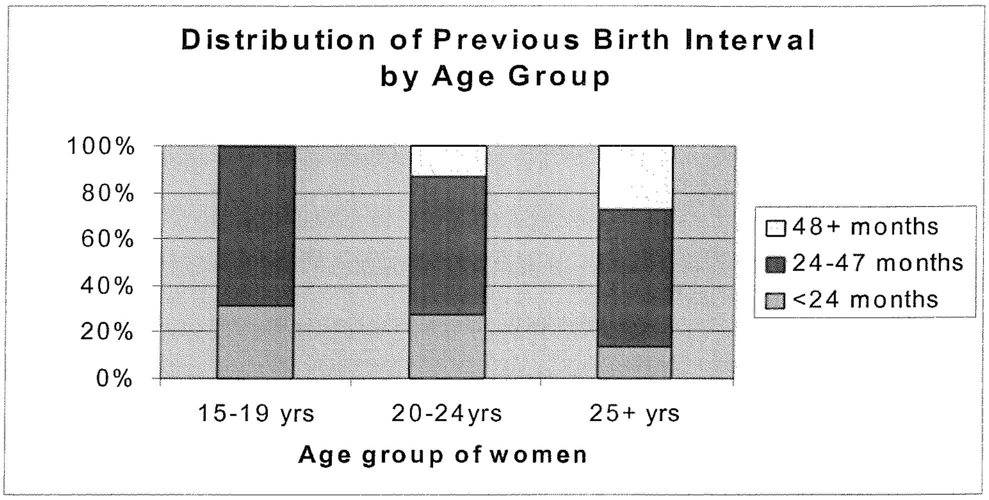
Figure 3.18 shows the distribution of birth intervals within different age groups of women. There is clearly a relationship whereby the proportion of women having short birth intervals is greatest in the younger age groups whilst the proportion having long birth intervals is greatest in the older age groups. The proportion having medium birth intervals (24 to 47 months) is similar throughout the age groups. This is as expected, younger women have greater fecundity and are likely to be building a family whilst the older women have had more childbearing years in which to experienced longer intervals. Coital frequency also tends to decrease with duration of marriage (or union) so it is likely to be lower for the older women.

Figure 3.17



Total Number = 156

Figure 3.18



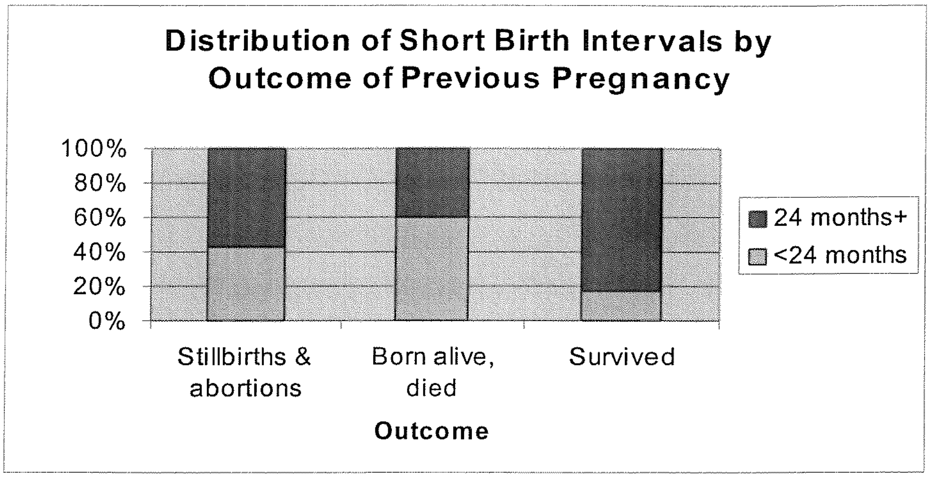
Total Number = 156

No particular pattern was identified between the distribution of birth intervals by parity. One might expect that high parity would be associated with close birth spacing, but the lack of association in this analysis could result from the small number of cases in the higher parity orders.

Figure 3.19 compares the distribution of birth intervals for different outcomes of the previous pregnancy. The proportion of short birth intervals is considerably greater for women whose previous (child or fetus) did not survive. Less than 20% of women whose previous child survived had an interval of less than 2 years. In contrast 40% of women who previously had an abortion or stillbirth, and 60% whose previous child died had a short birth interval. A considerable influence on the length of birth interval, then, is clearly the death of the previous child or fetus.

It is perhaps surprising that the proportion of short birth intervals is greater amongst women who experienced the death of the previous child compared to those who had an abortion or stillbirth. The latter would be likely return to a fecund state sooner. This could indicate that women who experienced the death of a child had a greater psychological need of replacement. Alternatively it is possible that women who experienced abortion or stillbirth were less fecund. Indeed, some biological factor could be responsible for both decreased fecundity and increased risk of fetal mortality.

Figure 3.19



3.6.4 The Index Birth

Few of the pregnancies in the study were unwanted, nearly all of the women (90%) said that they felt pleased that they were pregnant; only 7% reported that they were displeased, the remainder felt indifferent (Table 3.7). Child-bearing is important to young women in these rural areas. Being of patrilineal structure there is a strong need for sons to carry on the family line. The for NFHS Karnataka identified a fairly strong preference for sons, particularly in rural areas and particularly among women who do not have any living children. However, some of the women who attended the focus group discussions carried out with the fieldwork stated that it was important to also have daughters. Daughters were considered to be companions and provide greater support for the women. In the NFHS the ideal family size was identified as 2 to 3 children and the desire to have more children decreased with age and with the number of living sons.

Table 3.7 Health Care During Pregnancy

	%		
Feelings about pregnancy (n = 144)		**Contacted by ANM** (n = 142)	
No response	1.4	No	42.3
Pleased	90.3	Woman contacted ANM	11.3
Not pleased	6.9	ANM contacted woman	46.5
Indifferent	1.4		
		Anaemia pre-natal (n = 144)	
Seen health care provider during antenatal period (n = 144)		No	91.0
		Yes	9.0
Yes	98.6		
No	1.4	**Ever given iron** (n = 144)	
		No	14.1
Type health care provider seen* (n = 79)		Yes	85.9
None	1.4	**Taking iron tablets** (n = 143)	
ANM	63.9	Not given	7.7
Nurse	0.7	Regularly	79.7
Government doctor	29.8	Irregularly	6.3
Private doctor	54.9	Not taking	6.3
**Women may have seen more than one*			

All but 2 of the women had seen a health care provider at some time during the antenatal period. A third reported that they had seen more than one health care provider. Sixty four percent of the women had seen an ancillary nurse midwife (ANM), who, in most cases, visited when she heard of the pregnancy (Table 3.7). Over half (55%) of the of the women had seen a private doctor and 30% a government doctor. Many of the women preferred to see a private doctor than go to a government hospital or health care centre. The reason given by women in the focus group discussions was that they felt that they attained better treatment, there was little difference in the cost as unofficial fees were payable in a government facilities. This was mostly limited to the antenatal and postnatal period, however. Most could not afford to have a private doctor attend the birth or to go to a private hospital for delivery. Many of the women had seen more than one type of health care provider; the most common combination was an ANM and a private doctor or less commonly a government doctor.

The field workers carried out non-invasive observation of the women to identify signs of anaemia at each questionnaire. Nine percent of women were identified as being anaemic during the antenatal period. Iron tablets were routinely given to women during pregnancy to prevent anaemia. Eighty six percent of the women reported that they had been given iron tablets by a health care provider at some time during the antenatal period. Compliance was fairly high with 80% reporting that they took to the iron tablets regularly (as reported at the first antenatal questionnaire). Only 6.3% reported that they were not taking the tablets at all.

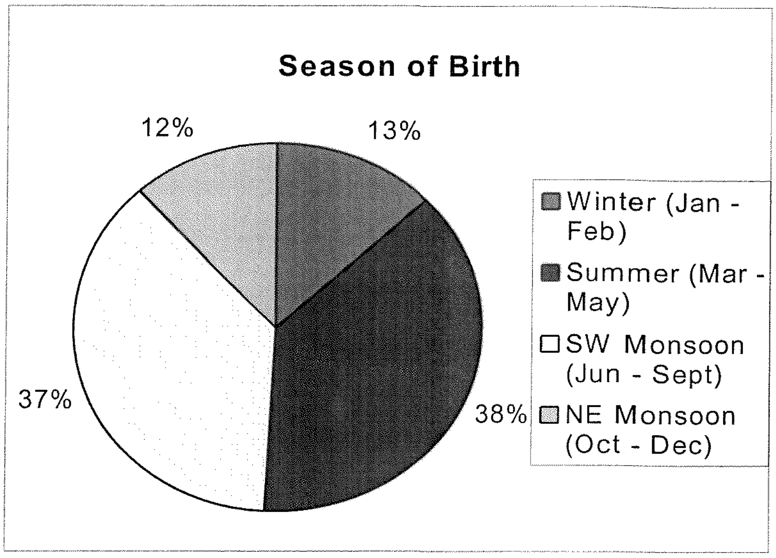
There is a clear seasonal variation in the index births, whereby 76% were born between March and September (Figure 3.20 and Table 3.8). This includes the summer (March - May) and the South West monsoon season (June - September). The remaining 24% were evenly distributed throughout the rest of the year.

Most of these children were conceived, therefore, during the two monsoon seasons: South West monsoon and the North East monsoon (October -December). It could be that people have more leisure time during the monsoon seasons if activities are restricted as a result of the rain. The rain, although heavy, is not severe in this region and does not result in such extensive flooding as occurs in other regions. It does, however cause problems with the power supply (where available) which continually fluctuates in strength and frequently fails altogether. The workload will vary by season for those who rely on agriculture and livestock for their subsistence or for agricultural wage labourers.

Table 3.8 Comparative Distribution of Season and Births per Annum

Season	Number of Months	% of year	% of births
Winter	2	16	13
Summer	3	25	38
SW Monsoon	4	33	37
NE Monsoon	3	25	12

Figure 3.20



Total Number = 156

The sex ratio at birth for the study population is 104, that is 104 boys to every 100 girls. This is within the 104-107 range identified by Visaria (1967) (cited in Griffiths, 1997) as being common across a number of countries for which reliable data was available (Table 3.9).

Table 3.9 The Index Birth

	%		%
Gender (n =143)		**Type of complication experienced**	
Girl	49.0	(n = 57)	
Boy	51.0	Inadequate pains	20.1
		Prolonged delivery	2.8
Woman's opinion of size		Heavy bleeding post delivery	6.3
of infant at birth (n = 144)		Not head first	2.1
No response	5.6	Convulsions	1.4
Normal	55.6	Other complications	6.9
Small	25.7		
Large	12.5	**Action to increase pain** (n = 144)	
Don't know	0.7	No	16.7
		Yes	83.3
Timing of birth (n = 144)			
3 months early	1.4	**Action taken to increase pain***	
2 months early	2.1	Injection	49.3
1 month early	5.6	Pitocin drip	4.9
As expected	45.8	Kashayam	49.3
1 month late	42.4	Walk around	8.3
2months late	2.8	Other	20.8
Complications at delivery (n = 144)		**Given pain relief** (n = 144)	
No	63.9	Yes	1.4
Yes	36.1	No	98.6
		**May have more than one*	

The mothers were asked their opinion of the size of the infant at birth. Half of the women reported that the baby was of normal size at birth, 26% reported a small baby and 13% a large baby (Table 3.9). This is, of course, subjective and will be influenced by previous experience and the opinion of other people. Nevertheless this question is used in large surveys, e.g. NFHS, and included in analyses as a proxy for birth weight. It will be demonstrated later in the analyses that on average it does tally with the anthropometric measurements.

Gestation at birth is estimated by the mother's opinion of gestation at the time of the initial questionnaire. This is a very crude estimation, and does not include specific information such as dates of last menstrual period. It does, however, indicate the expected timing of the birth according to the mother.

The number of months gestation, as stated by the mother at the time of the initial questionnaire, was subtracted from 9 (normal full term gestation), this was then subtracted from the difference between the date of the initial questionnaire and the actual delivery date. This gives the number of months that the baby was early or late in comparison to the mother's opinion of gestation.

Forty six percent of the women delivered up to two weeks either side of the estimated "due" date. It is fairly safe to assume that these babies were delivered at approximately 40 weeks gestation. Forty two percent of the babies were born one month after the estimated due date. It is likely that many of these babies were also delivered around 40 weeks gestation or soon after, but show evidence of the non-specific method of measurement and possibly recall error. Up to 42 weeks gestation is usually considered safe, after which, degeneration of the placenta can occur and the fetus become distressed. four births were calculated to be 2 months overdue. It is likely that these were later than 42 weeks gestation. Similarly 3 babies were recorded as being 2 months premature and 2 babies recorded as 3 months premature. Again it is likely these babies did not compete the full gestational period. No association was identified between gestation at delivery and the size of the infant (according to the mother).

Over a third (36%) of the women reported that they had a problem during delivery. The most commonly reported problem was inadequate pains (20%). This may indicate that the women fear a long, drawn out labour and hence focus on the importance of intense pain as an indication strong contractions. The majority (83%) of the women had some action taken to increase the pain. Half had an injection (pitocin), 5% had a pitocin drip, half had Kashayam, 8% were made to walk around and 21% had some other action taken. Many women had more than one of these (Table 3.9).

It appears then, that even if the women themselves do not perceive inadequate pains as a problem, the birth attendants consider it important to intensify or quicken the labour. This practice could actually be hazardous to both the mother and infant. The use of medication to increase the intensity of contractions requires strict monitoring as it can result in foetal distress or rupturing of the uterus. This is especially so when given by a single injection.

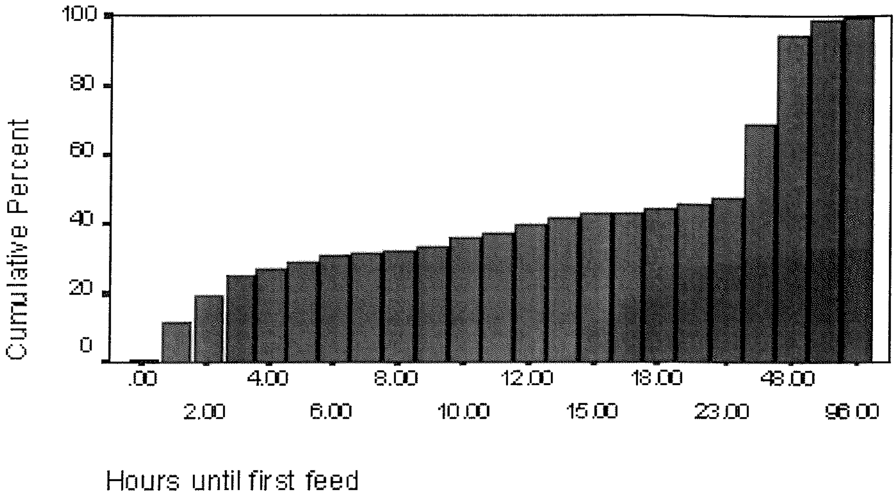
Other problems reported during delivery included a breach birth (2%), convulsions (1.4%), prolonged labour (2.8%), heavy bleeding post delivery (6.3%) and other unspecified problems (7%). Two women reported more than one problem.
Breast-feeding is almost universal; 98% of the women were breast-feeding during the post-delivery period (first 2 weeks after birth), 94% exclusively so, only 4% were giving supplements (Table 3.10).

Table 3.10 Breast-feeding

	%		%
Breastfeeding post-delivery		**Supplementation to breast milk in the post-delivery period**	
Yes	97.9		
No	2.1	Non response	2.1
		Breast milk only	93.8
Pre-lacteal feed given		Breast milk + other	4.2
Yes	84.7		
No	15.3		
		n = 144	

Many women do not begin breast-feeding immediately after birth, however. Only 25% fed their babies in the first 3 hours, and indeed only half in the first 24 hours (Figure 3.21). Most women (85%) claimed that they had given the baby other substances to the baby during this pre-lacteal period. The substances included castor oil, sugar water, diluted animal milk, another woman's breast milk, infant formula or just warm water.

Figure 3.21 Hours Between Delivery and First Breast-feed



A common belief is that colostrum is bad for the infant and should, therefore, be expelled prior to breast-feeding. It is in fact this substance that contains many antibodies which provide immunity for the infant during the early infancy. Giving pre-lacteal feeds exposes the infant to increased risk of infection due to contaminated food or utensils. The infant is particularly vulnerable during this early period until immunity has developed.

When the women did begin breast-feeding the number of breast-feeds given in 24 hours varied from 3 to 24. Surprisingly, Figure 3.22 shows that there is no particular association between number of breast-feeds and the age of the child (up to one year).

Figure 3.23 shows box plots of the age distribution of the infants for different stages of weaning or supplementation to breast-feeding. Although there is some overlap, there is a clear progression of supplementation with increasing age. The majority of women give only breast-milk for approximately 3 to 4 months. Between 4 and 8 months many women have introduced animal milk or powdered milk, and solids are introduced at around 7 to 8 months by most women.

Figure 3.22

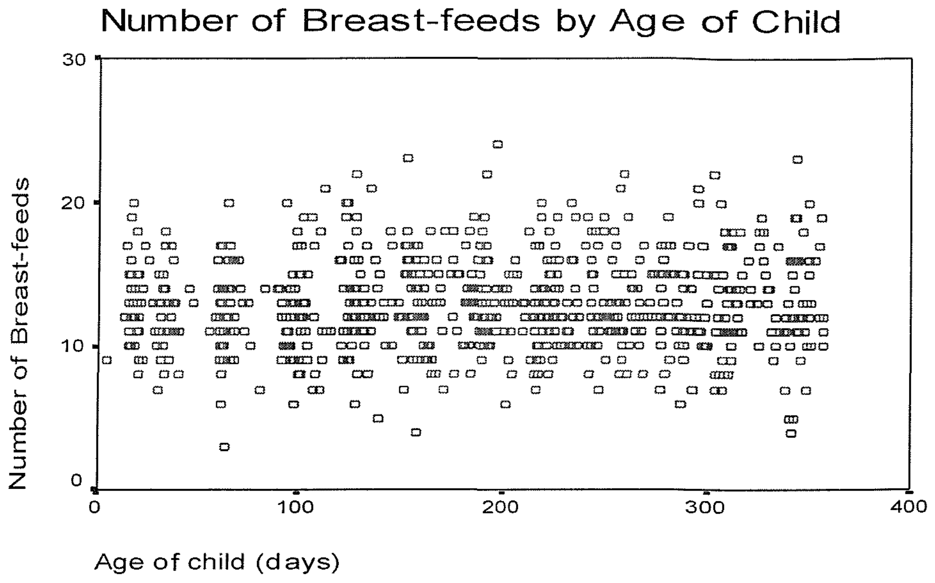
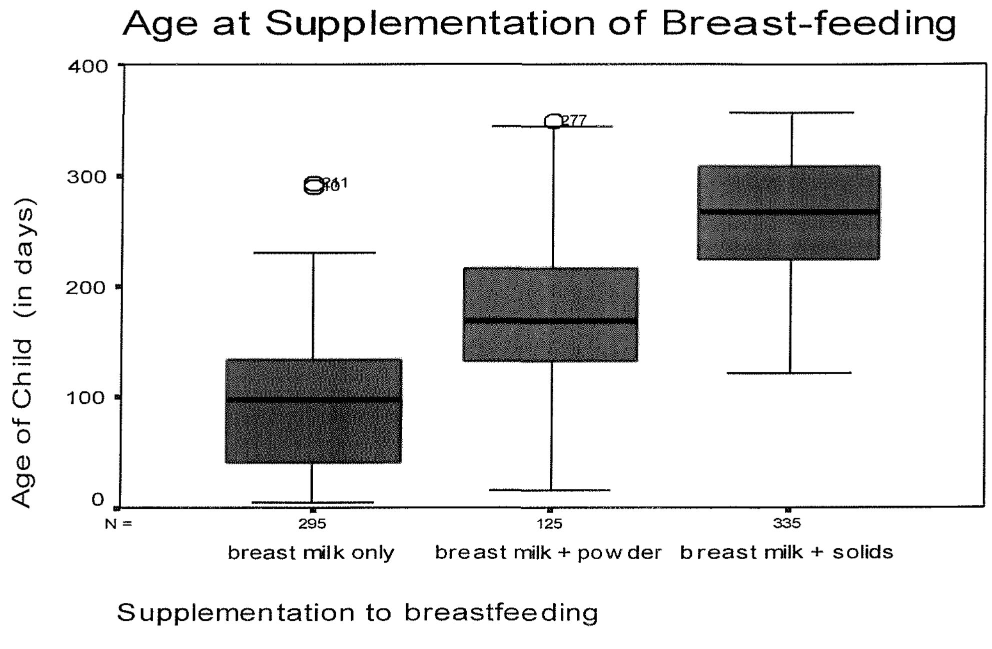


Figure 3.23



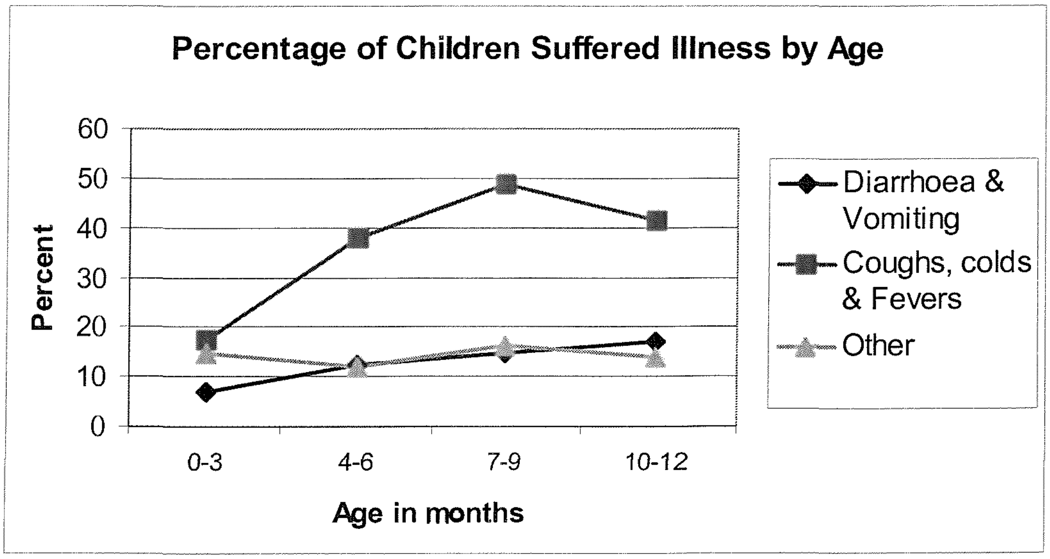
The prevalence of infant morbidity was high during the first year of life. At 55% of interviews it was reported that the infant had suffered illness since the last visit, 11% reported more than one episode (Table 3.11). The most common type of morbidity was coughs, colds and fevers, although episodes of diarrhoea and /or vomiting were fairly common.

Table 3.11 Morbidity

	%		%
Suffered morbidity since last visit		**Number of episodes of morbidity**	
(n = 824)		(n = 824)	
No	45.3	0	45.3
Yes	54.7	1	43.7
		2	10.4
Type of morbidity (n = 120)		3	0.6
Diarrhoea and vomiting	13.5		
Cough, colds and fevers	38.3		
Other	14.6		

Figure 3.24 shows the percentage of children that suffered different categories of illness by age. The most common illness for all ages was coughs, colds and fever, which were particularly prevalent in the 7 to 9 months age group. The percentage suffering such infectious illness increased from 18% at 0-3 months to nearly 50% at age 7-9 months, but then decreased for the 10-12 month age group. The percentage suffering diarrhoea and/or vomiting increased for each successive age group but by a lesser amount. At age 0-3 months about 7% of children were reported to have recently suffered diarrhoea and / or vomiting, by age 10-12 months this had increased to 18%. The percentage suffering other problems stayed fairly static with age at around 12-18%.

Figure 3.24



Summary

Many of the households in which the women live have a socio-economic wellbeing reasonable for at least a basic level of subsistence. Most own some land and livestock and many own basic commodities providing limited facilities for transport, media, utensils, etc. The normal way of life is for the woman to live with the husband's family after marriage, in an extended family structure. Relatives usually live in close proximity if not under the same roof. Household work forms a substantial portion of women's occupation, and most carry out additional tasks in agricultural work, sericulture or family enterprise. The husbands also do a combination of work in agriculture, livestock and family enterprise.

There is a dichotomy in educational attainment with half of the women being uneducated, but a considerable portion with least intermediate level if not higher education. It is important to note that although the greater portion of the sample appear to have a basic level of subsistence, a smaller proportion live in much poorer conditions. Being of an untouchable caste they have no land, few livestock and very limited possessions. Some adopt strategies of subsistence, supplemented with wage labour.

The age distribution of the women in the sample is young; 40% are less than 20 years of age. The women are married and begin childbearing at very early ages, the average age at prastha (when the women goes to live in the marital household) being 16.3 years and the average age at first birth being 18 years. Teenage pregnancy is thus the norm. Twenty five percent of second or higher order births follow intervals of less than 2 years and 13% of greater than four years. Short birth intervals tend to be concentrated amongst the younger women and amongst those whose previous child died. Long birth intervals are concentrated amongst the older women.

Breast-feeding is almost universal with 98% reporting exclusive breast-feeding during the neonatal period. Upon further investigation, however, it was apparent that other liquids are given to the child but are not considered food. Also many women do not commence breast-feeding immediately following the birth, as the pre-lacteal colostrum is thought to be harmful for the baby.

Incidence of morbidity is high; 55% or mothers reported that the child had suffered illness since the previous visit. The most common ailments were coughs, colds and fevers, which were most prevalent amongst infants aged 7 to 9 months. Finally infant mortality was also found to be high. Twenty six percent of women reported that they had experienced the death of a child at some time.

3.7 Cross-sectional and Longitudinal Approaches to Anthropometric Assessment

Cross-sectional and longitudinal surveys each have their own strengths and weaknesses in terms of analytical and explanatory power. The choice of approach will, therefore, invariably involve trading off one quality for another. Both approaches are described in this section and their particular strengths and weaknesses outlined.

3.7.1 Cross-sectional Data Analysis

A cross-sectional study refers to the collection of data at a single time point for a given number of individuals. Cross-sectional anthropometric data is often used to determine prevalence of poor growth attainment within populations and to identify malnourished children who may be targeted by health intervention programmes. It is also used in health research, when a range of data are collected to explore the associations with socio-economic and demographic variables. Identifying the correlates of poor growth attainment enables health care initiatives to be planned effectively (McMurray 1996).

Cross-sectional data has the advantage that large samples can be attained at a relatively low cost. A larger sample is more representative of the population from which it is derived. Also a wide scope of topics can be included to incorporate socio-economic, demographic and environmental factors.

Analyses can be made at a population level by exploring the mean growth attainment at different ages, using synthetic growth curves. These are derived from different children of different ages at one point of time. This approach is good for illuminating national and regional patterns in growth attainment, and for identifying differences between subgroups. For example, in her analysis of the Demographic and Health Survey (DHS) cross-sectional data sets for Burundi, Uganda and Zimabawe (1987 & 1989), McMurray (1996) finds that the mean weight at birth is similar to that of the reference population in all three countries. However, a negative deficit increases with the older age groups of children and the mean weights thus fall further behind that of the reference population. McMurray attributes this to growth faltering as a consequence of deprived socio-economic circumstances during childhood. Also using DHS data Sommerfelt (1991) identifies several factors which are strongly and consistently related to children's nutritional status across a number of countries. These include place of residence, mother's education, family possessions, type of toilet facilities and previous birth interval.

Cross-sectional data, however, have limitations which reflect their synthetic nature. The growth curves do not actually represent the growth of any one child and thus cannot provide information on growth trends. It is not possible, for example, to determine whether the very young children who have weights similar to those of the reference population, in the above example (McMurray 1996), will suffer growth faltering as shown by the synthetic growth curves. Similarly one cannot conclude that the older children in the sample had birth weights similar to that of the reference population as do their younger contemporaries.

Cross-sectional data is also unsuitable for assessing the impact of factors which have a very immediate and direct impact on growth. Analyses using cross-sectional anthropometric measurements have failed, for example, to identify a consistent relationship between reports of recent morbidity and growth attainment (McMurray 1996). Owing to the immediate and transient effect of illness on anthropometric measurement, information concerning growth history would be required to detect any causal associations.

3.7.2 Longitudinal Data Analysis

Longitudinal data consists of a sequence of measurements taken from a number of individuals over a period of time. This has two main advantages in terms of anthropometric analysis. Firstly, it allows the analysis of change. A knowledge of growth dynamics over time enables a more informed conclusion to be made about the health status of an individual. It is possible to assess, for example, whether a child who has a low weight for age, has always been underweight, or whether they have previously had an adequate weight but failed to thrive more recently. The time sequence of measurements can thus help to reveal the process which leads to events and facilitates a causal analysis (Plewis 1985). Secondly, longitudinal data allows a distinction to be made between age effects and cohort effects. Age effects are the changes over time within an individual, whilst cohort effects are the differences between groups of individuals who share a common experience (Diggle et al. 1994 and Plewis, 1985). Children, for example, are naturally expected to increase in weight as they grow older, however those born during a period of war may have a different growth curve than those born after a war. Cohort frequently refers to individuals who have a common date (or time period) of birth, but can refer to groups of individuals with any common experience.

If age and cohort effects are not distinguishable results can be misleading. Diggle et al. (1994) provides a clear demonstration of this using a hypothetical example of the reading ability of children at different ages. Although reading ability increases with age for all children, the younger cohorts have a higher initial reading ability. Without the longitudinal aspect of the data it appears that reading ability decreases with age. It is suggested that such a scenario might arise if an elementary education programme was introduced into a poor rural community, starting with the younger children.

Change can be thought of in relation to time, or in relation to age. There is considerable change in the anthropometric measurements of children as they grow older. For adults, however, change with age is less marked and the focus of interest is more likely to reflect time periods. For example changes in a woman's weight are found to vary with duration of breast-feeding, whereby the greatest weight loss tends to occur between 5 and 9 months postpartum (Miller et al., 1994). In this case weight change is considered in relation to a time period, i.e. months since birth.

As with cross-sectional data, strength is gained in the analysis of longitudinal data when patterns are consistent across individuals (Diggle et al., 1994). By considering changes in anthropometric status that are common to individuals, trends can be identified. For example, longitudinal data are good for identifying seasonal variations in nutrition since common patterns of weight change become evident. Also substantive conclusions can be made when growth patterns are shared by groups or subgroups within the population.

Although observations between individuals are usually considered to be independent, the repeated measurements for each individual, in longitudinal data, are associated. The correlation structure of the data has to be taken into consideration during statistical analyses, but may be of interest in itself. One may question, for example, how and why an individual's weight for height measurement at a given time point is related to weight for height at previous time points.

3.7.3 Prospectively Collected Data Versus Retrospectively Collected Data

A further advantage of longitudinal data is that it is usually collected prospectively and therefore avoids many of the problems associated with retrospectively collected data. This is of particular relevance to anthropometric data where age is frequently used to standardise measurements or as an important explanatory variable. Age, and dates of birth, suffer considerably from recall error and from heaping in retrospectively collected data.

Prospectively collected data, however, has the disadvantage that the behaviour of the population being studied may be influenced by the survey. Awareness that nutritional assessment is taking place may alter the thought processes and behaviour of the respondents. Furthermore, field workers carrying out the survey may provide intervention, where obvious improvements could be made for the health of the child. It may be considered unethical not to do so. The anthropometric assessment may even be carried out in conjunction with health promotion activities.

Summary

In comparison to a longitudinal survey, cross-sectional data collection has the advantage that large samples can be attained at a relatively lower cost, and thus a wider range of topics can be included. A large sample is more representative of the population and enables statistical inference by gaining strength across individuals. The synthetic nature of the growth curves attained from cross-sectional data, however, does not allow trends to be identified. A specific disadvantage of cross-sectional data, then, is that changes within an individual cannot be assessed and therefore transient effects are not identifiable. For example, the effects of morbidity on the weight change of an individual cannot be identified.

Longitudinal data, on the other hand, allows the dynamics of change over time to be assessed and thus facilitates a causal analysis. It also has greater explanatory power as it allows a distinction to be made between age and cohort effects. A disadvantage of longitudinal data perhaps, is that statistical analysis can be quite complex owing to the correlated observations for each individual.

CHAPTER 4

Analysis of Birth Spacing and Weight Measurements in Rural Karnataka: A Cross Sectional Approach

4.1 Introduction

In this chapter the nutritional status of children between the ages of 0 and 36 months, is analysed using the 1992-93 NFHS for Karnataka. This survey is cross-sectional and thus allows the effect of birth intervals to be assessed for children of each successive age group. The relatively large sample size provides statistical power with which to identify the correlates of nutritional status. The weight attainment of the children is used as a proxy for nutritional status reflecting both long and short-term welfare. The analysis of infant health rather than mortality provides a direct and sensitive indication of circumstances, which are disadvantageous to the wellbeing of the child. The weight measurements are expressed as WAZ scores and thus account for variations normally expected by the age and gender of the child. The reference population recommended by the World Health Organisation (WHO/NCHS/CDC) is used to calculate the z scores and they, thus, represent the relative advantage or disadvantage of the sample population in comparison to the reference population. The correlates of the WAZ scores are examined using multilevel modelling techniques, which allow for the hierarchical structure of the data. A particular focus of this analysis is to investigate how the relationship between birth spacing and nutritional status differs according to the age of the child.

The following section discusses the structure of the data and the motivation for using multilevel modelling techniques. The levels introduced within the modelling techniques are discussed as well as issues concerning the sample design. The variance components model and the random coefficients models are then described and the strategy of this analysis outlined. The preliminary analysis describes the model development, including selection of a cubic model of WAZ score by the age of the child and selection of the levels to be included in the final model. The results of the final model are presented in section 4.7 followed by a discussion which focuses particularly on the effect of birth intervals on WAZ scores.

4.2 Features of the data

The data consist of weight measurements of 941 children aged 0 to 36 months. The data are cross-sectional and thus weight measurements are recorded at one point of time for each child. A number of explanatory variables describe the demographic and socio-economic characteristics of both the mother and child, as well as breast-feeding behaviour and experience of child morbidity. Covariates also include information relating specifically to the household and village in which the child lives, for example the type of toilet facility available to household members, and the prevalence of recent epidemics within the village. The variables relating to the household and village can be considered as "global characteristics" as they directly measure the context of the individual (Kreft & De Leeuw, 1998).

The structure of the data is hierarchical in that the individuals are clearly divided into groups within the population. Figure 4.1 demonstrates this structure with children clustered within women, women clustered within households, households within villages, villages within districts and districts within regions.

Figure 4.1 Hierarchical Data Structure of NFHS for Rural Karnataka

NB. The figures represent the number of units within that hierarchical level.

Another hierarchical structure inherent within this data results from the survey design. This is largely based upon the structure within the population as described above but varies as a result of the stratification used in the multistage sampling design. Within each of the six geographical regions of Karnataka the villages were categorised into 6 strata according to the population size. The strata thus replace the district level. The primary sampling units (PSUs) were selected from each stratum. For the NFHS in rural Karnataka the PSU is the same as the village level in the hierarchical structure specified above, i.e. one village per PSU (The NFHS for other states includes more than one village per PSU).

Individuals within the same groups of the hierarchical structure are likely to be similar owing to their shared circumstances. For example children of the same mother share similar genetic characteristics, children of the same household share similar socio-economic circumstances, children of the same village share similar environmental circumstances and children of the same district share similar conditions determined by government policy or levels of development. This group homogeneity results in "intra-class correlation" and thus dependency amongst the observations of individuals. This violates the assumptions of independence inherent in standard statistical modelling procedures.

For this analysis traditional modelling procedures would assume that a child's WAZ score could be determined by his or her individual characteristics alone. In reality, however, the WAZ score of each child would be influenced by the wider contextual circumstances in which the child lives, and these contextual circumstances would be shared by other children. If this clustering effect within the data is ignored, over-dispersion may occur whereby the observed variance is greater than anticipated under the assumed normal distribution. For example, the contextual circumstances of some villages may promote child welfare and the children within these villages are thus likely to attain higher WAZ scores. The reverse may also be true for other villages. The distribution of WAZ scores within these villages then would have a much flatter and wider distribution than would be assumed under the normal distribution. As a consequence the standard errors attained from ordinary least squares modelling procedures would be underestimated. Furthermore, as the standard errors are inversely related to the number of independent observations, the larger the number of individuals within the group or cluster, the greater the underestimation of the standard error. Ultimately the significance tests traditionally used to identify correlates of WAZ scores may incorrectly reject the null hypothesis and spurious associations may be identified. It is thus important that modelling procedures recognise the clustering effects within hierarchical data and that standard errors reflect the correlated observations.

4.3 Methods for Hierarchical Data - Multilevel Models

One way of dealing with the correlated structure of hierarchical data is to conduct a single level regression model with the variation between the units at each level incorporated by the inclusion of terms representing that level. For example including a covariate with a category for each unit such as village or district. This method may not be feasible or may be inefficient however, if it is necessary to estimate large numbers of coefficients (there are 84 villages for example). Also the groups, or levels, are treated as fixed effects so no information is provided concerning the variation among the individuals within that level, which may be of interest in itself (Kreft and De Leeuw, 1998).

Alternatively, the analysis may be performed at a higher level by aggregating data at the individual level. So for example, the average WAZ score of each village would be modelled as a function of the percentage of female literacy within the village. There are a number of problems with this approach, however. Firstly, a large amount of information is lost because the within village variation is ignored. Secondly, the results are limited in their application as relationships at the aggregate level may not be the same as relationships at the individual level. In the above example, therefore, it would only be possible to make predictions about the average WAZ score of children within a village, given the percentage of female literacy. It would not be possible to make predictions at the individual level (Kreft, 1998). Finally, relationships at an aggregate level are likely to be stronger than those at the individual level and could therefore be misleading (Steele, 1996).

Multilevel models have been developed to allow for the hierarchical structure of the data by incorporating variation at all levels simultaneously. The standard errors are thus appropriate for data which is correlated within groups. Also the variation in the dependant variable that is not explained by the regression equation is divided according to the level within the hierarchy that it represents. In traditional linear regression models, this unexplained variance is assumed random, but for hierarchical data, it is clearly influenced by the grouped structure. Substantive information concerning variation in relationships across groups can thus be attained from multilevel models (Kreft and De Leeuw, 1998 and Steele, 1996).

The ordinary multiple regression model can be though of in multilevel terms as a model for individuals within one higher level unit and is represented by the equation

$y_i = \beta_0 + \beta_1 x^{(1)}_i + \cdots + \beta_p x^{(p)}_i + e_i$,

where y_i is the response for the i^{th} individual, $i = 1, \ldots, n$ and n is the number of individuals within the unit. β_0 is the intercept and $\beta_1, \ldots, \beta_p$ is a set of unknown regression coefficients for the corresponding covariates $x^{(1)}_i, \ldots, x^{(p)}_i$. e_i is a zero mean, random variable, representing the deviation of the ith individual from the predicted outcome. The e_i are independent within the higher level unit and are assumed to be normally distributed. Thus $cov\ (e_i, e_j) = 0$.

4.3.1 The Variance Components and Random Coefficients Models

The variance components model, or the random intercepts model, allows the relationship between the dependent and explanatory variables to have different intercepts for each unit within the higher levels. So for example, if the child is level one and the household level two, the variance components model allows different intercepts for each household. The effect of the explanatory covariates remains constant across units, however.

The model for individuals across a number of second level units is represented by the equation

$$y_{ij} = \beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij} + u_{0j} + e_{ij}. \qquad (1)$$

In this model j represents units at the second level and takes the value 1 to J. J is the number of units at the second level, i.e. the number of clusters. y_{ij} is thus the response of the i^{th} individual in the j^{th} cluster. The unknown regression coefficients, $\beta_1, \ldots, \beta_p$, are constant across all individuals but the value of the covariates, $x^{(1)}_{ij}, \ldots, x^{(p)}_{ij}$, vary across individuals and second level units. u_{0j} is a zero mean random variable representing the deviation of the j^{th} unit's intercept from the overall intercept. The error term, e_{ij}, is again specific to the individual so varies across individuals and the second level units. Both random terms u_{0j} and e_{ij} are assumed to be normally distributed. Variables at the second level may be included in this model. In the notation, these variables would have only the subscript j indicating that they vary across second level units, but are constant across individuals within the units. This model can also be extended to include additional levels representing the hierarchical structure of the data.

As an extension to the variance components model, the random coefficients model allows the effect of the explanatory covariates to vary across higher level units. A two level model, with covariates at level one, random intercepts and a random slope for the first covariate, is represented by the equation

$$y_{ij} = \beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij} + u_{0j} + x^{(1)}_{ij} u_{1j} + e_{ij}. \qquad (2)$$

Here u_{1j} is the random coefficient added to β_1 and varies across level two units but is constant for individuals within these units. $x^{(1)}_{ij} u_{1j}$ can be thought of as an interaction between the covariate $x^{(1)}_{ij}$ and the random effect u_{1j}. This model can be extended to include random slopes for any of the first level covariates.

4.3.2 The Effect of Sampling Design

The role of stratification in creating a hierarchical data structure has been mentioned previously. In their analysis of the Demographic and Health Survey's for five African Countries (Madise et al., 2000) found clustering to be particularly strong at the household level and thus emphasise the importance of multilevel models which allow for dependency at this level. There are, however, further methodological problems associated with sampling design and discussion has concerned the magnitude of effect, as well as the development of techniques to overcome them (Pfeffermann et al., 1998 and Madise et al., 2000).

Complex designs such as the multistage stratified sampling used by the NFHS can result in over sampling of some sectors. For example, stratification may be carried out according to geographical location. If some areas are over represented and the stratifying variable is associated with the outcome then standard modelling techniques which do not allow for this sampling design may produce biased parameter estimates. This is because any associations present within the over sampled sectors will have a greater weight in the analysis than would be the case if the sample provided a more accurate reflection of the true population. This is a matter of debate in relevant literature, however.

There are two main methods of accounting for the survey design: weights may be used to correct the unequal probability of selection or alternatively the variables used for the stratification may be included as explanatory variables in the model. Using child nutritional status as an outcome Madise et al. (2000) compared the parameter estimates attained from different methods across five African countries. They found that variables relating to family formation (i.e. birth intervals) tended to be the most volatile and that variables relating to health care provision appeared to be associated with the survey design. Whilst models which included weights to account for the survey design were thought to produce unbiased estimates, models which included variables representing the strata within the survey design were found to reduce some of the bias. In conclusion they emphasis the importance of the development of techniques which account for survey design and clustering simultaneously within one model.

4.4 Preliminary Analysis and Model Development

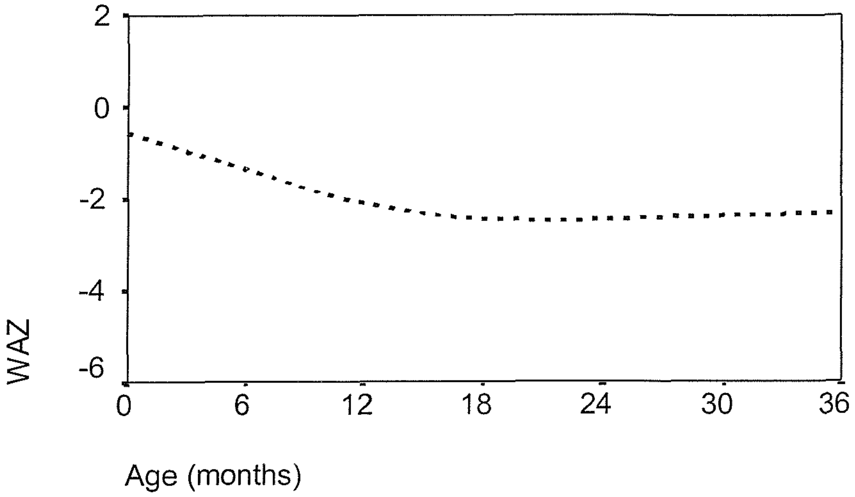
Figure 4.2 shows the WAZ scores by the age of the child with lowess, quadratic and cubic curves fitted to the data. The lowess curve represents a smoothed average of the WAZ scores over each age group. When compared to the lowess curve it appears that a cubic model of WAZ scores by the age of the child, best fits the data. Table 4.1 shows the parameter estimates and standard errors for the cubic model using ordinary least squares estimation. Age cubed is significant at the 5% level and thus age squared and age cubed are retained within the model.

Table 4.1 Cubic Model of Weight for Age Z Scores by the Age of the Child

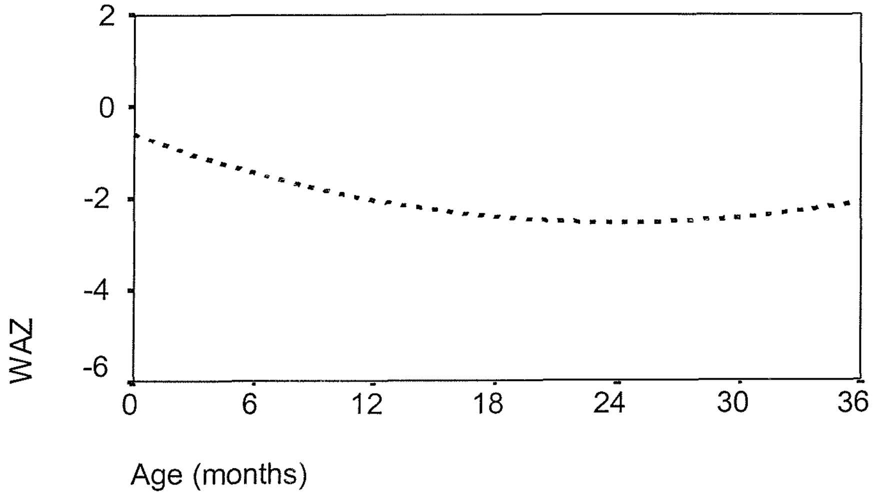
Parameter	Estimate	Standard Error
Constant	-0.36407	0.13827
Age (in months)	-0.23530	0.03326
Age squared	0.00841	0.00212
Age cubed	0.00009	0.00003

Figure 4.2 Weight-for-Age Z Scores by the Age of the Child

Lowess Curve



Quadratic Curve



Cubic Curve

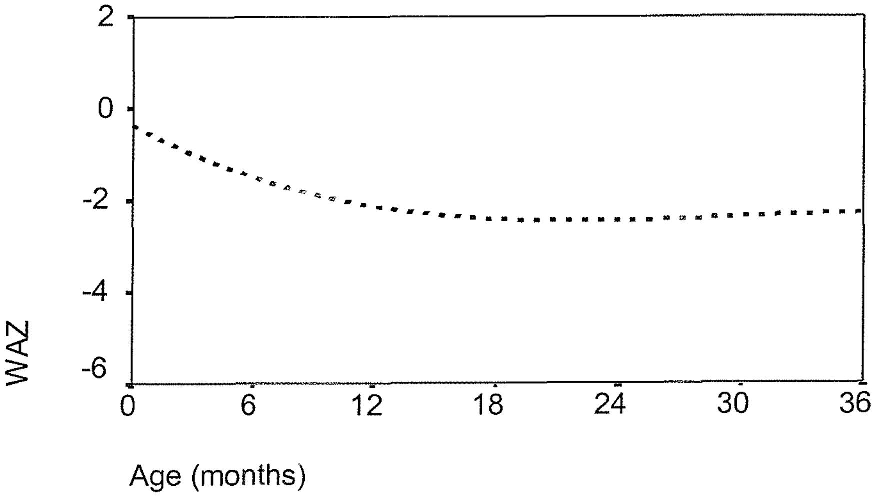


Table 4.1 shows that the age of the child is negatively associated with the WAZ but that age squared has a positive effect, this represents the curve whereby the negative effect of age declines for older children. Age cubed, however is negative in effect and flattens the positive effect of age squared. This prevents the effect of age squared becoming dominant for children age 26 months or more. A quartic term for WAZ score by the age of the child was tried but was found insignificant.

The strategy used for this analysis was first, to model the WAZ scores of the children using ordinary least squares regression, with the statistical package SPSS (See Appendix 1, Table 4.a for the significant parameter estimates and standard errors). Starting with the cubic model for the age of the child, the stepwise method was adopted for model selection, with variables included at the 5% level of significance. Interactions between each variable and the age of the child, age squared and age cubed were included as well as interactions between the covariates themselves.

Using the statistical package MlwiN, the variance components model was then used to allow random intercepts for levels within the population hierarchy, thus controlling for homogeneity among children in the same clusters. The random levels inherent within the data include the mother, household and village. Although the unexplained variation at the woman and household levels were both significant if included in the model alone, the woman level was not significant if included with the household level. This may reflect the small numbers of women clustered within households (Table 4.2).

Table 4.2 Clustering within Higher Level Units

Children per Households	Percent of Households	Children per Mother	Percent of Mothers	Mothers Per Household	Percent of Households
1	81.0	1	88.9	1	91.7
2	16.5	2	11.1	2	7.1
3	2.3	3	0.0	3	1.2
4	0.1	4	0.0	4	0.0
Total Households =774		Total Mothers = 847			

The household level was retained within the model in preference to the mother level as a greater number of children are clustered within households and thus underestimation of the standard errors attributable to this level is likely to be larger. The unexplained variation at the village level was found insignificant so was excluded from the model. (See Appendix 1, Table 4.b for the variance components model with variables at the child level only.)

A range of variables at the household level were then introduced systematically into the model to account for the unexplained variation at this level. Only two household variables were significant and these reduced the intra-correlation from 0.26 to 0.24. The unexplained variation at the household level remained significant even after inclusion of these covariates. Random slopes were introduced to the model for all the covariates but were found to be insignificant. This may reflect the relatively small number of children clustered within households (Table 4.2). Finally, covariates representing the strata within the sampling design were entered into the model to control for bias or correlation resulting from sampling procedures. These included region, strata (classified by population size or distance form urban centre – see description of survey design in section 3.4.1) and percent of female literacy within the village. The region and strata are considered fixed rather than random variables as all the units are included in the sample. The effects were found insignificant, however, so these variables were excluded from the model.

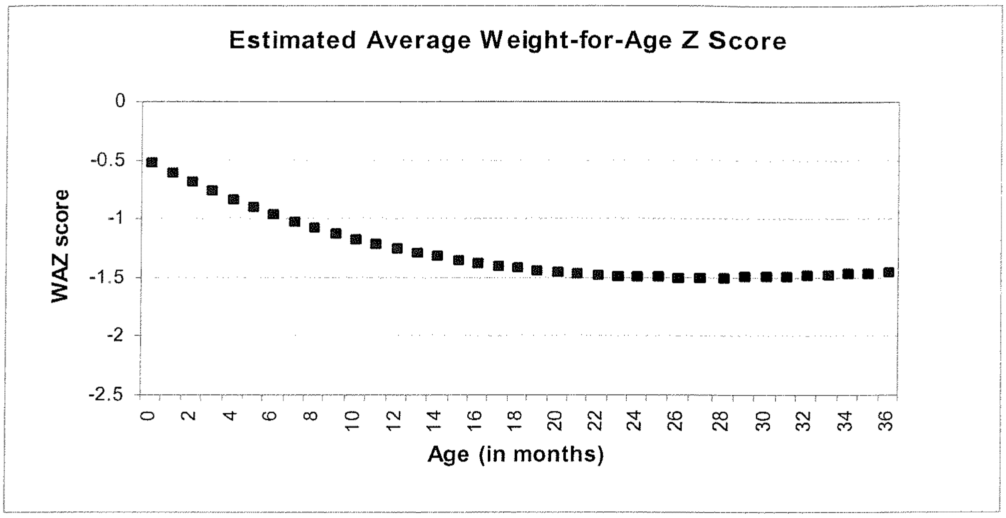
The selected model was thus a two level linear model with a random intercept at the household level and is represented by equation (1) with

y_{ij} = WAZ (for the i^{th} child from the j^{th} household)
$x^{(1)}_{ij}$ = the age of the child
$x^{(2)}_{ij}$ = age^2
$x^{(3)}_{ij}$ = age^3
$x^{(4)}_{ij}, \ldots, x^{(p)}_{ij}$ are a range of explanatory variables
u_{0j} = the departure of the j^{th} households intercept from the overall intercept.
e_{ij} = the departure of the i^{th} childs waz score from the j^{th} household intercept.

4.5 Results

Table 4.3 shows the significant parameter estimates and standard errors for the variance components model of weight-for-age z scores for children aged between 0 to 36 months. Figure 4.3 demonstrates the estimated weight-for-age z scores by the age of the child when all the explanatory covariates are kept at their average value. It can thus be taken to represent the average child's nutritional status by age group, net of all other effects. The line is broken to portray the cross-sectional structure of the data.

Figure 4.3



At birth the average WAZ score is approximately 0.5 of a standard deviation below that of the reference population. The deficit becomes increasingly great in magnitude with each successive age group, for children up to approximately 18 months of age. This trend does not continue during early childhood however: for children aged 18 to 36 years the WAZ scores remain fairly constant throughout the age groups at approximately –1.5.

A previous birth interval of less than two years is shown to be positively associated with WAZ scores and there is a negative interaction between previous birth interval and the age of the child. Figure 4.4 demonstrates the association of birth intervals with the WAZ over the different age groups. The broken lines again represent the synthetic nature of the curve attained from cross-sectional data.

Table 4.3 Parameter Estimates and Standard Errors for the Variance Components Model for Weight-for-Age Z Scores

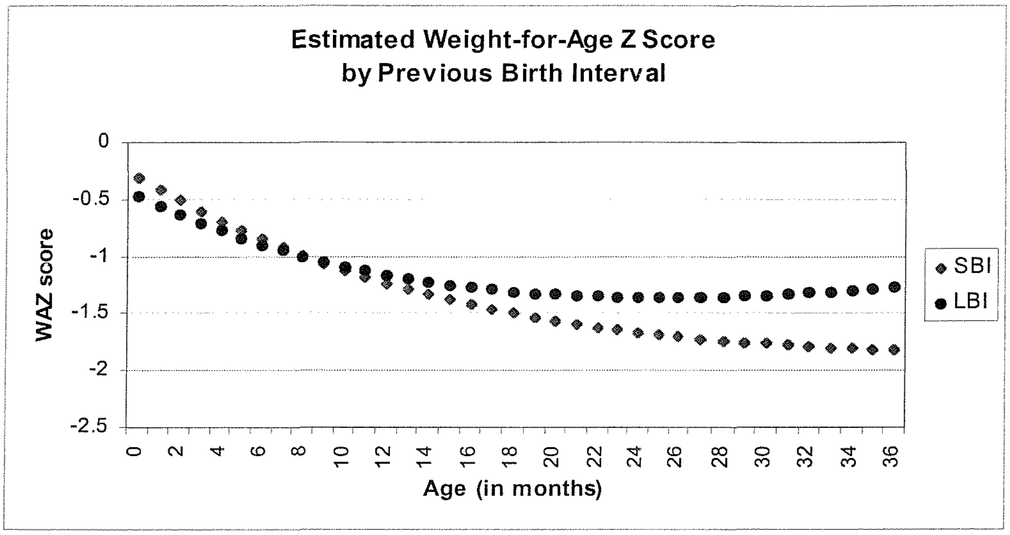
Parameter		Estimate	Standard Error
Constant		-3.59999	0.60147
Age in Months			
Age		0.15059	0.06794
Age squared		-0.00374	0.00293
Age cubed		0.00002	0.00004
Previous Birth Interval			
24 months or more		Ref	
< 24 months		0.16626	0.16166
First Birth		-0.26468	0.07743
Size at Birth (Mothers opinion)			
Average or large		Ref	
Small		-0.41181	0.0666
Feeding			
Not breastfeeding		Ref	
Breastfeeding		3.1085	0.57179
Weaning appropriate for age		Ref	
Not appropriate for age		-0.18961	0.06740
Morbidity			
No diarrhoea		Ref	
Diarrhoea in past two weeks		0.79692	0.52966
Hospital Delivery			
No		Ref	
Yes		0.17356	0.07568
Maternal Education			
Illiterate		Ref	
Primary		0.33545	0.08247
Middle or High		0.40478	0.11110
Sibling deaths			
Number of deaths		0.35769	0.15861
Children within Household Under 5 years		-0.07010	0.02744
House Construction			
Katcha		Ref	
Pucca		0.11295	0.14228
Semi pucca		0.17848	0.06865
Interactions with age			
Previous Birth Interval			
Short birth interval:	Age	-0.01976	0.00775
Feeding			
Still breast-feeding:	Age	-0.28464	0.05166
	Age squared	0.00551	0.00115

Continued below

Table 4.3 - continued

Parameter		Estimate	Standard Error
Morbidity in last 2 weeks			
Diarrhoea:	Age	-0.26636	0.11638
	Age squared	0.01714	0.00701
	Age cubed	-0.00031	0.00012
Sibling deaths			
Number of deaths:	Age	-0.05385	0.01893
	Age squared	0.00138	0.00048
Random Effects			
Child level		0.65750	0.06428
Household		0.20227	0.06304

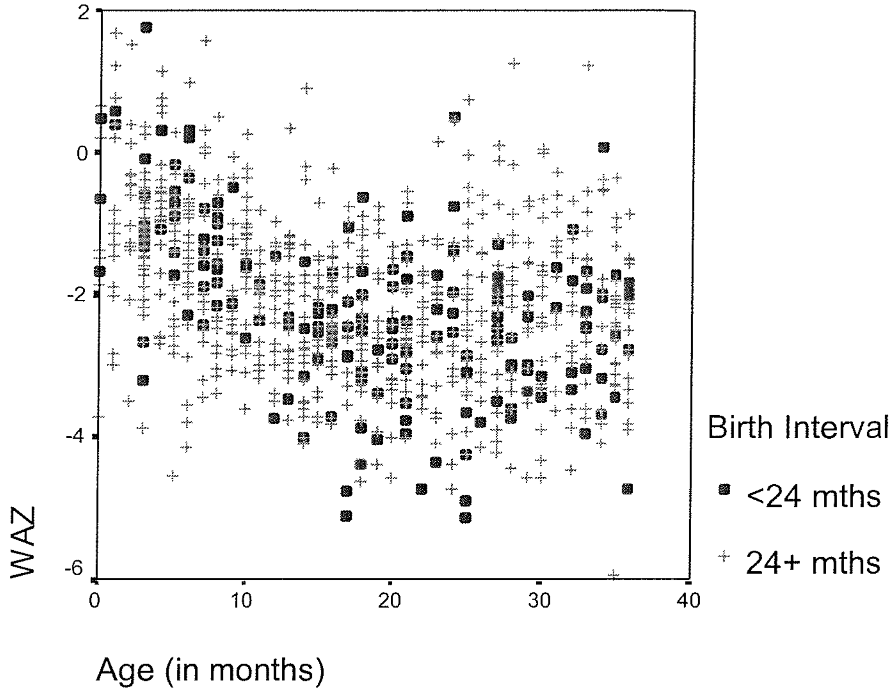
Figure 4.4



Key – SBI = Birth interval <24 months
LBI = Birth interval 24+ months

For children up to six months of age short birth intervals are associated with slightly higher WAZ scores although the effect is small and insignificant if the model is run for children up to one year of age only. The association becomes negative, however, for children over the age of 12 months as a result of the negative interaction between short birth intervals and the age of the child. The magnitude of the negative association increases for each successive age group so that the estimated WAZ score of children aged 36 months who have a previous short birth interval is 1.8 standard deviations below the median of the reference population. For children following long birth intervals the decline in the estimated WAZ over the age groups is less severe and remains constant at approximately −1.3 for children aged over 14 months of age. Figure 4.5 shows the distribution of short birth intervals by the age of the child. Children following short birth intervals are well represented in all the age groups.

Figure 4.5 Weight-for-Age Z Score by Previous Birth Interval



Other significant correlates at the child level included the feeding regime, recent incidence of diarrhoea, the number of sibling deaths, the size of the child at birth, maternal education, and whether the delivery took place in a hospital.

Breast-feeding is positively associated with WAZ score during early infancy. There is a negative interaction with the age of the child, however, and a positive interaction with age squared. Figure 4.6 demonstrates the effect of breast-feeding over the age groups of the children. During early infancy children who are not breast-fed are shown to have particularly low WAZ scores with the estimated average at less than –2.5 standard deviations. Those who are breast-fed, however, demonstrate a much higher estimated average, close not the reference population. This differential decreases quite sharply as the age of the child increases. For children aged 18 and 33 months the association reverses and the estimated WAZ scores of children who are not breast-fed are higher than those of children who are breast-fed. The magnitude of difference is small however and is not significant if the model is run for children over one year of age only.

Figure 4.6

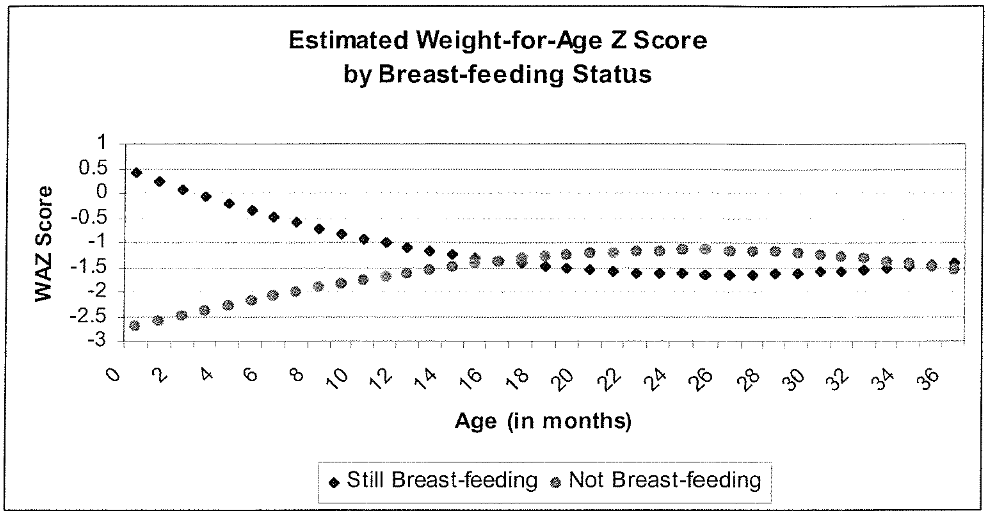


Figure 4.7 Weight-for-Age Z Score by Breast-feeding Status

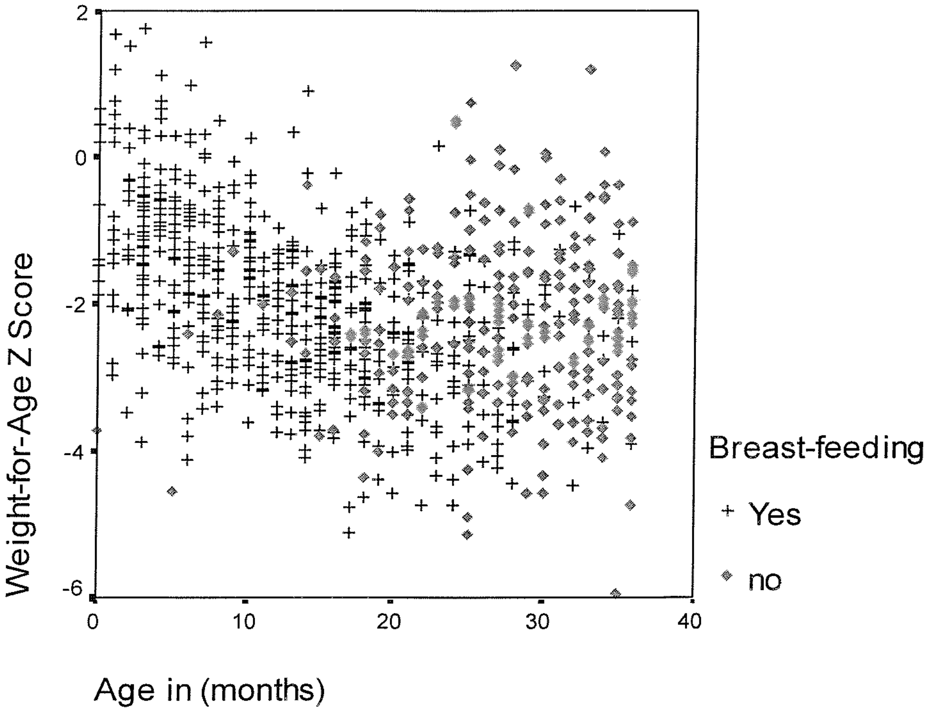


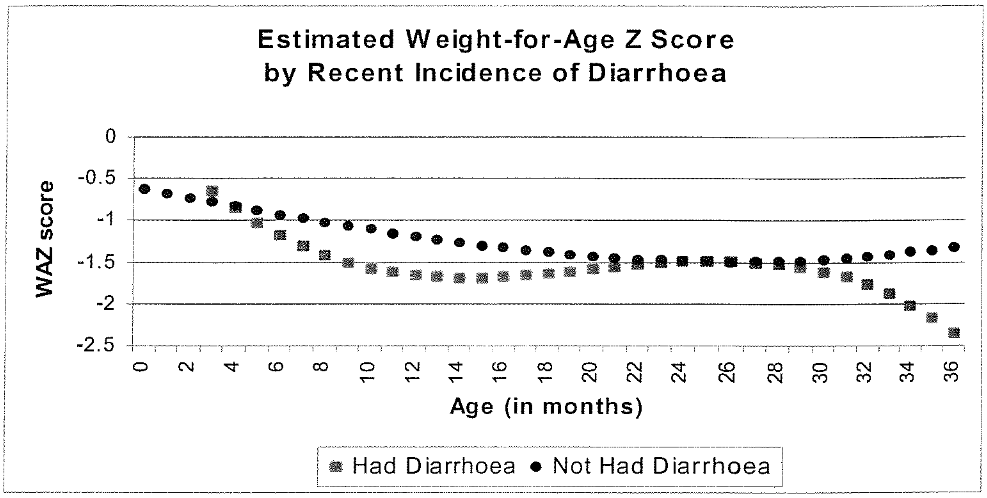
Figure 4.7 shows the distribution of the WAZ scores by breast-feeding status over the age groups. Most children under 18 months were still being breast-fed at the time of the survey. The large negative association for children not breast-fed during early infancy (Figure 4.6) is thus based upon small numbers of children only, and interpretations of the results should be made with caution. Nevertheless the effect is significant and the WAZ scores are clearly different from those of children who were breast-fed.

Breast feeding status varies with time, so it is not appropriate to think of the curves, shown in Figure 4.6, as demonstrating weight change, even if it is assumed that there are no cohort effects. A child who is fed according to the United Nations recommendations, for example, would be breast fed for the first 4 to 6 months of life and then weaned to solid food. They would thus be represented by the blue curve in Figure 4.6 during the first few months of life and thereafter the red curve.

The age at which solid foods were introduced was also significantly associated with WAZ scores. The variable was constructed to represent whether the introduction of solid foods was according to the infant feeding recommendations set out by the World Health Organisation. For example, the recommendations state that a child should be exclusively breast fed for the first four to six months of life then supplementation should be commenced (World Health Organisation, 1989). Thus if a child of less than 4 months was already being given solid foods they were classified as not fed according to the WHO recommendations. Conversely if a child over 7 months of age was not being given solid foods then they were not fed according to the WHO recommendations. Infants between the ages of 5 and 7 months were classified as being fed according to the recommendations whether or not they were receiving solid foods. The introduction of solid foods is usually supplementary to breast-feeding so does not necessarily coincide with the cessation of breast-feeding. Table 4.3 shows that failure to introduce solids at the appropriate age was associated with lower WAZ scores by approximately 0.2 of a standard deviation. There was no interaction with the age of the child so the effect was constant for both young and older children.

Incidence of diarrhoea in the previous two weeks before the survey was also significantly associated with WAZ scores and the relationship differed by the age of the child. Figure 4.8 demonstrates this association by plotting the modelled WAZ Scores by diarrhoea status. No children under two months of age were reported to have suffered diarrhoea and newly born children were classified as not having had diarrhoea. For children aged 3 to 6 months there was little difference in the WAZ scores by experience of diarrhoea. However, for children between the ages of 6 to 18 months there was a negative association which was greatest in effect for children around one year of age.

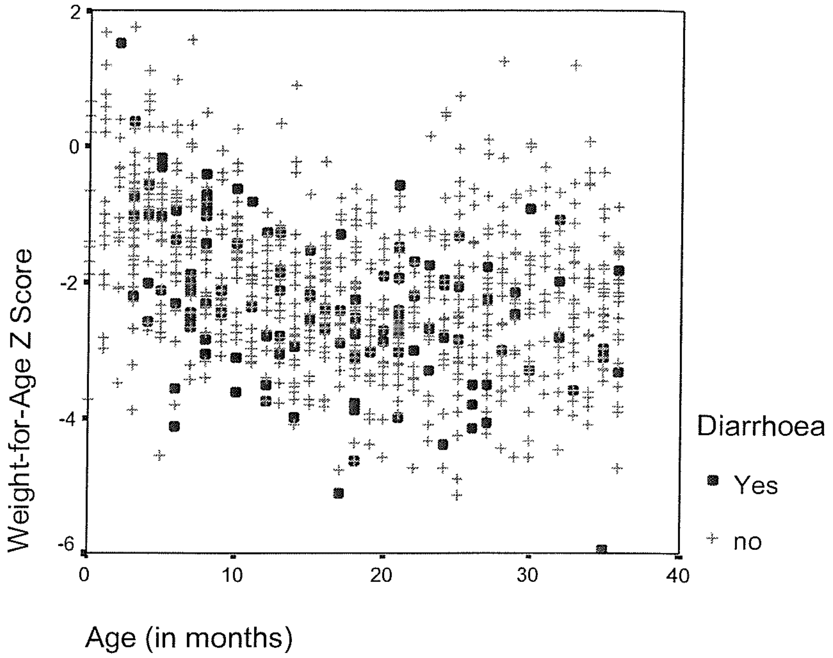
Figure 4.8



No association was evident for children aged 20 to 30 months but for children over this age there was a strong and increasingly negative effect with the increasing age of the child. For children who had not suffered diarrhoea during the previous 2 weeks, the decline in estimated WAZ score with increasing age groups was much less severe.

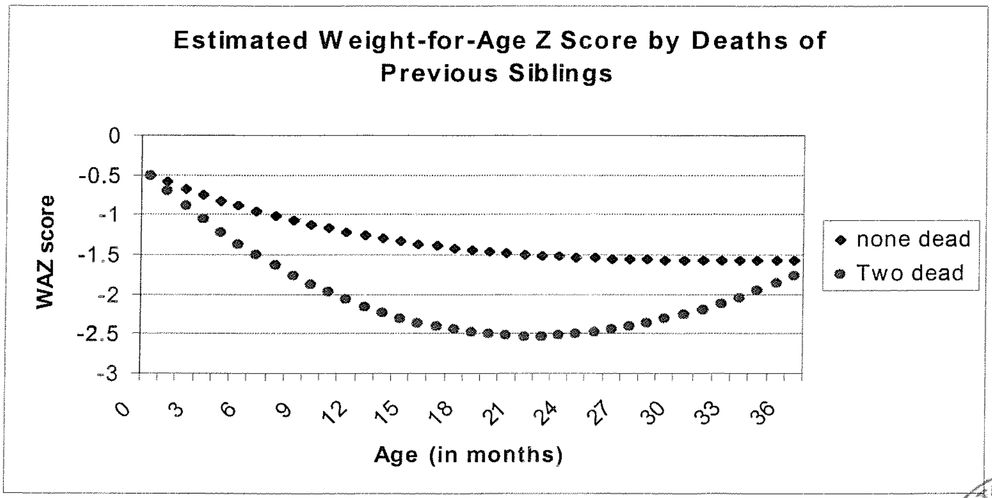
Figure 4.9 shows the distribution of WAZ scores by the incidence of diarrhoea for the different age groups. Incidence of diarrhoea is quite evenly distributed for children aged 3 to 26 months. For children over 26 months the incidence is less frequent. There is one outlying child aged 35 months with a low weight-for-age z score. This child had a recent episode of diarrhoea and could be the cause of the steep decline in WAZ score for children aged over 30 months. The model was repeated excluding this case but the change in results was minimal (see Appendix 1, Table 4.c).

Figure 4.9 Distribution of WAZ Scores by Recent Incidence of Diarrhoea



A history of deaths amongst older siblings was associated with lower WAZ scores and the effect is more severe the greater the number of deaths that have occurred. Figure 4.10 compares the WAZ scores for children who have no siblings who have died and those who have two older siblings who have died. For newly born children the WAZ scores are –0.5 regardless of the mortality history. However, the negative interaction with the age of the child is evident for children aged between 1 and 24 months. The effect is particularly severe for children aged between 12 and 27 months but decreases in magnitude for children over 27 months.

Figure 4.10



The size of the infant at birth was associated with lower weight-for-age z scores by approximately 0.4 of a standard deviation throughout infancy and early childhood. Hospital delivery was positively associated with a higher WAZ score by 0.18 standard deviation and maternal education by 0.32 and 0.37 of standard deviation for primary and middle or high school levels respectively.

At the household level the number of children within the household and the type of house construction was associated with WAZ scores. Each additional child under five years of age was associated with a WAZ 0.08 of a standard deviation lower. A house constructed of semi-pucca materials was associated with a WAZ score 0.17 standard deviations higher than one constructed of katcha materials. These associations were both constant throughout all age groups.

Variables that were insignificant and thus excluded from the model are shown in Table 4.4.

Table 4.4 Excluded Variables

Child specific	**Mother specific**
Month that the weight was recorded	Maternal age
Gender	Mother's occupation
Birth order	Father's occupation
Preceeding sibling died	Maternal knowledge of legal age at marriage
Child was wanted	
Colestrum was discarded before breast feeding	
Mother received prenatal care	
Household level	**Village**
Toilet facilities within household	Health care provisions
Number of items owned	Adult education provision
Source of drinking water	Calamity in past 2 years
Religion	Epidemics
Caste	
Variables representing survey structure	
Region	
Stratum	
Female literacy (percent)	
District	

4.5.1 Residual Analysis

The random coefficients show that at the child level the unexplained variance is 0.66 and at the household level the unexplained variance is 0.20. The household level, therefore, accounts for approximately 25% of the total variance. This is a sizeable proportion and is significant at the 1% level. The variation at the child level, however, accounts for a much greater proportion of the unexplained variation in WAZ scores. Figures 4.11 and 4.12 illustrate the difference between the residual variation at the child and household levels.

Figure 4.11 Residual with 95% Confidence Interval Ranked by each Child

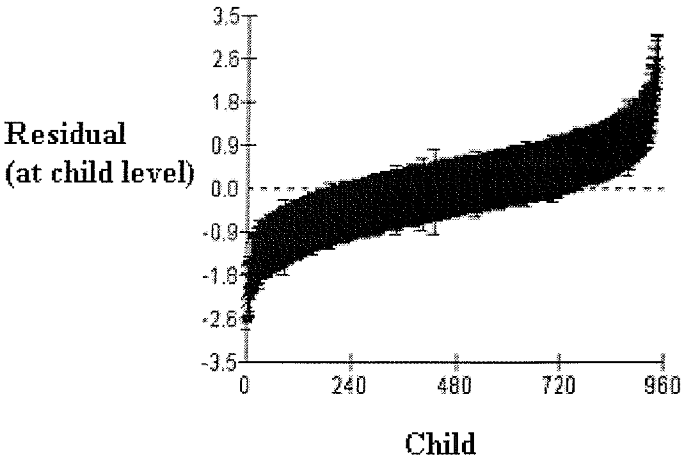
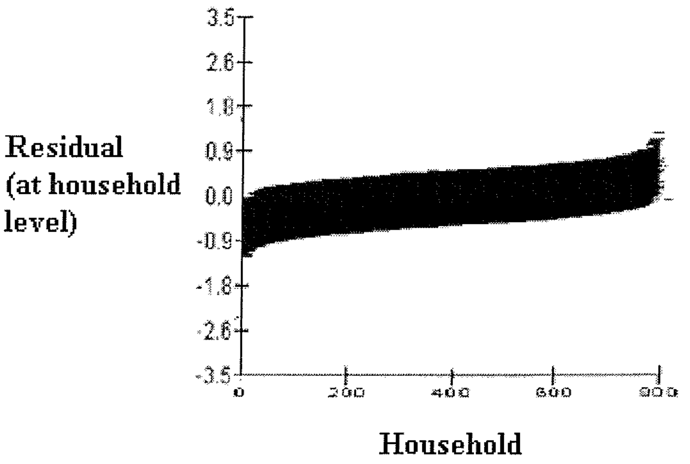


Figure 4.12 Residual with 95% Confidence Interval Ranked by Household



Each point estimate is given with a 95% confidence interval, the residuals for the individual children and the households can thus be considered to have significantly different residuals if the errors bars do not overlap. Owing to the large number of cases the error bars form a band but nevertheless provide a clear illustration of the variation in residuals at each level.

Further analysis was performed of the distribution of the residuals at both the child and household levels to check for conformity with the assumptions inherent within modelling procedures. The results show close conformity to normality and constant variance (Appendix, Figures 4a and 4b). There is no evidence therefore to suggest that these assumptions have been violated.

4.6 Discussion

4.6.1 The Average WAZ score by the Age of the Child

The results show that the estimated WAZ score at birth for the average child in rural Karnataka is lower than the median of the reference population by 0.5 standard deviation. Previous research has established that although there are racial differences in the genetic growth potential of adults, there is no such difference before puberty (Pelletier, 1991 and McMurray, 1996). This has been confirmed by a number of studies which have found that whilst nutritional and environmental factors account for a considerable amount of variation in anthropometric assessment, the role of ethnicity is minimal (Eveleth, Tanner, 1976 and Habicht et al., 1974, cited in McMurray, 1996). It is likely therefore that any difference in WAZ score at birth results from the nutritional status of the mother, thus influencing the growth or weight gain of the fetus. Literature concerning the analysis of maternal nutritional status on the birth weight of the infants has generally found that although there is some effect, the magnitude tends to be small owing to compensatory mechanisms which protect the infant. For example, Prentice and Prentice (1988) suggest that the metabolic rate may decrease to maximise resources. The difference shown in these results (0.5 standard deviation), although not large is therefore worthy of attention.

The typical diet of women in rural Karnataka is likely to consist of meals made from wheat, sorghum, rice or pulses. Vegetables as available are cooked with chillies and also form a substantial portion of the meal. Many women are vegetarian but even those who are not, are likely to have a limited consumption of chicken, fish or mutton owing to economic constraints. Many foods are seasonal and thus availability varies during the year. Women also have lower priority in the allocation of resources; it is custom for men to eat first, followed by children and then women to eat last. Further exacerbating the risk of under-nutrition is the common practise of dietary restrictions, particularly during the last trimester of pregnancy. A very common belief is that women suffer problems if food restrictions are not followed during pregnancy. Many of the problems relate to the woman's own comfort such as avoiding indigestion or acidity. Others, however, relate to the size of the child. If, for example, a woman does not restrict food consumption during pregnancy it is believed that the child will be big and this may cause difficulties during childbirth. Conversely, some women claim that if they eat too much there is no room for the baby to grow (Hutter 1998).

The daily energy expenditure is also likely to be high for these rural women as energy intensive activities form their normal daily routine. Many undertake agricultural work or care for livestock, for example, and household tasks may involve activities such as walking many miles to collect water.

The results show that the low WAZ score at birth is followed by a further decline for each successive age group, for children up to the age of approximately 14 months. This clearly indicates that the children suffer further disadvantage, during infancy, in comparison to the reference population. The greatest deficit shown for older children during the toddler and early childhood periods indicates that exogenous factors prevent the children from attaining their full growth or weight potential.

When considering the results of this analysis it is important to bear in mind that the average WAZ score for each age group is not related to that at other age groups and the curve, therefore does not represent expected weight change. Cohort effects may result in children at different age groups being exposed to unique factors which have influenced their weight attainment, which are not common to other age groups. It can only be assumed, therefore, that the WAZ score of a child will follow the curve if there are no cohort effects and thus children at each age group are exposed to the same circumstances.

4.6.2 The Effect of the Previous Birth Interval

The results show that, whilst a previous birth interval of less than two years has little effect on the WAZ score of children during the first year of life, a negative association increases in magnitude for children aged 12 to 36 months. As mentioned above, when analysing cross-sectional data, it is not possible to disentangle age effects from cohort effects. However, if it is assumed that there are no cohort effects, the results suggest that the detrimental effect of a short birth interval becomes clear only as the child becomes older. In this case the results indicate that it is exogenous factors associated with short birth intervals that are detrimental to the welfare of the child. Such factors would include competition for resources or for maternal care and attention.

It is easy to see how these factors could become intensified as the child grows older. A child during the second and third year of life requires a diet which is not only balanced nutritionally but also one which provides sufficient calories for the high energy demands of a growing, active child. Breast milk alone becomes increasingly inadequate in providing for these needs and supplementation with a varied diet is important for nutritional wellbeing. Research has consistently confirmed the negative association of breast-feeding after the first year of life with WAZ scores and this is thought to result form inadequate supplementation (Madise et al., 1999). A woman who has two young children close in age may have less time for preparing food specifically to meet the needs of the children. Food may be given which has been prepared for other family members and which may not necessarily be best suited for the less mature digestive system of a young child. Also where resources are scarce the child may have to compete with the older siblings for food.

As the child becomes more mobile exposure to pathogens and physical danger become a greater risk. Owing to the heavy workload of a mother with more than one young child to care for, she may afford the child less attention and be less particular in terms of hygiene and sanitation. In addition she may be less able to monitor the child for signs of illness and less able to take time to attain advice or treatment from health care providers. Infectious disease is particularly prevalent for children around 2 years of age exacerbating the effect.

There is no evidence in this analysis that maternal depletion has a detrimental effect on the weight gain of the foetus. If this were the case one might expect short birth intervals to be associated with low birth weights. The association between low birth weight and infant mortality, however, has been well documented so it is possible that the lack of association merely reflects selection bias within the data (see section 6.5 for discussion of potential bias resulting from the under-representation of children who died). Nevertheless it is surprising that this fully removes any association of short birth intervals with the WAZ for children throughout the first year of life.

Other variables, which may be related to maternal depletion, include maternal age and parity. If reproductive cycles are nutritionally depletive and this effect is cumulative then one might expect that a high maternal age and parity might be associated with lower maternal nutritional status of the mother and consequently the child. These variables were not significant, however, so were excluded from the model.

4.6.3 The Effect of Breast-feeding Behaviour

Breast-feeding is a time varying covariate and thus even if it is assumed there are no cohort effects it is not appropriate to think of the curves in terms of weight change. A child who is still breast fed at six months may not be breast fed at 10 months and thus would have moved from one group to the other. The results show that breast feeding is associated with higher WAZ for children in early infancy and for those up to one year of age. The benefits of breast-feeding during this early stage have been strongly advocated by health care workers and organisations (WHO, 1989). Breast milk is, of course, the most nutritionally balanced food, specifically meeting the requirements of an infant. It is easily digested and metabolised, and contains antibodies protecting the infant against infection. The very low WAZ scores, however, for those not breast fed could reflect a reverse causality whereby some other problem has caused the cessation of breast-feeding. Children who are ill, for example, suckle less well. As suckling stimulates the release of the hormone prolactin, which is required for milk production, lactation declines. The positive effect of breast-feeding declines with the increasing age group of the child. For those aged between 18 and 35 months the association becomes negative so that children who are breast fed have lower WAZ scores than children who are not breast fed. The effect is fairly small in magnitude, however, and the difference is not significant for these age groups. This overall trend is consistent, however, with the findings of previous literature which has identified a negative association between breast feeding and the WAZ scores of children over 12 months of age (Madise et al., 1999). One possible explanation cited is that weaning may be commence when the mother perceives the child as being robust enough to survive without breast milk. Less healthy children would therefore be breast-fed for a longer period of time.

The negative association between inappropriate supplementation to breast feeding or weaning and lower WAZ scores demonstrates the importance of feeding regimes which reflect the needs of the child at each stage of infancy and childhood. The introduction of supplementary foods during early infancy increases exposure to bacterial infection from contaminated foods and utensils (WHO, 1991*)*. This risk may be exacerbated for communities that do not have access to a clean water source and where sanitation is poor. Additionally where time and resources are scarce food may be kept for periods of time, before being eaten thus increasing the risk of bacterial contamination. Also, the foods given to young children may not be appropriate for their less mature digestive systems. The negative association across the age groups also demonstrates the importance of introducing supplementary foods at around 6 or 7 months to meet the increasing nutritional and energy needs of the growing child. Madise et al. (1999) suggests that the negative association of breast feeding for children over one year of age (mentioned above) may result from poorer complementary feeding in comparison to children who are weaned.

4.6.4 Other Correlates of WAZ Score

Gastro-enteritis suppresses the appetite and causes diarrhoea. A child suffering from such infection may thus be come malnourished through both inadequate food intake and through excessive excretion. The results show that a recent episode of diarrhoea is associated with low WAZ scores for children aged 6 to 18 months. As discussed earlier this is a period of time when the child has a greater exposure to bacterial infection and pathogens as supplementation to breast-feeding is increased and the child becomes mobile. In addition, the immune system of the infant is not fully developed and thus the child may be particularly susceptible to and less able to fight off infections. Also it is plausible that children who have recently had suffered diarrhoea may have had a history of gastrointestinal infection. The viscous circle whereby infection causes the child to become less resistant to further infection has been well documented (Scrimshaw et al., 1968). Also there is likely to be a higher prevalence of infection in families who have poorer environment and sanitary facilities. The low WAZ score may therefore be the result of cumulative bouts of diarrhoea. The lack of association between incidence of diarrhoea and WAZ scores for children aged 20-28 months is not obviously explained. The effect of morbidity on WAZ scores is transient in nature and thus not easy to capture in cross sectional data. One possibility is that the results shown for these age groups reflect the methodological limitations.

The delivery of the child in a hospital was associated with higher WAZ scores. It is likely that this variable reflects availability and use of health care facilities more generally and thus the positive association is evident across all age groups. The variable may also represent socio-economic status and the ability to pay for services.

The benefits of maternal education in reducing the risk of child mortality have been well established (Cleland & Van Ginneken, 1988 and The United Nations, 1985). These results show that maternal education at primary and middle/high school level is associated with higher WAZ scores across all the age groups. A focus of analysis in academic literature has concerned the pathways through which maternal education is transferred to the welfare of the child. Authors hypothesise that education is associated with different behaviour and attitudes of the woman and the way that she is viewed by society. A more educated woman may have a greater awareness of issues concerning nutrition, hygiene and sanitation, for example. She may gain greater autonomy, confidence and ability to communicate her wishes or concerns. Educated women are less likely to commence child bearing at a very early age and tend to have fewer children. These factors are known to influence infant survival (Mosely and Chen, 1984 and Cleland, 1990). Another hypothesis concerns the association of maternal education with economic status; United Nations (1985) for example state, that "approximately half the gross effect of mothers education could be attributed to economic advantage. Overall it seems that education equips the woman, to exploit her own particular circumstances, in a way which is beneficial to the welfare of her children. These results suggest that this beneficial effect is the same for children of all age groups and is similar across levels of educational attainment.

Authors have previously confirmed that children of the same family tend to share similar risks of mortality (Das Gupta, 1997 and Curtis, 1996). Curtis & Steele (1996) compared the strength of familial association of neonatal mortality across 4 countries from South America and Africa. They found that the strength of association was very similar across the countries despite their different settings and suggest biological explanations such as shared genetic characteristics are important in creating this clustering effect.

In this analysis a history of sibling deaths was found to be associated with the WAZ scores of the children indicating that they are tend to thrive less well. The effect was greatest for children aged between 12 and 30 months and peaked around 24 months. It could be argued that this provides evidence that exogenous factors shared between siblings are also important in determining to their overall welfare. It is intuitive that socio-economic wellbeing would influence the welfare of children within the same family but also behavioural factors such as attitudes towards childcare would have similar effects.

The lack of association of sibling deaths with the WAZ score at birth could partly result from a selection effect whereby infants with low birth weight suffer higher mortality and thus are not included in the analysis. Alternatively, it could be that the exogenous circumstances have less effect in this early period and for children aged around 36 months. Very young infants are breast-fed and less mobile whilst older children are better able to fend for themselves and become more robust.

The size of the child at birth, as perceived by the mother was negatively associated with WAZ scores and the effect was constant across all age groups. Assuming there are no cohort effects this indicates that children follow a trajectory whereby a relatively light child at birth remains relatively light during later infancy and childhood. This data cannot provide conclusive evidence of this, however. It is possible that a mothers' report of birth weight is influenced by the WAZ score recorded later in childhood. Also children reported as being small at birth may have been born prematurely. The variables size at birth and prematurity are highly correlated and thus both could not be included in the model. Size at birth explained a greater proportion of the variation in WAZ score so was retained within the model. For some children then the lower WAZ score may reflect their lower gestational age.

The significant variables at the household level include the number of children under five years of age within the household and the materials of the household construction. Each additional child under five years within the household was associated with a lower WAZ score. There are a number of possible explanations for this, firstly families of lower socio-economic status have a greater incentive for larger families as this provides a greater workforce and insurance for old age. However, the more children within the family, the further limited food resources have to be spread. Secondly a high number of young children within a household may be an indicator of extended family structures. Women within more traditional communities often suffer lower status and limited autonomy. The number of children under five may also indicate overcrowding and poor living environmental conditions.

Finally, the type of household construction was associated with WAZ scores. This variable is a proxy for socio-economic welfare and an indicator of resources. Katcha houses consist of mud and bamboo whilst Pucca houses are constructed with a more robust brick material. As expected children from houses constructed from semi-pucca (part brick or cement) demonstrated higher estimated WAZ scores than children from houses constructed of Katcha. The lack of association between Pucca houses and WAZ scores is unexpected and may reflect the small numbers of houses constructed of Pucca in rural Karnataka.

4.6.5 Random Effects

The significance of the household effect indicates that the nutritional status of children varies between households and that whilst children from one household may tend to have high WAZ scores, children from another may tend to have low WAZ scores. This variation is in addition to that which is explained by the independent variables included in the model. Thus two children with the same characteristics, as described in the model, may have different WAZ scores if they come from different households.

The results show that for rural Karnataka the correlation coefficient at the household level is 0.25. (That is 25% of the total unexplained variance is attributable to the household level.) This is higher than has been identified in other states of India, for example Uttar Pradesh at 21%, Maharashtra at 22% and the neighbouring state of Tamil Nadu at only 11 % (Griffiths et al., 2000). This indicates that there is a greater disparity between households in their influence on child nutrition.

Factors which may explain the unobserved household heterogeneity include genetic constitution, values and beliefs shared by the household members and socio-economic status. It is quite feasible that individuals have an inherited physical and mental constitution which influences their health status even from birth. Curtis and Steele (1996) suggest that such biological factors explain the similarity of familial correlation in neonatal mortality across countries of different socio-economic status. Bakketeig et al. (1979) observed a tendency of low birth weight babies amongst some mothers in their sample from Norway (cited in Madise et al., 1999).

Members within the same household are likely to share or be subject to particular beliefs and attitudes which shape their behaviour and way they interact within the community. Cultural beliefs, for example, may shape the way in which women are viewed, their status and autonomy. This in turn may have an impact on child care and the ability of the woman to act on behalf of her children. Families may also vary in the extent to which they follow traditional rituals which sometimes reflect spiritual beliefs rather than health or hygeine. A common practise in rural Karnataka, for example, is to bathe the umbilical cord of a newly born child in cow dung.

These factors are difficult to capture with the explanatory variables. A number of variables were included to represent the socio-economic status of the family. For example, the number of items owned, the household construction and the occupation of the mother and father. Although these variables may to some extent represent socio-economic status, they clearly are unlikely to fully capture the complex way in which ownership, subsistence and status influences child welfare.

The community effect was not significant in the analysis. This indicates that the variation in WAZ scores between children is not influenced by the characteristics of the village in which they live after controlling for household differences and the other covariates in the model. Other research has demonstrated that the significance of the community level varies between different states of India. In Maharashtra, for example it was insignificant, in Tamil Nadu it was significant at the 5% level only and in Uttar Pradesh it was significant at the 1% level. In all states however, the magnitude of the effect was small, with the correlation coefficient ranging 2% in Karnataka and 6% in Uttar Pradesh. Clustering effects at the household level were found to be significant in all of these areas. (Griffiths et al., 2000).

The community level variation is expected to be greatest where there are large disparities in environmental conditions, levels of infrastructure, health care provision, etc. Karnataka can be divided into four regions based upon physical and geographic characteristics: the Northern Karnataka Plateau, the Central Karnataka Plateau and the Southern Karnataka Plateau and the Coastal Region. Climatic conditions are determined largely by its geographic proximity to the sea, the monsoons and the physio-graphic characteristics. One might expect there to be differences in agricultural production and food availability owing to these geographic and climatic characteristics. However, a considerable proportion of crops are used for commercial purposes and thus food availability is not necessarily related to agricultural production. Also as a result of the Alma Ata Declaration of 1978 and the commitment to attain "Health for All" by 2000 AD the Government has focused health care services and infrastructural development on the more neglected rural areas. The National Health Policy established in Parliament in 1983 has focused on certain aspects of health care such as nutrition, maternal and child health care and water provisions. As a result of these factors disparity between villages in welfare and risk of malnutrition may have reduced.

Summary

The children of rural Karnataka are considerably less well nourished than the reference population. On average the WAZ score of children at birth is lower and this disparity increases during infancy before stabilising at around –1.5 standard deviations. This indicates that many children receive a comparatively poor nutritional intake and suffer a higher prevalence of disease.

Short birth intervals are associated with lower WAZ scores, although the effect varies with the age of child. Little effect is evident for children under one year of age, but the negative association increases in magnitude for children aged between 12 and 36 months. This indicates that exogenous factors associated with short birth intervals are detrimental to the welfare of the child. These might include competition between siblings for resources or for maternal care and attention. It is intuitive that the detrimental effect of such factors are likely to become more acute during later infancy and early childhood, as the nutritional requirements become more complex and as the child becomes mobile thus increasing exposure to pathogens and to physical danger. However, with cross-sectional data age, or time, effects cannot be disentangled from cohort effects and thus the analysis is limited in its capacity to support such a hypothesis.

Factors, which directly influence nutritional status, include nutritional intake and incidence of morbidity. Breast-feeding behaviour and the timing of supplementation with solid foods are shown in this analysis to be important in explaining the variation in WAZ scores. Again this effect varies with the age of the child, reflecting the changing needs of children throughout infancy and early childhood. As expected recent experience of diarrhoea is associated with lower WAZ scores, particularly amongst children around one year of age.

Other significant correlates at the child level include the size of the child at birth, whether the child was delivered in a hospital, maternal education and a history of deaths amongst older siblings. At the household level the number of children under five years of age and the household construction were significant. These variables represent the constitution of the individual child and the socio-economic circumstances within which the child lives.

The unexplained variance was found to be significantly correlated at the household level indicating that the nutritional status of children within households, tend to be similar even after controlling for the explanatory variables at this level. Factors which may account for this unobserved heterogeneity, include genetic constitution, values and beliefs shared by the household members and socio-economic status. The variation at the child level accounts for by far the greater proportion of variation, however. This confirms that the individual characteristics and circumstances of the child is a large determinant of nutritional welfare even within the household.

A disadvantage of using cross-sectional data to analyse the anthropometric status of children is that growth curves are synthetic in nature and thus statements cannot be made concerning change over time without making fundamental assumptions which rule out any cohort effects. It cannot therefore be assumed the average weight attainment of younger children will be similar to that of older children, even if they share similar characteristics known to be associated with weight attainment. This reduces the sensitivity of the analysis and limits its explanatory power considerably.

CHAPTER 5

Analysis of Birth Spacing and Weight Measurements in Kanakpura Taluk: A Longitudinal Approach

5.1 Introduction

In this chapter the nutritional status of infants during the first year of life is analysed using longitudinal anthropometric assessment. The data consists of weight measurements, recorded monthly, for children of the rural villages of Karnakapura, Karnataka. Specifically, the effect of birth spacing patterns on the birth weight and growth of the infant during the first year of life is explored using a multivariate regression model which allows for the correlation structure of longitudinal data. This model is used to determine the role of bio-demographic and socio-economic variables associated with the weight change of the infant. The effect of birth spacing patterns can thus be assessed net of other confounding factors. A particular focus of the study concerns the potential of longitudinal data to illuminate changes in the relationship over time. This temporal dimension provides a sensitive indicator of circumstances in which a child to thrives less well.

Sections 5.2 to 5.6 describe the methodology used to analyse the repeated weight measurements. First the features of the data are outlined and the notation used to describe its structure are introduced. Second, issues surrounding methodology for the analysis of longitudinal data are discussed, including factors which influence and restrict the choice of appropriate models. Third exploratory techniques are described, and finally the different types of models for longitudinal data are outlined together with their specific applications. Section 5.7 presents the exploratory analysis in which the overall pattern of weight change experienced by the children, is explored. This includes change in the rate of weight gain over the year, variation in weight gain between individuals and, in the wider context, comparison with a reference population. The preliminary analysis is outlined in section 5.8. This includes selection of a cubic model of WAZ score by the age of the child, and selection of the type of model appropriate for the analysis of this data. This is followed by the results of the final model and a discussion in sections 5.9 and 5.10 respectively.

5.2 Features of the Data

The data consists of a time-sequence of weight measurements for each infant, recorded monthly for a period of one year. A number of explanatory variables describe the socio-economic and bio-demographic characteristics of the mother. These were recorded during the Obstetric Health Survey and at an initial questionnaire during the Maternal and Infant Follow up Survey. Data are also included concerning infant morbidity. This was collected during the infant follow up survey and consists of monthly reports of recent experience of morbidity, for example, incidence of diarrhoea since the previous visit.

The monthly timing of the observations was approximate, owing to the practical restrictions of data collection in these rural villages. In addition the data features intermittent missing observations resulting from the absence of the women and children who were carrying out agricultural work in the fields, or who were temporarily staying at the natal household. The missing data are thus unlikely to cause bias as the reason for its omission is unrelated to the variable of interest, i.e. infant weight. It cannot be ruled out, however, that on occasion a woman would avoid having her child weighed because she was aware that it was underweight or had not been feeding properly. Nevertheless missing data of this nature is uncommon as the fieldworkers visited the respondents in their own environment and made an effort to revisit women who were not in their homes.

Weight measurements are unavailable for those infants who died during the first year of life. The analysis thus applies only to children who survive at least to at least one year of age. The bias that this creates must be considered in the interpretation of results (see section 6.5 for discussion of bias caused by deaths).

5.3 Notation and Data Structure

The weight measurements for each individual can be written as y_{ij}, where $i = 1,\ldots,m$ individuals, and $j = 1,\ldots, n_i$ observations. (Note here that the i and j are reversed in comparison to the previous model in which i represented the observations and j second level units or clusters.) For an individual with monthly observations recorded for the full year $n_i = 12$. However, as not all individuals completed the full series of weight measurements and as some measurements were missed, $n_i \neq 12$ for all individuals in this data set. The series of weight measurements for each individual may be expressed in matrix format as:

$$\boldsymbol{y}_i = (y_{i1}, \ldots, y_{n_i})^T.$$

Each observation y_{ij} is measured at a time point t_{ij}. t_{ij} corresponds to the months since birth for individual i at observation j. The time points are unequally spaced and thus $t_{ij} - t_{ik}$ is not equal for all i. The series of time points for each individual can be expressed as

$$\boldsymbol{t}_{ij} = (t_{i1}, \ldots, t_{in_i})^T.$$

The observations for all the individuals may be represented by a single vector **y**:

$$\boldsymbol{y} = (\boldsymbol{y}_1^T, \boldsymbol{y}_2^T, \ldots, \boldsymbol{y}_m^T)^T,$$

where $\boldsymbol{y}_1$ is the vector of responses for the first individual.

The single vector t records the corresponding n_i time points for the m individuals:

$$\boldsymbol{t} = (\boldsymbol{t}_1^T, \boldsymbol{t}_2^T, \ldots, \boldsymbol{t}_m^T)^T$$

(Smith, Robertson and Diggle, 1996).

With each observation y_{ij}, a series of covariates are also observed. The covariates are represented by the vector $\boldsymbol{x}_{ij}$, of length p. The series of covariates for an individual at time point t_{ij} can be expressed as

$$\boldsymbol{x}_{ij} = \begin{pmatrix} x^{(1)}_{ij} \\ \vdots \\ x^{(p)}_{ij} \end{pmatrix} = (x^{(1)}_{ij}, x^{(2)}_{ij}, \ldots, x^{(p)}_{ij})^T$$

and the series of covariates for an individual at all time points as

$$\boldsymbol{X}_i = \begin{pmatrix} \boldsymbol{x}_{i1}^T \\ \boldsymbol{x}_{i2}^T \\ \vdots \\ \boldsymbol{x}_{in_i}^T \end{pmatrix} = (\boldsymbol{x}^{(1)}_i, \boldsymbol{x}^{(2)}_i, \ldots, \boldsymbol{x}^{(p)}_i) \text{ of dimension } n_i \text{ x } p, \text{ where } \boldsymbol{x}^{(k)}_i = \begin{pmatrix} x^{(k)}_{i1} \\ x^{(k)}_{i2} \\ \vdots \\ x^{(k)}_{in} \end{pmatrix}.$$

The repeated observations for the series of covariates for all the individuals can be expressed as

$$\boldsymbol{X} = \begin{pmatrix} \boldsymbol{X}_1 \\ \boldsymbol{X}_2 \\ \vdots \\ \boldsymbol{X}_m \end{pmatrix} = (\boldsymbol{x}^{(1)}, \boldsymbol{x}^{(2)}, \ldots, \boldsymbol{x}^{(p)}) \text{ of dimension N x p,}$$

where

$$\boldsymbol{x}^{(k)} = \begin{pmatrix} \boldsymbol{x}^{(k)}{}_1 \\ \vdots \\ \boldsymbol{x}^{(k)}{}_m \end{pmatrix}$$

and $\mathrm{N} = \sum_{i=1}^{n} n_i$.

Covariate values which change with the subject, but remain constant through time, are termed "subject specific variables" and include background characteristics such as the mothers educational level. Such variables can be expressed as a vector of length N with the same value for each time point for a subject, but different values for different subjects.

The values of "time varying" covariates change with the subject and with time. An example is recent experience of diarrhoea where a child may or may not have experienced diarrhoea within the previous two weeks. Again such a variable can be expressed as a vector of length N, the value may be repeated at some time points for an individual, but may change at other time points.

Finally, "time-specific" variables vary over time but are constant across subjects. Such variables usually occur in studies in which subjects are measured at common time points. An example in this study, however, is the season in which the measurement was recorded.

5.4 Issues Concerning the Analysis of Longitudinal Data

Between subject variation in anthropometric measurements occurs as a result of both measured and unmeasured factors. Inherited growth potential, for example, can be measured to some extent by maternal height. The particular genetic characteristics of the individual, however, cannot be measured.

The variance for each observation, for each individual is represented by $var(y_{ij}) = v_{ij}$. As a result of the between subject variance, the repeated observations for each individual in longitudinally collected data are correlated. The covariance between two observations for an individual is expressed as $cov\ (y_{ij}, y_{ik}) = v_{ijk}$. The covariance of the full series of repeated observations for an individual is represented by the n_i x n_i covariance matrix:

$$var(y_i) = V_i = \begin{pmatrix} v_{i11} & v_{i12} & \cdots & v_{i1n_i} \\ v_{i12} & v_{i22} & & \vdots \\ \vdots & & \ddots & \vdots \\ v_{i1n_i} & \cdots & \cdots & v_{in_in_i} \end{pmatrix} .$$

It is assumed that observations are independent between individuals so the variance for the repeated observations for all the individuals is expressed as an N x N covariance matrix which is block diagonal:

$$var(y) = V = \begin{pmatrix} \mathbf{V}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{V}_2 & & \vdots \\ \vdots & & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \mathbf{0} & \mathbf{V}_m \end{pmatrix}$$

It is necessary to take the covariance structure of longitudinal data into consideration when selecting appropriate modelling techniques. Failing to do so may result in imprecise estimates of the regression coefficients and incorrect inference.

When selecting the appropriate method of analysis it is also important to consider the aims of the research and the questions that are being answered. For example, whether the inferential focus is on the mean response over time, and how this varies with the explanatory covariates, or on the individual, possibly with an emphasis on prediction. In both of these cases, however, the covariance structure of the data must be accounted for although it is of no analytical interest.

Conversely, the focus of the analysis may be the covariance structure itself, e.g. the relationship of an observation at a given time point to one at a previous time point. In this case, it would be necessary to model the covariance structure of the data in addition to the mean.

Finally, some types of model are better suited to specific data structures. Factors to consider when selecting a model includes:

1) Whether the observations are balanced or unbalanced.

   For example in balanced data, in general

   $t_{1j} = t_{2j} = t_{3j} = \cdots = t_{mj} = t_j$.

   The time of observation j for individual i is equal to the time of the corresponding observation for all other subjects, i.e. the time of the first observation for the first subject is the same as the time of the first observation for all other subjects.

   Also

   $t_{12}\text{-}t_{11} = t_{13}\text{-}t_{12} = t_{22}\text{-}t_{21}$.

   The difference in time between any two successive observations is equal to the difference between any other two successive observations for that for that individual or for any other individual. Also the number of observations for a given subject equals the number of observations for all subjects; there are thus no missing observations.

   In unbalanced data, the time of the observations are not equal across subjects and observations may be missing, either intermittently or as a result of drop-out.

2) Ratio of subjects to the number of observations per subject.

   A long time sequence of observations may be recorded for a small number of subjects or a small number of observations may be recorded for a large number of subjects. This has an impact on different procedures used to estimate the covariance matrix and thus may render one method more suitable than another (Diggle et al., 1994).

5.5 Methods of Exploratory Analysis for Longitudinal Data

A simple method of exploring the outcome variable in relation to time is by use of a scatter plot. Whilst this is easy to construct and to read, it captures only the cross-sectional aspect of the data, and hence cohort effects cannot be distinguished from time or age effects. By linking the time points for each individual, however, the sequence of observations for subjects can be compared. Where the number of subjects is large, selecting a few cases for representation may enhance clarity.

An alternative exploratory method is to construct a smooth line representing the mean of the observations over time. Examples include the kernel, spline and lowess smooth curves (for a brief description of these methods see Diggle et al., (1994), or for a more detailed description see Hastie and Tibshirani, 1990). The lowess method is adopted for this analysis and uses ordinary least squares regression to fit a line to the data in a 'moving time frame'. Greater weight is given to observations close to the center of the window and for each time frame an iterative process is carried out in which the values with large residuals are progressively down-weighted. The method is, thus, fairly accurate and robust to outlying observations. By using the lowess curve, comparison can be made between the mean measurements over time for different categories of a covariate. The mean weight change of infants over the first year of life, for example, can be compared by previous birth interval.

The covariance structure of the data can be explored by one of two methods.

1. For balanced data a correlation matrix can be calculated to show the association of the outcome variable at two different points in time. This method can also be used for unbalanced data if the time points are rounded to equal intervals.

   The data are considered stationary if the absolute time of the observations is not important in determining the correlation between observations of a given time lag. For example, the correlation between weights taken at age one month and two months would be the same as the correlation in weights taken at age five months and six months. Assuming stationarity, autocorrelation can be estimated by pooling the correlation coefficients of the same time lag. In many analyses, however, one might expect the correlation to decrease in strength with increasing time.

2. The sample variogram (described below) is perhaps a preferable method for unbalanced data as it does not require evenly spaced observations. Parametric methods are used to estimate the correlation structure.

5.6 Models for Longitudinal Data

The different types of model for longitudinal data are outlined in this section, together with their specific applications. These include the "Derived Variables Model" which analyses change in the outcome variable, "Marginal Models" which analyse the average outcome over time, "Multilevel Models" which are concerned with the individual outcome over time and "Transitional Models" which regress an individual response conditional upon previous outcomes.

5.6.1 Regression Models Using Derived Variables

One method of modelling longitudinal data is to compute a summary variable from the repeated measurements and to carry out a cross-sectional analysis. For example, the weight gain between age one month and three months may be used as the outcome variable.

Although this method has the advantage that it is easy to use, it is inefficient and has limited use. First, data are lost by summarising the repeated measurements in this way. Second, as replication is assumed to be independent it is only suitable for use with balanced data. Finally, by reducing it to a cross-sectional analysis the outcome variable can only be regressed on time constant covariates. The method is, therefore, of limited use when time varying covariates are important in explaining the outcome (Diggle et al., 1994).

5.6.2 Models of the Marginal Mean

The mean response is estimated for a hypothetical individual who has a set of given values for the explanatory covariates. The linear model is the basis for most longitudinal analyses with a continuous outcome:

$$y_{ij} = \beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij} + e_{ij}$$

$= \boldsymbol{x}_{ij}^{T}\boldsymbol{\beta} + e_{ij},$

where y_{ij} is the response for individual i at a time j point and $\boldsymbol{\beta} = (\beta_0, \beta_1, \ldots, \beta_p)^{\mathrm{T}}$ is a vector of length p of unknown regression coefficients. e_{ij} is a zero-mean random variable, which represents the deviation of the response from the model prediction, $\boldsymbol{x}_{ij}^{T}\boldsymbol{\beta}$.

The linear model for the full series of observations for an individual is represented by

$y_i = X_i\boldsymbol{\beta} + \boldsymbol{e}_i$

where $\boldsymbol{e}_i$ is a zero-mean random vector with elements e_{ij} which are correlated for each individual with covariance matrix

$var(\boldsymbol{e}_i) = V_i$.

The linear model for the entire data is expressed as

$y = X\boldsymbol{\beta} + \boldsymbol{e}$

where the covariance matrix of $\boldsymbol{e}$ is the block diagonal matrix

$\boldsymbol{Var\ (e) = V}$.

For longitudinal data, in order to model the outcome variable as a linear function of a series of explanatory variables it is necessary to use a technique which recognises the correlation structure of the data. There are two main methods of achieving this:

a) To use methods of inference which are robust to the specification of the covariance structure of the data.

b) To construct a parametric model of the covariance structure.

a) Non-parametric estimation of the covariance matrix

The premise of the robust ordinary least squares model is that estimation of the parameters in the regression equation is the focus of interest but the covariance structure of the data must be estimated in order to provide valid inference. The covariance matrix is thus estimated separately from the parameter estimates using non-parametric methods and based upon an assumed underlying structure. A weighting matrix corresponding to the estimated covariance matrix is then used for parameter estimation. The accuracy of the assumed underlying covariance structure is not crucial as valid inference may still be gained even if assumptions are incorrect. Efficiency of inference, however, is maximised the nearer the assumed covariance to the truth.

The estimated covariance matrix should be distinguished from the true covariance matrix and is thus termed the working covariance matrix denoted by W^{-1}. As the focus of the analysis concerns the relationship between the explanatory variables and the outcome, the specification of a relatively simple underlying form for the working covariance matrix (W^{-1}) is generally adequate. Confidence intervals and thus hypothesis tests will be asymtotically correct whatever the true from of V so only the efficiency of inference will be affected by a poor choice of W^{1} (Diggle et al., 1994).

The working structure of the covariance matrix may take one of several basic forms: The identity matrix is the simplest and assumes that the within subject observations are independent from one another. The covariance matrix for the individual, $\mathbf{y}_i$, would thus be diagonal with the off diagonal elements equal to zero. The estimator for β would then be equivalent to the ordinary least squares estimator β. Alternatively the correlation may be uniform or constant and thus all the off diagonal elements of the matrix would have the same positive value. In this case the correlation between two observations would be the same regardless of the time lag separating them. The uniform correlation is represented by the working covariance

$W^{-1} = (1-\rho)I + \rho J,$

where ρ is the correlation between two observations of the same individual, I represents the n x n identity matrix and J the n x n matrix with all elements equal to 1.

The exponential structure is common to longitudinal data and is characterised by a decaying correlation with increasing time lag between observations. The exponential correlation may be represented by

$v_{jk} = \sigma^2 exp\ (-\phi|\ t_j - t_k|),$

where v_{jk} is the jk^{th} element of W^{-1} and, v_{jk} is the assumed covariance between Y_{ij}, Y_{ik}. The correlation between pairs of observations for the same individual decays towards zero as the time separation increases. The decay is faster the larger the value of ϕ.

A weighting matrix is then used in conjunction with the working covariance matrix for the least squares estimation of the parameters. The weighted least squares estimator can be defined by the equation

$$\tilde{\beta}_W = (X^T W X)^{-1} X^T W \boldsymbol{y}$$

which is derived through manipulation of the quadratic form $(\boldsymbol{y} - X\beta)^T W (\boldsymbol{y} - X\beta)$.

The robust estimated variance matrix is defined by the equation:

$$R_W = \{(X^T W X)^{-1} X^T W\} \hat{V} \{W X (X^T W X)^{-1}\}$$

V is the final matrix of residuals.

Inference starts with the general linear model for longitudinal data

$$\boldsymbol{y} \sim MVN(X\beta, \sigma^2 V).$$

In which $\boldsymbol{y}$ is a realisation of a multivariate Gaussian random vector, and $\sigma^2 V$ is the covariance structure of the data and proceed as if

$$\tilde{\beta}_W \sim MVN(\beta, R_W).$$

The robust estimation technique has the advantage that it is fairly simple to compute and is thought to be reasonably efficient, especially if a weighting matrix reflecting the empirical covariance structure is used. It can, however, be inefficient in some circumstances where the data suffers missing values. Also for an accurate non-parametric estimation of V, high replication is necessary as strength is gained across individuals. This requires a large number of subjects (*m*) in relation to the number of observations (*n*).

b) Parametric Models for Covariance Structure

An alternative method is to estimate the marginal mean using a parametric model to specify the covariance structure. These models can incorporate three sources of variation:

- Random effects. This arises from the innate characteristics of the individual, which may result in higher than average values for the response or conversely lower than average values.

- Serial correlation. The repeated measurements for an individual are correlated, and typically have a stronger correlation if they are close in time and weaker as they become further apart in time.
- Measurement error. Variation may occur when two observations are taken from the same subject at the same time period. This particularly occurs where measurements are either sensitive, or subjective in nature.

The model can be expressed as

$y_{ij} = \mu_{ij} + u_i + w_i(t_{ij}) + z_{ij}$

where

u_i = random variation for an individual,

$w_i(t_{ij})$ = the serial correlation,

and z_{ij} = measurement error.

Also

$\mu_{ij} = x_{ij}^T\beta = E(y_{ij})$

$u_i \sim N(0,v^2)$

$\{w_i(t) : t \in \mathbb{R}\}$ ~ independent copies of stationary Gaussian process with

$Cov\{w_i(t),w_i(s)\} = \sigma^2\rho(|t-s|)$

$z_{ij} \sim N(0, \tau^2)$.

The $\rho(|t-s|)$ is the autocorrelation function for $w_i(t)$. It is usual to specify this function as either exponential where $\rho(u)$=exp $(-\phi u)$ or gaussian where $\rho(u)$=exp $(-\phi u^2)$

ϕ represents the rapidity of the decay in correlation with the increase in time lag. With large values for ϕ the correlations at greater time separations decay rapidly to zero. (Diggle et al., 1994).

The sample variogram can be used to estimate initial values for the parameters of the random terms, i.e., v^2, σ^2, ϕ and τ^2. A saturated model for the mean response is fitted, using ordinary least squares regression, to obtain an estimate of β. The residuals

$r_{ij} = y_{ij} - \mathbf{x}_{ij}^T \tilde{\beta}$ are calculated. Then the variogram is the plot of the observed half-squared differences between pairs of residuals:

$v_{ijk} = .5(r_{ij} - r_{ik})^2$

against the corresponding time differences

$u_{ijk} = t_{ij} - t_{ik}$.

A smooth curve can then be fitted to the variogram.

Using the vaiogram the total variance can be divided into that corresponding to the random variation for the individual, the serial correlation and the measurement error. In notation Var $(e_{ij}) = \upsilon^2 + \sigma^2 + \tau^2$

where

v^2 provides an estimate of the individual random variation (random intercept).

σ^2 estimates the serial correlation and

τ^2 estimates the measurement error.

In addition the correlation function parameter, ϕ, can also be estimated.

After fitting the initial model, inference about β uses the approximation

$\hat{\beta} \sim MVN(\beta, \hat{R})$

where $\hat{R}=(X'\hat{V}^{-1}X)^{-1}$.

Although ordinary least squares is a useful method for the initial exploration of the covariance structure it does not take into account the serial correlation during estimation of β and thus is less appropriate for making inference.

Estimation of the parameters in the model is done by maximising the ordinary likelihood over the variance parameters $v^{2,}$ τ^2 and ϕ. Restricted maximum likelihood may be used to reduce bias in the estimators (See Diggle et al., 1994 for further detatils). The values $v^{2,}$ τ^2 and ϕ attained from the ordinary least squares model are used for initial specification of the random effect variance, the measurement error variance and the correlation function parameter (Smith et al., 1997).

This method, although technically sophisticated is highly efficient provided that the covariance structure is correctly specified. It also has the advantage of being suitable for use with data where replication is low (small m) and the number of observations on each subject is large (large n). It is essential, however, that the covariance structure is correctly specified in order to gain valid inference and hence the method is not robust to miss-specification of the covariance structure. Also it can only be used where the covariance structure is stationary.

5.6.3 Transition Models

For transition models the present response for an individual depends explicitly on previous responses. This correlation among the repeated observations, exists because the past values for that individual partially determine the outcome of the present observation. The model is formulated with both explanatory variables and the prior response as predictors of the present outcome. In notation the conditional expectation, $E(y_{ij}| y_{i(j-1)},\ldots,y_{i1},x_{ij})$, is thus regressed as an function of x_{ij} and $y_{i(j-1)},\ldots,y_{i1}$. This combines assumptions concerning the relationship between the dependant and explanatory covariates with the correlation among repeated observations into a single model.

A linear simple transition model with a continuous outcome may be represented by the equations

$$y_{ij} = \beta_0 + \beta_1 t_{ij} + e_{ij}$$

$$e_{ij} = \alpha e_{ij-1} + z_{ij}$$

where $\alpha = \exp(-\phi)$ and z are independent, zero mean random variables with variance σ^2.

The formulation can be expressed in a single equation as:

$$y_{ij} = \beta_0 + \beta_1 t_{ij} + \alpha (y_{ij-1} - \beta_0 - \beta_1 t_{i-1}) + z_{ij}$$

(Diggle et al., 1994).

The name transition model reflects the inherent focus of the analysis, which concerns the transition from a prior state to the present state. This model gains strength where a previous outcome is of direct and explicit relevance to the present outcome. For example, where the probability of suffering from a recent episode of diarrhoea is the outcome variable, episodes suffered at previous time points may be of direct relevance. The vicious circle of diarrhoea, malnutrition and increased susceptibility is well established (Van Vianen et al., 1989).

5.6.4 Multilevel Models for Repeated Measurements

Multilevel modelling techniques provide an alternative method for analysing data consisting of repeated measurements. Chapter 4 includes a description of multilevel models, this section will focus on the application of multilevel models for longitudinal data analysis.

Longitudinal data can be considered hierarchical in structure in that observations are nested within individuals. If the observations for individuals are thought of as a random sample from a distribution, then a random effects model may be considered to provide an appropriate description. The observations would thus be defined as level one units, and the subjects or individuals as level two units. Additional levels may also be included in the model where further hierarchical structures exist within the population.

The variance components model described in section 4.3.1 incorporates variation between subjects and is represented by the following equation:

$$y_{ij} = \beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij} + u_{0j} + e_{ij}. \qquad (1)$$

Contrary to the description of the previous models for longitudinal data, in this equation i refers to an observation, or measurement, and takes the value 1 to n. n is the number of observations per subject. j refers to the subject from whom a set of observations where recorded and takes the value 1 to J. J is the number of individuals within the sample. y_{ij} thus represents the i^{th} observation for the j^{th} individual.

$\beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij}$ forms the fixed part of the model. β_0 is the intercept and $\beta_1, \ldots, \beta_p$ a range of unknown regression coefficients for the corresponding covariates $x^{(1)}_{ij}, \ldots, x^{(p)}_{ij}$. $u_{0j} + e_{ij}$ forms the random part of the model. u_{0j} represents the deviation of the j^{th} individuals intercept from the overall intercept and e_{ij} is the departure of the observation from the j^{th} individuals intercept.

With the repeated observations of longitudinal data the time point t_{ij} associate with each observation is often important in explaining the variation in the dependant variable. Time, which often corresponds to the age of the individual, would thus be included as an explanatory variable. In this case the intercept would be the average outcome when time equals zero. The effect of time on the outcome variable is likely to be different between individuals owing to innate characteristics, which cannot be measured. The random coefficients model described in section 5.3.1 can be applied to allow the effect of time to vary between individuals. The model is represented by the equation

$$y_{ij} = \beta_0 + \beta_1 x^{(1)}_{ij} + \cdots + \beta_p x^{(p)}_{ij} + u_{0j} + x^{(1)}_{ij} u_{1j} + e_{ij}, \qquad (2)$$

where u_{1j} represents the deviation of the j^{th} individuals coefficient for the corresponding covariate $x^{(1)}_{ij,}$ from the overall coefficient, β_1.

The random effects model thus recognises the hierarchical structure of the data resulting from the natural heterogeneity among subjects in the regression coefficients. By incorporating variation at the subject level, multilevel models provide standard errors which are appropriate for the correlated observations within individuals. Furthermore, they provide some information concerning the distribution of unexplained variation between individuals and between observations across individuals.

Although a marginal interpretation can be attained, a particular strength of the multilevel model is in using the random effects to make inference about individuals and for prediction of an individuals' outcome. This is in contrast to the marginal models which describe the effect of explanatory variables on the population average.

Multilevel structures do not require balanced data to obtain efficient estimates. The models can be used for unbalanced data and where there are missing observations. However, with standard multilevel modelling techniques only one random parameter is used to assess the unexplained variability at the subject level. This clearly cannot capture more complicated structures frequently evident in serial correlation. To gain efficiency it would therefore be necessary to incorporate more structured covariance matrices.

5.7 Results of Exploratory Analysis

In the first section of this analysis the overall pattern of weight change experienced by the children in this sample is explored. This includes change in the rate of weight gain over the year, variation in weight gain between individuals and, in the wider context, comparison with a well-fed reference population.

Figure 5.1 shows the weight change of the children over the first year of life. Each line represents a single child's weight trajectory. The dotted lines join observations where there is missing data, i.e. more than a fifty day gap between observations. The graph shows that most children undergo a steep weight gain for the first three to four months of life, but in the later half of the year weight gain progresses at a much slower rate. At birth the weight measurements vary between 1.8 and 3.8 Kg. The variation between the children increases over time, however, and by the end of the first year the weight measurements range between approximately 5 and 10 Kgs. Much of this change in variation is likely to result from differences in height attainment.

Figure 5.2 shows weight change over the first year for a selected sample of infants. Selection was carried out to provide a sub-sample of infants with a wide range of weights at birth. The sub-sample thus consists of cases exhibiting birth weights closest to the following z scores (based upon the WHO reference population): -3.5, -3, -2.5, -2, -1.5, -1, -0.5, 0, 0.5, 1, 1.5, 2.

The graph shows tracking amongst the majority of weight curves, whereby individuals follow a weight gain trajectory according to their relative weight at birth. Those with a comparatively low birth weight, for example, tend to be comparatively light at later measurements and similarly, those with a high birth weight tend to be heavier at later measurements. There is one particular exception, however, whereby the child has a comparatively low birth weight, but maintains a higher than average weight gain over subsequent months.

In contrast to the pattern shown for the whole sample, the variation in weights between individuals in the sub-sample appear to remain fairly constant over time. This contrast is more evident if the selected sub-sample is compared to a random sub-sample (Figure 5.3). In the random sample the increasing variation in weight attainment is clearly

Figure 5.1

Infant Weight Change

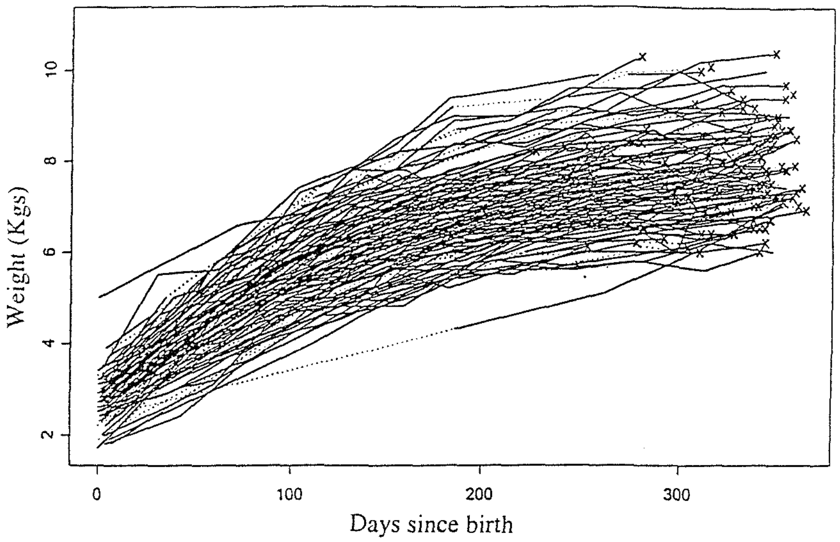


Figure 5.2

Infant Weight Change (Selected Sample)

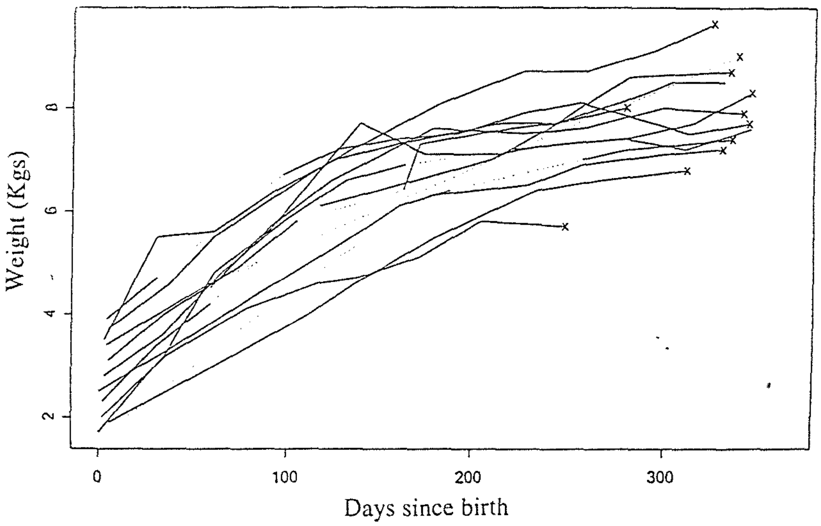
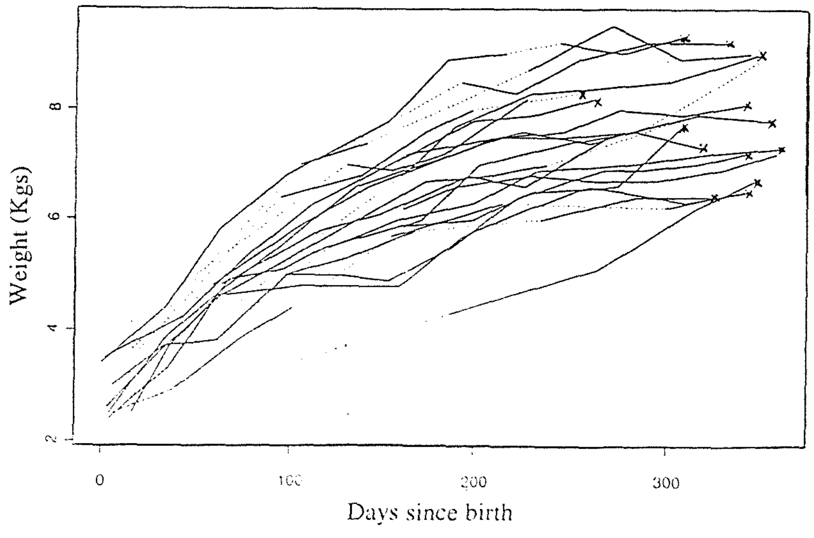


Figure 5.3

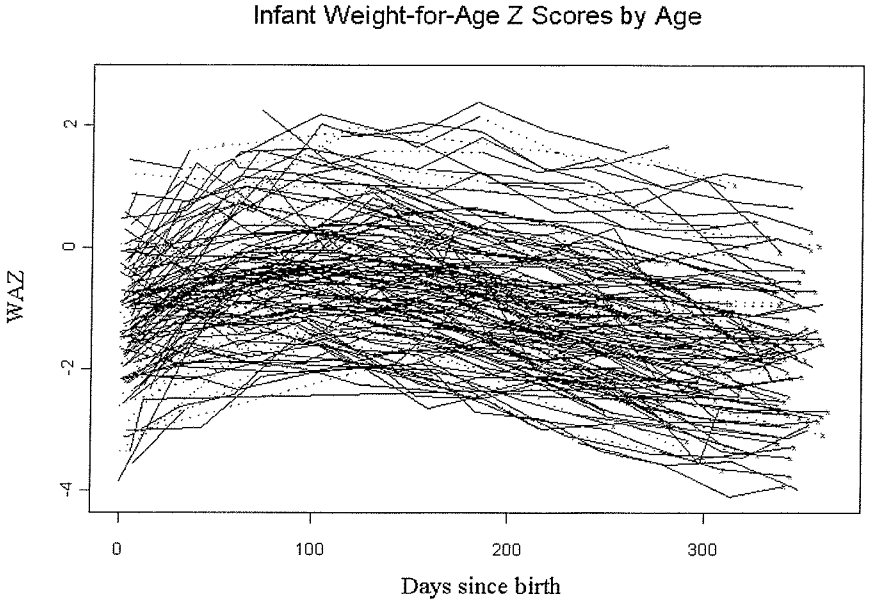
Infant Weight Change (Random Sample)



evident. Although the relative weight at birth, provides some indication of growth potential for an individual, other factors are also clearly important in determining the overall weight gain over the period of a year.

Figure 5.4 shows the weight measurements expressed as WAZ scores. Each line therefore represents the change in WAZ score for a child throughout the first year of life. The graph shows that the majority of children have WAZ scores below that of the reference population throughout the whole of the year. The WAZ scores at birth are particularly low with a substantial proportion of children exhibiting scores two standard deviations below that of the reference population. For many children this deficit decreases over the first three months but during the second half of the year all children show a steady decline in WAZ score. By the age of one year nearly all the children have scores below the median of the reference population and over a third have scores of –2 or less. According to the WHO Global Database on Child Growth and Malnutrition these children would be classified as having moderate to severe under-nutrition.

Figure 5.4



In summary the children undergo a fairly steep weight gain in the first four months of life, after which the rate of weight gain slows considerably. When compared to a reference population the weights of the sample children fall increasingly behind those of the reference population in the second half of the year. There are clearly circumstances during later infancy, which cause the children to thrive less well.

Although to a certain extent infants appear to follow a weight gain trajectory according to their weight at birth (Figure 5.2), there is evidence that other factors have a considerable influence in the rate of weight gain over the year (Figure 5.3).

5.7.1 Demographic and Socio-economic Influences of Infant Weight Change

"Too many, too close, too young" – this is considered risky reproductive behaviour putting both the mother and infant at increased risk of morbidity or mortality (NFHS India 1992-3). The lowess curves in Figure 5.5 show the mean weight change over the first year of life for infants following long and short birth intervals as well as first born infants. Of those children who have a previous sibling, those following short birth intervals demonstrate the lowest mean weight at all time points after the neonatal period. In particular their mean weight levels off considerably at around 7 months. Although first born infants show a lower mean weight for the first 9 to 10 months of the year, even than those following short birth intervals, they tend to maintain a higher rate of weight gain during the later part of the year. Although Figure 5.5 shows that the weights of the children increase over the year, Figure 5.6 demonstrates that it is not equivalent to that of the reference population. The WAZ scores show a clear decline during the second half of the year. The differences in weight change shown by the previous birth intervals are reflected in the change in WAZ scores, with the average for infants following short birth intervals demonstrating a steeper decline than that of other infants.

Lowess curves by the age and parity of the mother showed little effect on the birth weight or subsequent weight change of the infant. Parity was defined as including all previous reported pregnancies regardless of the outcome. If sibling rivalry is the casual mechanism in the relationship between short birth intervals and infant welfare then one might expect the number of siblings under five years of age within a family to influence the weight change of the infant. Also one might expect infants whose previous sibling survived to fare worse than those whose previous sibling died. Figure 5.7 and 5.8 indicate that those with other children under 5 years of age within in the family have a lower weight gain at the end of the year. This is particularly marked if there are two children under 5 years. No difference was evident, however, by the survival status of the previous sibling. It is possible that the effect is masked by shared

Figure 5.5

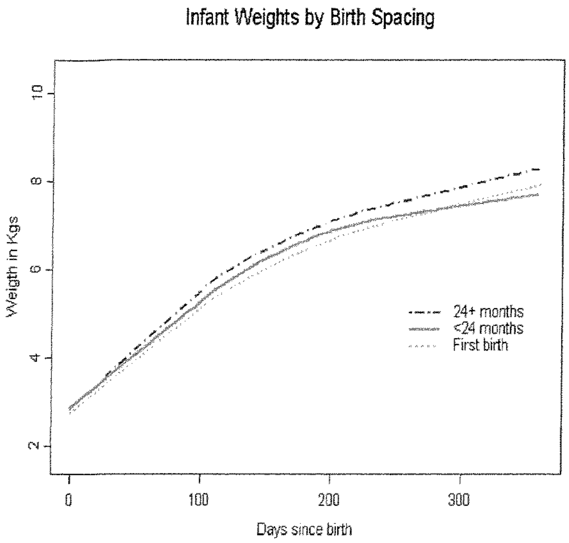


Figure 5.6

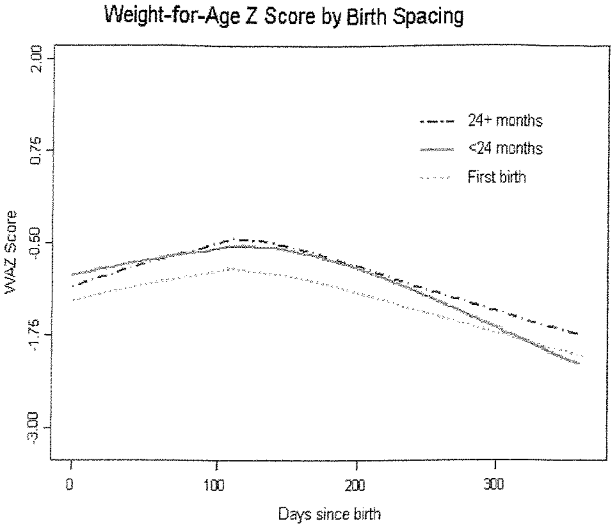


Figure 5.7

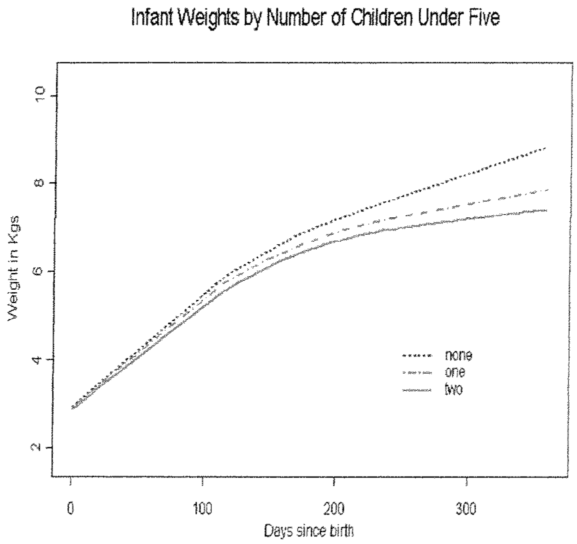


Figure 5.8

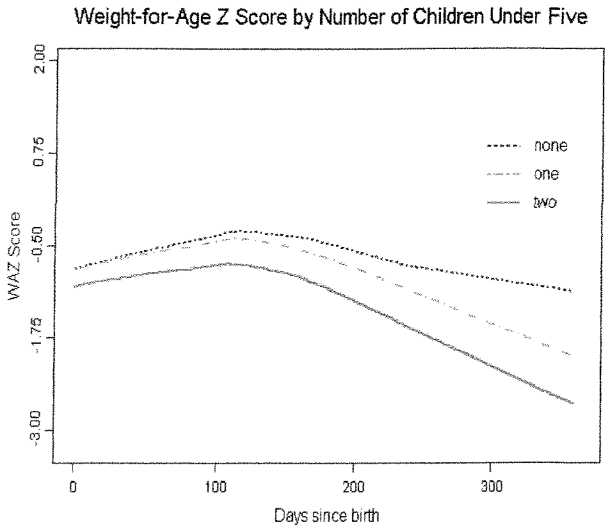


Figure 5.9

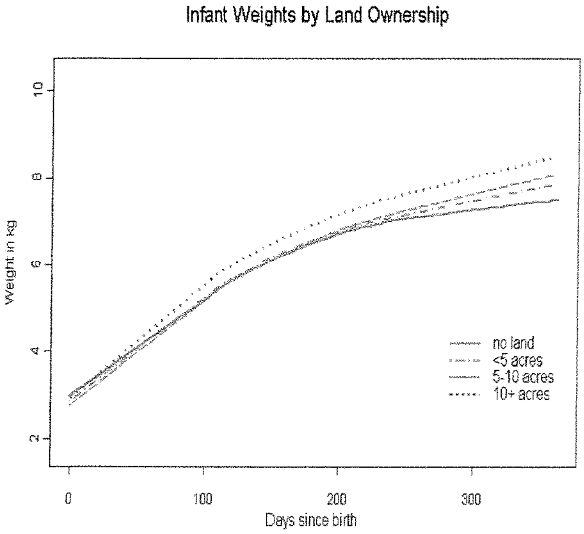
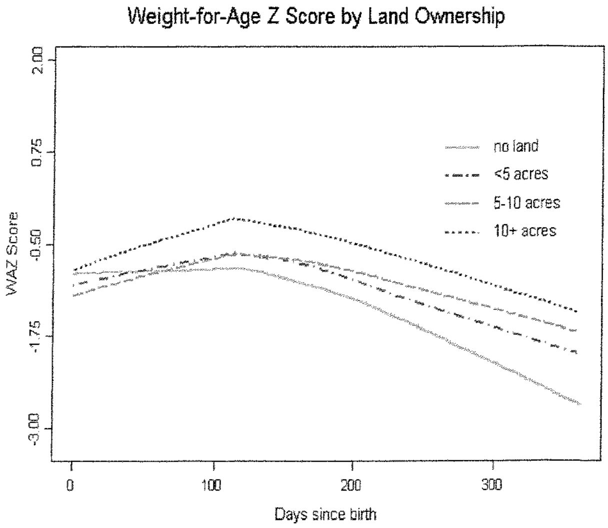


Figure 5.10



circumstances that are adverse to child welfare. The correlated risk of mortality between siblings has been well documented (Curtis, 1992).

The relationship between the economic wellbeing of the household and infant weight change was explored using proxy variables selected specifically to reflect the ability of the household to gain command over resources and of their status within society. Figure 5.9 shows the average infant weight gain for categories of land ownership. As expected those infants in larger land owning households fair better than those with smaller plots and the land-less. For all but the largest land owning category, the effect does not become evident until 6 to 7 months of age. By the end of the year, however, the mean weight is greater for each successive land owning category. When the average WAZ scores are compared this ordering is clearly evident from an early age (Figure 5.10). A similar pattern is also evident for the variable reflecting the value of possessions owned by the household.

Surprisingly, maternal education up to high-school level showed little effect on the weight gain of the infant. This is contrary to the findings of previous research, which has found a strong and consistent relationship between maternal education and infant welfare. Those who attained college or post-graduate education, however, do show some advantage. For this category the mean weight is greater at birth and weight gain is greater towards the end of the year.

In summary, the exploratory analysis suggests that the infants born after short birth intervals may have lower weight measurements towards the end of their first year compared to those following longer birth intervals. Of particular note is the levelling off of the rate of weight gain between the ages of seven and twelve months. There is little evidence that other factors related to reproductive behaviour have an adverse effect on infant weight change. The socio-economic wellbeing of the household in which the infant lives, does appear, however, to influence the weight gain of the infant during the first year of life. Although there is some effect in the early part of the year this pattern is most marked in the last six months. Contrary to expectation maternal education only appears to influence the weight gain of the infant if college or postgraduate level was attained. It is likely therefore that education below this level has little bearing on the status of women.

5.8 Preliminary Analysis and Model Development

This section outlines the selection procedure for the type of model used for this analysis and demonstrates why it is the most appropriate model for the particular data being analysed. First the selection of a cubic model of WAZ score by the age of the child is described.

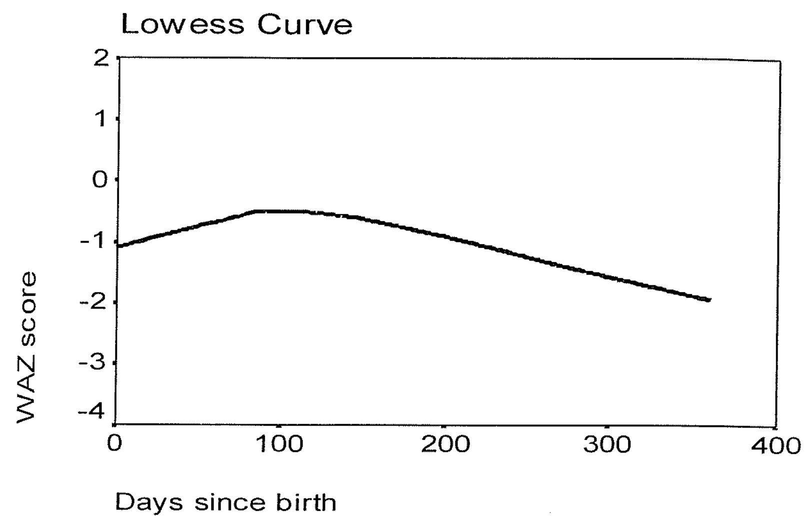
5.8.1 A Model of Weight-for-Age Z Score by Age of Child

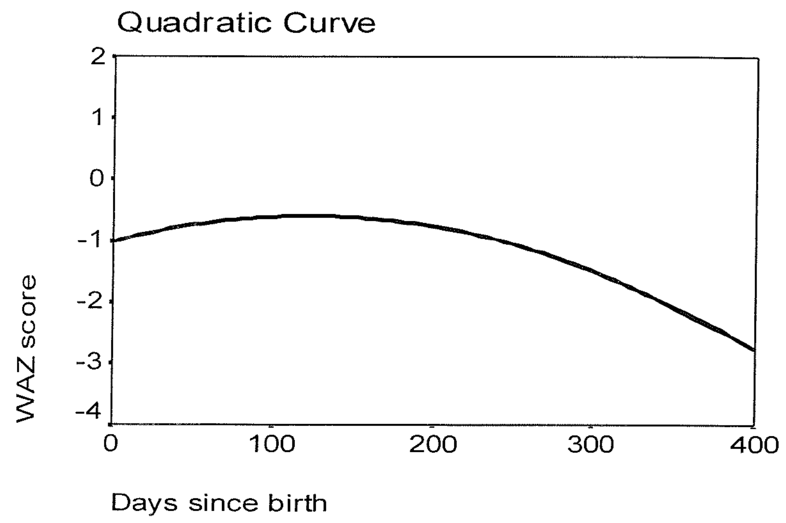
The WAZ scores are used for this analysis since the increasing variance of the weight measurements with the age of the child violates the assumption of constant variance inherent within the statistical modelling techniques. Figure 5.11 shows the WAZ scores by the age of the child with lowess, quadratic and cubic curves fitted to the data. As with the cross-sectional analysis it appears that a cubic model of WAZ scores by the age of the child, is closest to the average weights shown by the lowess curve. Table 5.1 shows the parameter estimates and standard errors for the cubic model, using ordinary least squares estimation. Age cubed is highly significant and thus age squared and age cubed are retained within the model. In contrast to the cross-sectional analysis Table 5.1 shows that the age of the child is positively associated with the WAZ scores but that age squared has a negative effect. This negative effect becomes dominant at around three to four months of age. Time cubed, however has a positive effect flattening the quadratic curve and slowing the decline in WAZ at the end of the year. A quartic term of WAZ score by age of child was added but found to be insignificant.

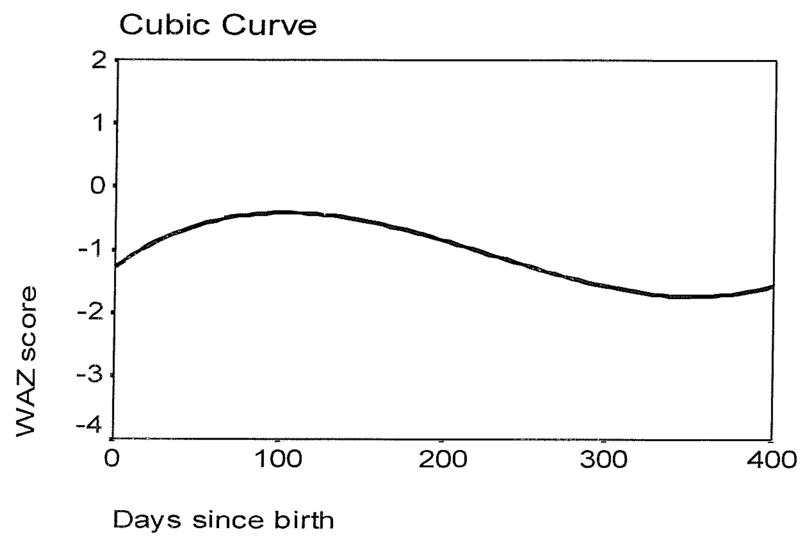
Table 5.1 Cubic Model of Weight-for-Age Z Scores by the Age of the Child Using Ordinary Least Squares Regression

Parameter	Estimate	Standard Error
Constant	-1.27042	0.07343
Age (in months)	0.55905	0.05963
Age squared	-0.10698	0.01267
Age cubed	0.04775	0.00074

Figure 5.11 Weight for Age Z Scores by Age of Child: Three Fitted Curves







5.8.2 Correlation Structure of the Data

As an exploratory analysis of the covariance structure, a correlation matrix was calculated using the residuals attained from a saturated, ordinary least squares regression model. The correlation matrix thus allows for the effect of the explanatory variables. Table 5.2 shows that there is a substantial positive correlation between the residuals where the time lag is small. For example the correlation between the residuals at months two and three is 0.54. As expected a decay in correlation is evident for increasing time lags.

The correlation between month two and twelve, for example, is only 0.1. Indeed the coefficients for large time lags are very small or even negative. They are not significantly different from zero and thus can be thought of as uncorrelated.

The absolute time of the observations is also important, the correlation becomes greater the older the child, even where the time lag between observations remains the same. For example whilst the correlation between residuals at months two and three is 0.54, the correlation between residuals at months ten and eleven is 0.77. This indicates that the data are not stationary.

Table 5.2 Correlation Matrix of Residuals

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1												
1	.44**	1											
2	.39	.49**	1										
3	.05	.42**	.54**	1									
4	.11	.31*	.56**	.72**	1								
5	-.16	.06	.34**	.64**	.73**	1							
6	-.05	.08	.08	.36**	.46**	.68**	1						
7	.05	.10	.13	.46**	.26*	.56**	.77**	1					
8	.07	.14	.33**	.44**	.44**	.64**	.79**	.84**	1				
9	-.11	-.13	-.03	.19	.32*	.48**	.58**	.69**	.76**	1			
10	-.16	-.12	.25	.31**	.14	.42**	.63**	.76**	.65**	.77**	1		
11	-.25	-.24	.05	.24	.09	.49**	.53**	.64**	.67**	.71**	.77**	1	
12	.19	.26	.10	-.06	.25	.34	.37	.58**	.42	.74**	.67**	.77**	1

** Significant at the 1% level
* Significant at the 5% level

In order to conduct this analysis it was necessary to round the time of the observations to the nearest month and thus some precision has been lost. A variogram is calculated to gain a more accurate representation of the covariance structure.

Figure 5.12 shows the variogram for the saturated model of infant WAZ scores. The time lag between the observations is represented by the x axis and the correlation (measured by the half squared differences in the residual) by the y axis. The line is a smoothed average of the correlation and thus represents the change in correlation as the time lag increases. The initially sharp decline in the variogram between lag 0 and 1 probably results from the small number of observations at lag 0. The delay in the rise of the variogram however indicates that a Guassian correlation function is most appropriate. The subsequent rise in the variogram is gradual indicating that the correlation is generally slow to decrease with increasing time lag between observations. Although the variogram starts to level off at lag 6 to 8 appearing to reach its asymptote, it then rises sharply. This rise again indicates that the correlation structure is not stationary. A parametric model for the covariance structure is likely to be very inefficient in this case.

A variogram was also calculated for the same model using the log of the weight measurements. This transformation is recommended by Diggle et al. (1994) where a parametric model of the covariance structure is used for non-stationary data. Figure 5.13 still demonstrates a continued rise in the variogram and thus it is concluded that a non-parametric assessment of the covariance is more appropriate.

5.8.3 Generalised Estimating Equations

Generalised estimating equations (GEE) can be used to perform non-parmetric estimation of the covariance structure as described in section 6.2 (a) above. The underlying format of the correlation structure is specified for the working covariance matrix, using one of the following assumptions.

- the repeated observations for the individual are independent from one another
- each pair of observations, within the series of observations for each individual, is considered to have the same correlation, irrespective of the time lag
- the variance matrix is unstructured , and every element is estimated

Figure 5.12

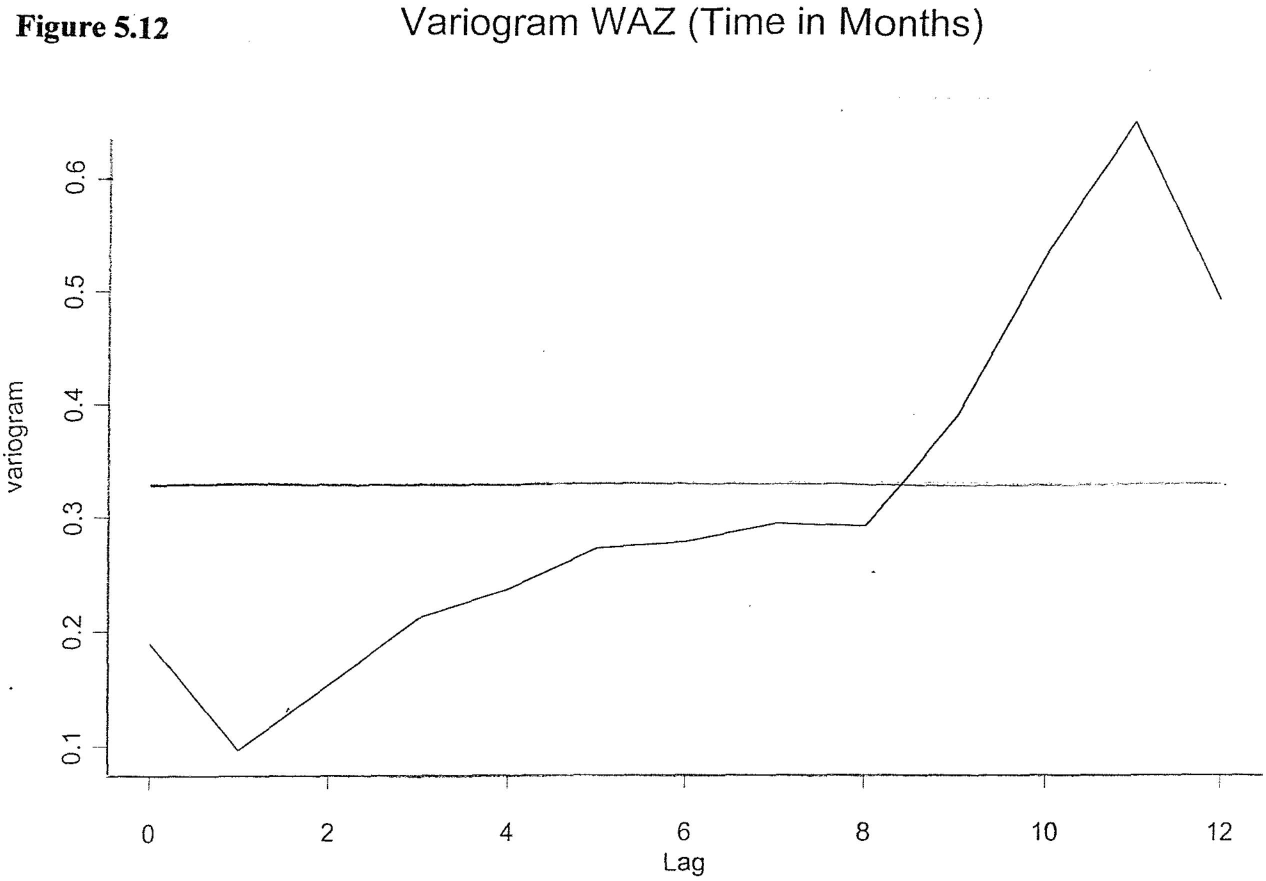
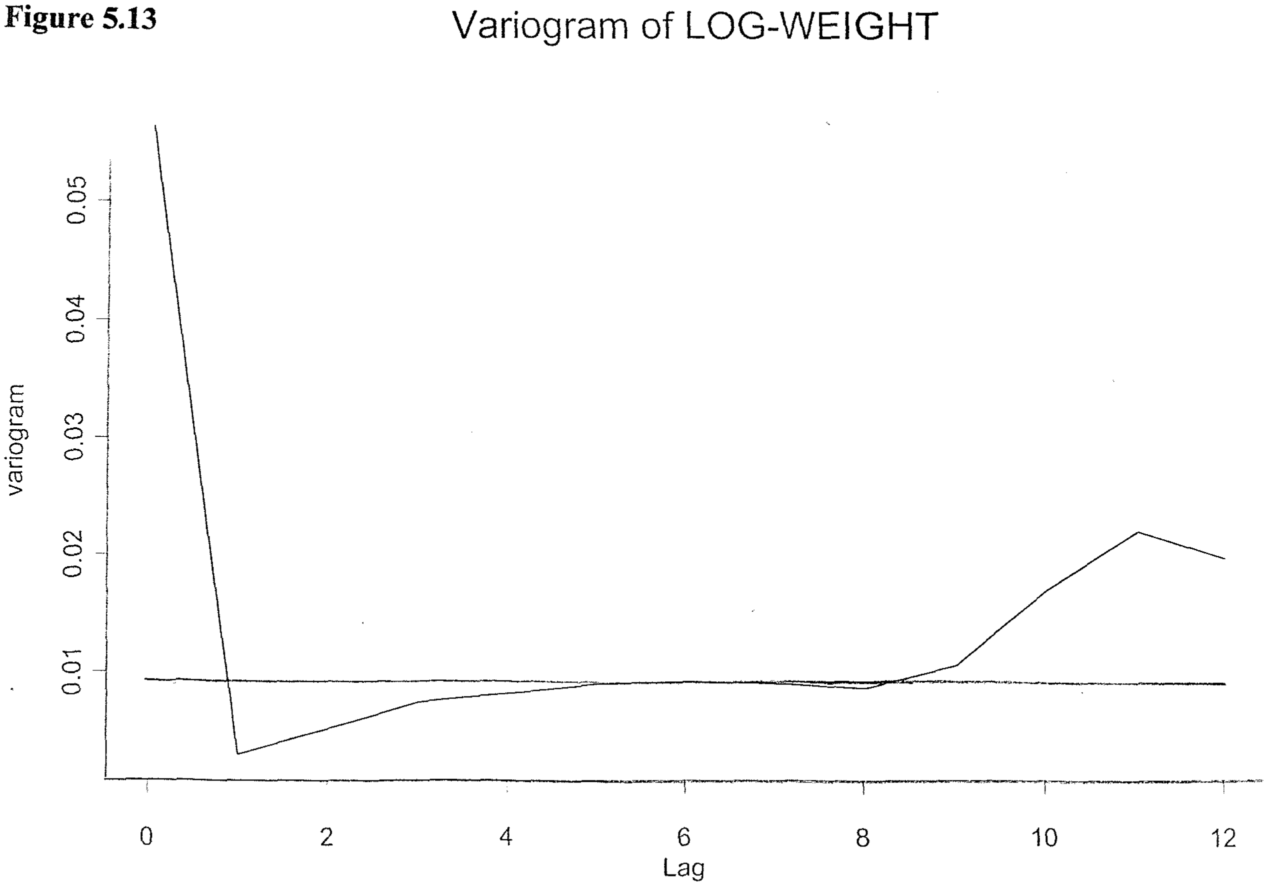


Figure 5.13



- the matrix is fixed at a user defined value
- each individual series of observations is considered to be stationary Markov process of degree M
- each time series is considered to be a non-stationary Markov process of degree M

(Smith et al., 1997).

GEE ignores the time component of the data, and therefore the observations before and after any intermittent missing values are considered adjacent. This can change the interpretation of the correlation matrix when the off-diagonal elements are not uniform. Dropout missing values, i.e. an incomplete sequence of values at the end, do not cause such problems. Caution is therefore required when using all but the independence or exchangeable methods if there are intermittently missing observations.

The aim of this analysis is to attain valid inference for the regression coefficients, it is not a priority therefore, to estimate a highly accurate covariance matrix. Although consistent parameter estimates and robust standard errors can be attained using all of the underlying structures described above it is worth spending time to select the most appropriate method in order to increase efficiency of inference.

The approach of this analysis is, in the first instance, to use the independence method for model selection using the cubic model of WAZ scores by the age of the child. This is virtually the same as a standard linear model, whereby all observations are considered independent. Robust standard errors are provided however, which are appropriate for the data, given the assumed correlation structure. The exchangeable method is then used and any improvement in efficiency assessed. The unstructured method has the potential to attain a more accurate covariance matrix but is likely to be distorted by the missing values.

Table 5.3 shows the parameter estimates, with both the naïve and robust standard errors that are appropriate if the underlying correlation structure is assumed to be independent. The naïve standard errors are those that would be attained from a standard linear model using ordinary least squares. The naïve z indicates the significance of the estimate ie a value of at least 1.96 for the 5% level and 2.57 for the 1% level. The robust standard error and robust z have been adjusted to account for the correlation of the residuals. If the naïve and robust z scores are compared it is apparent that for the main effects there is considerable reduction in the significance of the estimates. For the interactions either between the covariates and time or between the covariates themselves there is consistently an increase in significance.

Table 5.4 shows the same model when the exchangeable structure is assumed for the correlation. The parameter estimates and standard errors are thus appropriate where the correlation between each pair of observations for each individual is constant. The average correlation between observations is used for the working covariance matrix and thus for this model the off diagonal elements would be equal to 0.55. Again, the robust standard errors have been adjusted to account for the remaining correlation present in the residuals. The parameter estimates for this model vary slightly from those attained in the previous model but the difference is small, to a maximum of one decimal place. Although there is some fluctuation, overall the robust z scores are greater than those attained using independence. This indicates that there is an increase in efficiency using this underlying structure. The naïve and robust z scores for this model are much closer and although the naïve scores are generally greater than the robust scores, the direction does tend to fluctuate. The difference between the naïve and robust standard errors would be expected to be smaller, where the assumed underlying correlation structure is closer to the truth.

Finally, Table 5.5 shows the model when an unstructured covariance form is assumed. In this case each element of the working covariance matrix is estimated separately and is shown in Table 5.6. Again there is a minimal variation in the parameter estimates. The robust z scores attained from this model are generally smaller than those attained using the exchangeable method. This indicates that the model is less efficient possibly resulting from the intermittently missing observations. The working covariance matrix (Table 5.6) shows very low correlations between residuals at large time lags and fails to capture the much higher correlations at later time points which were evident in the exploratory analysis (Table 5.2). The exchangeable method is thus considered the most appropriate for use with this data.

Table 5.3 Selected Model Using Generalised Estimating Equations, with Independence as the Underlying Correlation Structure

	Estimate	Naïve S.E.	Naïve z	Robust S.E.	Robust z
(Intercept)	-0.8913	0.1253	-7.1156	0.1882	-4.7350
Time (Months since birth)					
Time	0.6854	0.0874	7.8451	0.1038	6.6010
Time squared	-0.1295	0.0186	-6.9536	0.0190	-6.8103
Time cubed	0.0058	0.0011	5.3785	0.0010	5.7463
Previous Birth Interval					
Short Birth Interval (< 24 mths)	0.1608	0.1910	0.8418	0.2160	0.7445
First Birth	-0.5899	0.1302	-4.5319	0.1861	-3.1694
Maternal Height					
(difference from average)	0.0473	0.0074	6.3635	0.0132	3.5786
Death of older siblings					
Two or more died	-0.1860	0.1153	-1.6132	0.1820	-1.0216
Season					
Summer (Mar - May)	-0.0347	0.0665	-0.5217	0.1318	-0.2633
SW Monsoon (Jun - Sept)	-0.4256	0.0670	-6.3524	0.1293	-3.2928
NE Monsoon (Oct - Dec)	-0.9667	0.0898	-10.7645	0.2194	-4.4054
Caste					
Lingayath	-0.0183	0.2497	-0.0733	0.2233	-0.0820
Madiga & Holeya	-0.0445	0.1590	-0.2799	0.1828	-0.2434
Others	0.5785	0.1759	3.2883	0.2049	2.8228
Lambani	1.0637	0.2889	3.6817	0.2758	3.8574
Paternal Education					
Primary (grades 1-5)	-0.1368	0.0669	-2.0454	0.1394	-0.9814
Middle (grades 6-8)	0.4515	0.0790	5.7189	0.1507	2.9971
High+ (grades 9+)	0.1352	0.0500	2.7052	0.1155	1.1713
Maternal Education					
Primary (grades 1-5)	-0.4422	0.0747	-5.9206	0.1552	-2.8497
Middle (grades 6-8)	-0.0602	0.0670	-0.8995	0.1606	-0.3751
High/college (grades 9-12)	0.2721	0.0603	4.5170	0.1560	1.7447
Maternal Primary Occupation					
Household work/ child care					
Agricultural work	-0.3144	0.2240	-1.4039	0.3814	-0.8244
Other	-0.0345	0.2393	-0.1441	0.1952	-0.1766
Interactions with Time					
Maternal height : Time	0.0030	0.0011	2.6735	0.0016	1.8422
Birth Spacing					
Short Birth Interval : Time	-0.3573	0.1420	-2.5171	0.1175	-3.0418
: Time squared	0.0743	0.0304	2.4469	0.0232	3.2067
: Time cubed	-0.0041	0.0018	-2.2842	0.0013	-3.2170
First Birth : Time	-0.1262	0.1046	-1.2065	0.1063	-1.1872
: Time squared	0.0265	0.0223	1.1924	0.0205	1.2971
: Time cubed	-0.0013	0.0013	-1.0193	0.0011	-1.1594
Maternal occupation					
Agricultural work : Time	0.1415	0.1740	0.8133	0.1442	0.9812
: Time squared	-0.0492	0.0362	-1.3598	0.0258	-1.9039
: Time cubed	0.0033	0.0021	1.5831	0.0014	2.3151
Other occupation : Time	-0.0905	0.1877	-0.4824	0.1441	-0.6281
: Time squared	0.0278	0.0393	0.7076	0.0328	0.8476
: Time cubed	-0.0018	0.0023	-0.8083	0.0019	-0.9473
Caste group					
Lingayath : Time	-0.1591	0.1918	-0.8292	0.1219	-1.3054
: Time squared	0.0463	0.0403	1.1481	0.0248	1.8645
: Time cubed	-0.0028	0.0023	-1.2010	0.0017	-1.6692
Madiga and Holya : Time	0.0215	0.1272	0.1690	0.1218	0.1764
: Time squared	-0.0111	0.0269	-0.4131	0.0247	-0.4500
: Time cubed	0.0006	0.0016	0.4141	0.0014	0.4756
Others : Time	-0.0598	0.1433	-0.4171	0.1241	-0.4817
: Time squared	0.0050	0.0309	0.1621	0.0242	0.2071
: Time cubed	-0.0001	0.0018	-0.0396	0.0014	-0.0536
Lambani : Time	-0.6094	0.2373	-2.5681	0.1617	-3.7690
: Time squared	0.1425	0.0518	2.7488	0.0302	4.7223
: Time cubed	-0.0085	0.0031	-2.7452	0.0016	-5.2813
Interactions between covariates					
SBI : Maternal height	-0.0557	0.0183	-3.0489	0.0227	-2.4486
SBI : Two siblings died	-0.7503	0.2075	-3.6154	0.2311	-3.2472
SBI : Maternal Education					
: Primary	0.4454	0.2208	2.0177	0.2025	2.1999

Table 5.4 Selected Model Using Generalised Estimating Equations, with Exchangeable as the Underlying Correlation Structure

	Estimate	Naive S.E.	Naive z	Robust S.E.	Robust z
(Intercept)	-0.9908	0.1809	-5.4758	0.1995	-4.9662
Time (Months since birth)					
Time	0.6952	0.0591	11.7645	0.1040	6.6848
Time squared	-0.1317	0.0126	-10.4431	0.0187	-7.0390
Time cubed	0.0061	0.0007	8.2446	0.0010	6.1869
Previous Birth Interval					
Short Birth Interval (< 24 mths)	0.2273	0.2507	0.9067	0.2267	1.0027
First Birth	-0.4576	0.1376	-3.3255	0.1897	-2.4118
Maternal Height					
(difference from average)	0.0488	0.0105	4.6499	0.0134	3.6330
Death of older siblings					
Two or more died	-0.1383	0.2415	-0.5728	0.1802	-0.7675
Season					
Summer (Mar - May)	-0.0459	0.1484	-0.3091	0.1374	-0.3337
SW Monsoon (Jun - Sept)	-0.4378	0.1494	-2.9309	0.1331	-3.2906
NE Monsoon (Oct - Dec)	-0.9925	0.1969	-5.0411	0.2199	-4.5129
Caste					
Lingayath	0.2238	0.2533	0.8834	0.3033	0.7378
Madiga & Holeya	-0.1117	0.1633	-0.6843	0.1821	-0.6136
Others	0.5762	0.1893	3.0443	0.2012	2.8631
Lambani	1.1252	0.3030	3.7131	0.2705	4.1593
Paternal Education					
Primary (grades 1-5)	-0.0926	0.1502	-0.6163	0.1314	-0.7043
Middle (grades 6-8)	0.4998	0.1827	2.7348	0.1400	3.5695
High+ (grades 9+)	0.1694	0.1134	1.4947	0.1192	1.4217
Maternal Education					
Primary (grades 1-5)	-0.4013	0.1652	-2.4295	0.1613	-2.4882
Middle (grades 6-8)	-0.0221	0.1507	-0.1465	0.1633	-0.1352
High/college (grades 9-12)	0.2779	0.1382	2.0109	0.1591	1.7474
Maternal Primary Occupation					
Household work/ child care					
Agricultural work	-0.4221	0.2172	-1.9430	0.3422	-1.2333
Other	0.0836	0.2378	0.3516	0.1976	0.4233
Interactions with Time					
Maternal height : Time	0.0029	0.0008	3.6962	0.0016	1.7962
Birth Spacing					
Short Birth Interval : Time	-0.3402	0.0962	-3.5354	0.1198	-2.8406
: Time squared	0.0695	0.0206	3.3722	0.0229	3.0344
: Time cubed	-0.0038	0.0012	-3.1748	0.0012	-3.1294
First Birth : Time	-0.1391	0.0708	-1.9638	0.1006	-1.3828
: Time squared	0.0256	0.0151	1.6951	0.0186	1.3793
: Time cubed	-0.0012	0.0009	-1.3684	0.0010	-1.2123
Maternal occupation					
Agricultural work : Time	0.2040	0.1180	1.7289	0.1431	1.4251
: Time squared	-0.0600	0.0246	-2.4374	0.0239	-2.5107
: Time cubed	0.0037	0.0014	2.6146	0.0012	3.0161
Other occupation : Time	-0.0649	0.1275	-0.5086	0.1172	-0.5534
: Time squared	0.0140	0.0268	0.5248	0.0252	0.5574
: Time cubed	-0.0007	0.0015	-0.4785	0.0015	-0.5025
Castergroup					
Lingayath : Time	-0.1759	0.1299	-1.3540	0.1382	-1.2728
: Time squared	0.0395	0.0273	1.4429	0.0233	1.6932
: Time cubed	-0.0022	0.0016	-1.3819	0.0012	-1.7597
Madiga and Holya : Time	-0.0045	0.0864	-0.0526	0.1103	-0.0412
: Time squared	0.0010	0.0183	0.0531	0.0220	0.0444
: Time cubed	-0.0002	0.0011	-0.2166	0.0012	-0.1921
Others : Time	-0.0366	0.0972	-0.3765	0.1189	-0.3076
: Time squared	0.0012	0.0210	0.0557	0.0232	0.0505
: Time cubed	0.0001	0.0013	0.0624	0.0013	0.0600
Lambani : Time	-0.6161	0.1615	-3.8136	0.1548	-3.9801
: Time squared	0.1438	0.0354	4.0569	0.0295	4.8750
: Time cubed	-0.0086	0.0021	-4.0349	0.0016	-5.4525
Interactions between covariates					
SBI : Maternal height	-0.0666	0.0416	-1.5999	0.0233	-2.8638
SBI : Two siblings died	-0.7191	0.4279	-1.6806	0.2602	-2.7632
SBI : Maternal Education					
: Primary	0.3794	0.4708	0.8059	0.2219	1.7095
: Middle	0.1356	0.3672	0.3694	0.2537	0.5346

Table 5.5 Selected Model Using Generalised Estimating Equations, with Unstructured Underlying Correlation Structure

	Estimate	Naive S.E.	Naive z	Robust S.E.	Robust z
(Intercept)	-0.9733	0.1608	-6.0545	0.1896	-5.1338
Time (Months since birth)					
Time	0.6625	0.0630	10.5236	0.0920	7.2004
Time squared	-0.1236	0.0138	-8.9271	0.0174	-7.1103
Time cubed	0.0056	0.0008	6.7648	0.0009	5.8814
Previous Birth Interval					
Short Birth Interval (< 24 mths)	0.1260	0.2256	0.5586	0.2242	0.5623
First Birth	-0.6596	0.1345	-4.9043	0.1792	-3.6820
Maternal Height					
(difference from average)	0.0425	0.0111	3.8275	0.0125	3.4040
Death of older siblings					
Two or more died	-0.0720	0.2160	-0.3333	0.2216	-0.3248
Season					
Summer (Mar - May)	0.0022	0.1228	0.0181	0.1273	0.0174
SW Monsoon (Jun - Sept)	-0.3954	0.1237	-3.1964	0.1233	-3.2076
NE Monsoon (Oct - Dec)	-0.9170	0.1691	-5.4216	0.2112	-4.3422
Caste					
Lingayath	-0.0765	0.2491	-0.3073	0.2285	-0.3350
Madiga & Holeya	0.0327	0.1615	0.2023	0.2057	0.1588
Others	0.5812	0.1875	3.0989	0.1927	3.0157
Lambani	1.1212	0.2944	3.8079	0.3114	3.6010
Paternal Education					
Primary (grades 1-5)	-0.1730	0.1239	-1.3964	0.1387	-1.2479
Middle (grades 6-8)	0.4877	0.1470	3.3178	0.1422	3.4299
High+ (grades 9+)	0.1471	0.0935	1.5730	0.1118	1.3153
Maternal Education					
Primary (grades 1-5)	-0.4473	0.1386	-3.2281	0.1439	-3.0091
Middle (grades 6-8)	-0.0781	0.1253	-0.6232	0.1558	-0.6330
High/college (grades 9-12)	0.3053	0.1120	2.7252	0.1546	2.7052
Maternal Primary Occupation					
Household work/ child care					
Agricultural work	-0.4958	0.2221	-2.2326	0.3218	-2.0411
Other	-0.0031	0.2352	-0.0133	0.2269	-0.0031
Interactions with Time					
Maternal height : Time	0.0020	0.0006	2.6061	0.0018	2.4001
Birth Spacing					
Short Birth Interval : Time	-0.2750	0.1056	-2.6043	0.1152	-2.3880
: Time squared	0.0546	0.0229	2.3830	0.0217	2.5175
: Time cubed	-0.0030	0.0014	-2.1810	0.0012	-2.5850
First Birth : Time	-0.0224	0.0784	-0.2856	0.1016	-0.2205
: Time squared	0.0056	0.0170	0.3282	0.0192	0.2912
: Time cubed	-0.0002	0.0010	-0.2308	0.0010	-0.2241
Maternal occupation					
Agricultural work : Time	0.2911	0.1285	2.2656	0.1634	1.7819
: Time squared	-0.0707	0.0270	-2.6166	0.0294	-2.4073
: Time cubed	0.0041	0.0016	2.6214	0.0016	2.6346
Other occupation : Time	-0.0304	0.1384	-0.2197	0.1281	-0.2372
: Time squared	0.0123	0.0297	0.4120	0.0287	0.4273
: Time cubed	-0.0009	0.0018	-0.5166	0.0017	-0.5453
Castergroup					
Lingayath : Time	-0.0023	0.1344	-0.0169	0.1418	-0.0160
: Time squared	0.0121	0.0291	0.4171	0.0219	0.5542
: Time cubed	-0.0009	0.0017	-0.5458	0.0011	-0.8315
Madiga and Holya : Time	-0.0955	0.0927	-1.0300	0.1290	-0.7401
: Time squared	0.0154	0.0200	0.7698	0.0250	0.6168
: Time cubed	-0.0009	0.0012	-0.7488	0.0013	-0.6635
Others : Time	-0.0545	0.1119	-0.4870	0.1124	-0.4851
: Time squared	0.0033	0.0242	0.1355	0.0222	0.1479
: Time cubed	0.0000	0.0015	0.0034	0.0012	0.0040
Lambani : Time	-0.6785	0.1718	-3.9502	0.1508	-4.4993
: Time squared	0.1517	0.0392	3.8673	0.0280	5.4120
: Time cubed	-0.0089	0.0024	-3.6601	0.0014	-6.1475
Maternal Height : Time	0.0029	0.0013	2.2512	0.0015	1.9780
Interactions between covariates					
SBI : Maternal height	-0.0563	0.0342	-1.6457	0.0233	-2.4137
SBI : Two siblings died	-0.7301	0.3740	-1.9521	0.2652	-2.7536
SBI : Maternal Education					

Table 5.6 Working Covariance Matrix Using the Unstructured Method

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2	.74	1										
3	.43	.65	1									
4	.35	.54	.72	1								
5	.32	.45	.68	.77	1							
6	.32	.37	.56	.63	.77	1						
7	.16	.22	.40	.48	.59	.64	1					
8	.17	.19	.35	.41	.46	.50	.53	1				
9	.04	.04	.17	.22	.29	.32	.35	.33	1			
10	.02	.04	.08	.13	.17	.19	.20	.20	.26	1		
11	.04	.06	.05	.09	.10	.10	.09	.09	.10	.10	1	
12	.02	.04	.02	.04	.04	.05	.05	.04	.04	.04	.04	1

5.9 Results

Table 5.7 shows the significant parameter estimates and the robust standard errors for the model of infant WAZ scores. A significant association was found between the length of the previous birth interval and the WAZ scores of the infant. The interaction between short birth intervals and time cubed was also significant, indicating that the effect of a short birth interval varies with the age of the child during the year. To illustrate this, Figure 5.14 compares the estimated WAZ scores over time, for infants following both long and short previous birth intervals. The estimates are attained, holding all other variables within the model at their average values. The effect of age within the relationship between birth spacing and infant WAZ sores is thus given, net of all confounding factors.

The weights at birth were shown to be approximately one standard deviation below the reference population for both groups. Those following birth intervals greater than two years, however, showed a fairly steep increase during the first three months such, that the weights were equivalent to the median for the reference population at age three to four months. The estimated WAZ score is shown to decline quite steeply, however, between the ages of four and ten months before leveling off at just over 1.5 standard deviations below the reference median.

Table 5.7 Parameter Estimates and Standard Errors for Model of Weight-for-Age Z Scores Using Generalised Estimating Equations

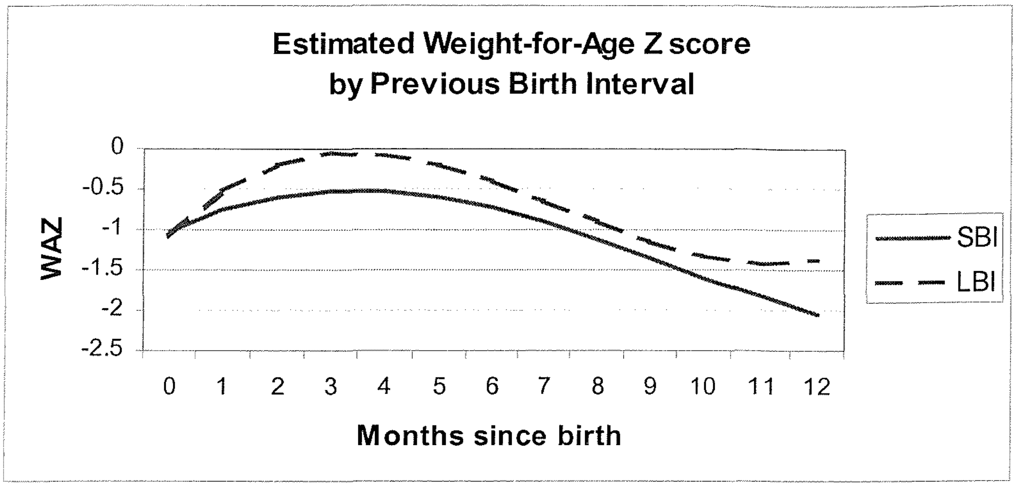
Parameter	Estimate	Robust S.E.
(Intercept)**	-0.991	0.200
Time (Months since birth)		
Time**	0.695	0.104
Time squared**	-0.132	0.019
Time cubed**	0.006	0.001
Previous Birth Interval		
Long Birth Intervals (24 mths or more)	Ref	
Short Birth Interval (< 24 mths)	0.227	0.227
First Birth*	-0.458	0.190
Maternal Height		
(difference from average)**	0.049	0.013
Death of older siblings		
None or one died	Ref	
Two or more died	-0.138	0.180
Season		
Winter (Jan-Feb)	Ref	
Summer (Mar - May)	-0.046	0.137
SW Monsoon (Jun - Sept)**	-0.438	0.133
NE Monsoon (Oct - Dec)**	-0.992	0.220
Caste		
Gowda	Ref	
Lingayath	0.224	0.303
Madiga & Holeya	-0.112	0.182
Others**	0.576	0.201
Lambani**	1.125	0.271
Paternal Education		
Uneducated	Ref	
Primary (grades 1-5)	-0.093	0.131
Middle (grades 6-8)**	0.500	0.140
High+ (grades 9+)	0.169	0.119
Maternal Education		
Uneducated	Ref	
Primary (grades 1-5)*	-0.401	0.161
Middle (grades 6-8)	-0.022	0.163
High/college (grades 9-12)	0.278	0.159
Maternal Primary Occupation		
Household work/ child care	Ref	
Agricultural work	0.084	0.198
Other	-0.422	0.342

Table 5.7 Continued

Parameter		Estimate	Robust S.E.
Interactions with Time			
Maternal height	: Time*	0.003	0.002
Birth Spacing			
Short Birth Interval	: Time**	-0.340	0.120
	: Time squared**	0.069	0.023
	: Time cubed**	-0.004	0.001
First Birth	: Time	-0.139	0.101
	: Time squared	0.026	0.019
	: Time cubed	-0.001	0.001
Maternal occupation			
Agricultural work	: Time	0.204	0.143
	: Time squared**	-0.060	0.024
	: Time cubed**	0.004	0.001
Other occupation	: Time	-0.065	0.117
	: Time squared	0.014	0.025
	: Time cubed	-0.001	0.001
Castergroup			
Lingayath	: Time	-0.176	0.138
	: Time squared	0.039	0.023
	: Time cubed*	-0.002	0.001
Madiga and Holya	: Time	-0.005	0.110
	: Time squared	0.001	0.022
	: Time cubed	0.000	0.001
Others	: Time	-0.037	0.119
	: Time squared	0.001	0.023
	: Time cubed	8E-05	1E-03
Lambani	: Time**	-0.616	0.155
	: Time squared**	0.144	0.030
	: Time cubed**	-0.009	0.002
Interactions between covariates			
Short birth interval	: Maternal height**	-0.067	0.023
Short birth interval	: Two siblings died**	-0.719	0.260
Short birth interval	: Maternal Education		
	: Primary	0.379	0.222
	: Middle	0.136	0.254
	: High	-0.653	0.265

* *significant at 5% level*
** *significant at 1% level*

Figure 5.14



Key SBI = Short birth interval LBI = Long birth interval

Figure 5.15

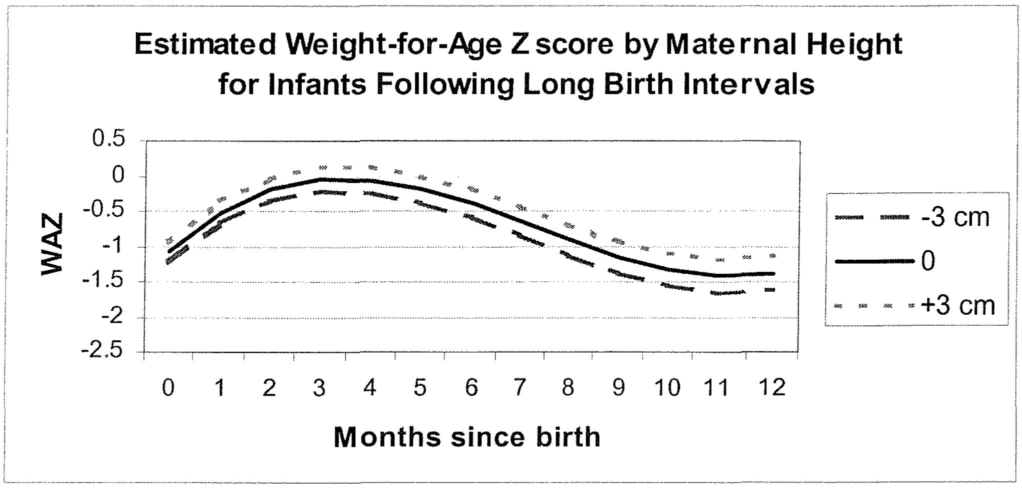
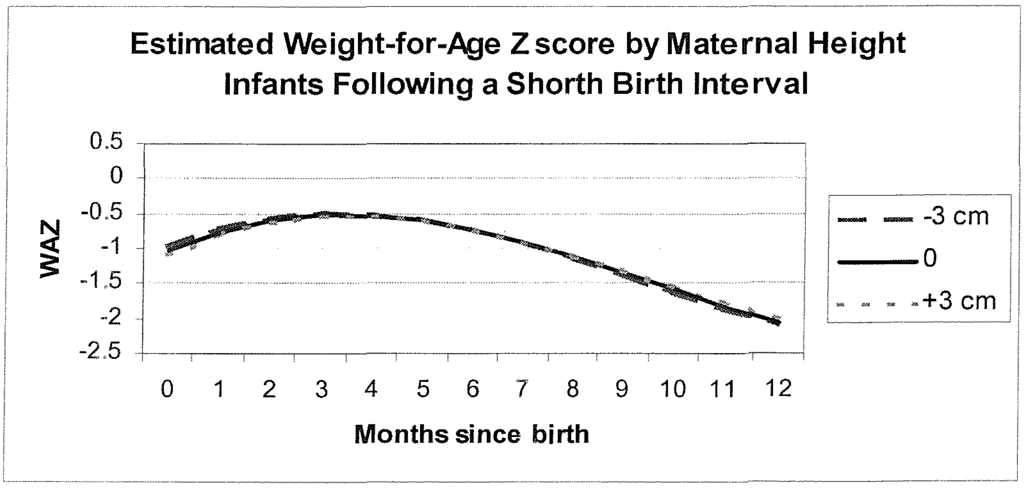


Figure 5.16



NB Maternal height measured as difference from average.

In contrast the estimated z scores of infants following a short birth interval showed a much smaller increase during the early part of the year so that the maximum estimated WAZ score at age three to four months was still 0.5 standard deviations below the reference population. During the second half of the year the WAZ score declined slightly less steeply, narrowing the gap between long and short birth intervals. At the end of the first year, however, the estimated WAZ score continued to decline for infants following short birth intervals reaching –2 standard deviations by month twelve.

Maternal height was also found to be significantly associated with the WAZ scores. At birth each centimeter increase in height (from the average) was associated with an increase in the WAZ score of the infant by 0.05 of a standard deviation. A significant positive interaction between maternal height and time was evident, indicating that the relationship increased in magnitude as the child became older. A negative interaction was also identified, however, between the effect of short birth intervals and maternal height. Figures 5.15 and 5.16 demonstrate the effect of maternal height for infants following both long and short birth intervals. Figure 5.16 shows that if the infant followed a short birth interval, maternal height had no influence on the WAZ score of the infant.

The model shows that the effect of a short birth interval also interacted with the survival status of older siblings. An infant who followed a previous birth interval of less than two years and had two or more siblings who had died, demonstrated a particularly low WAZ score. This difference was greater than would be expected given the independent effects of the two variables. Figures 5.17 and 5.18 show the estimated WAZ scores for infants by the survival status of older siblings and previous birth interval. Figure 5.17 shows that for infants following long birth intervals, the death of two or more siblings was associated with only a small and insignificant decrease in WAZ score, i.e. –0.14 standard deviations. For infants following short birth intervals the effect is much larger at –0.86 standard deviations (Figure 5.18).

The level of education received by the mother was also associated with WAZ scores and again interacts with short birth intervals. For infants following long birth intervals, maternal education at the primary level was negatively associated with WAZ scores.

Figure 5.17

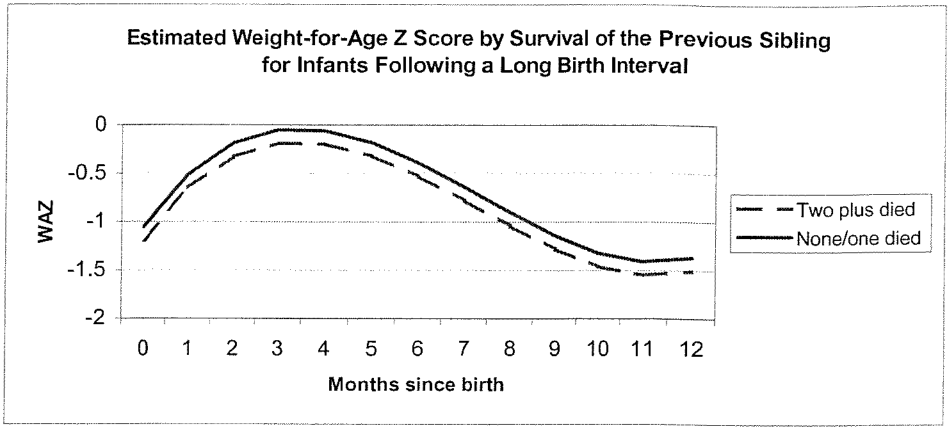


Figure 5.18

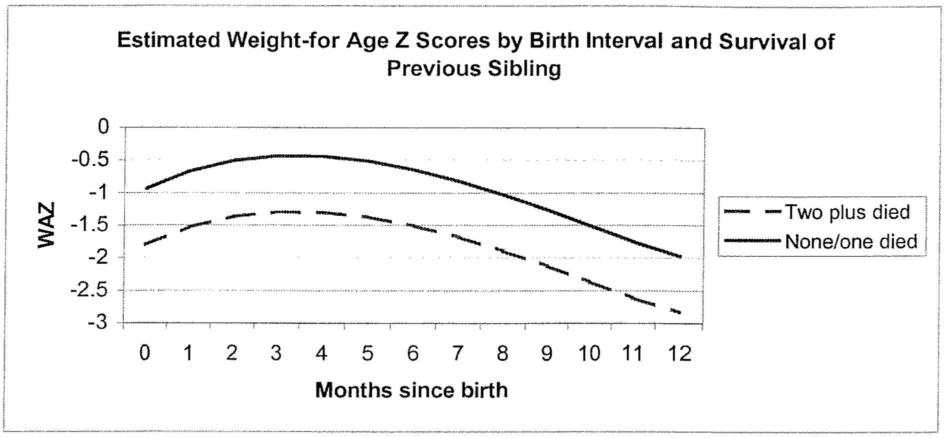


Figure 5.19

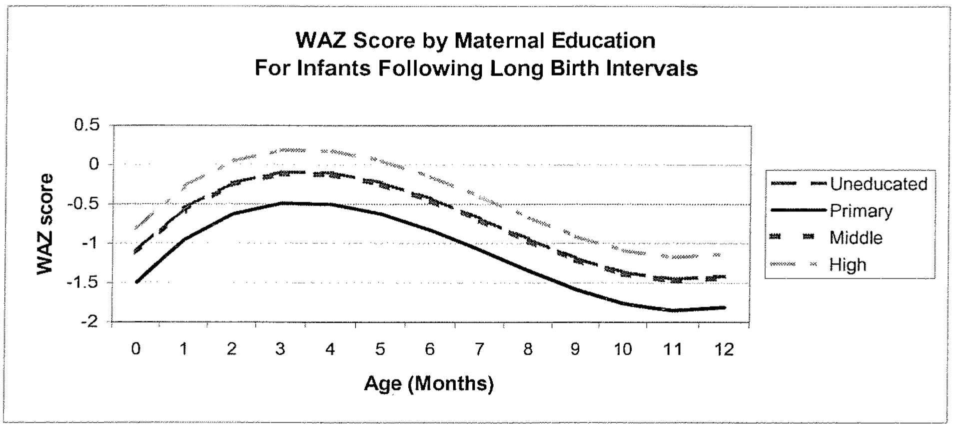


Figure 5.20

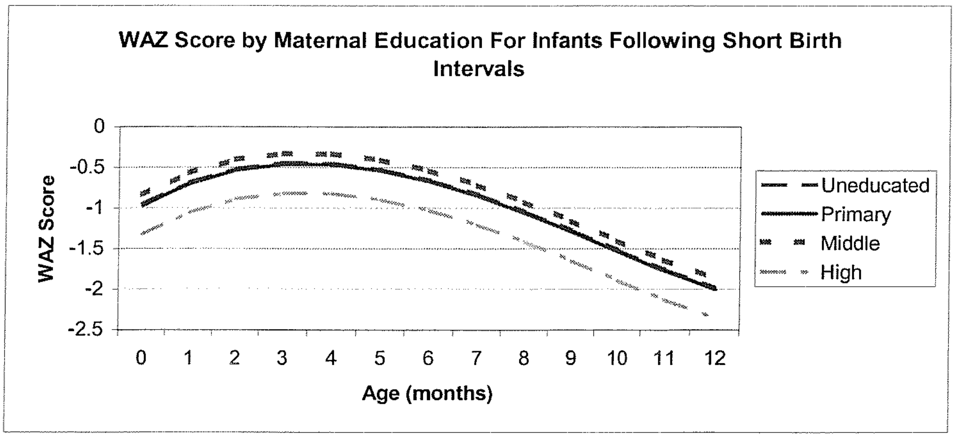


Table 5.7 shows that the average estimated WAZ score was 0.4 of a standard deviation lower than if the mother was uneducated and that this effect is constant throughout the year. Although maternal education at high school level demonstrates an association with higher WAZ scores, this effect is insignificant at the 5% level. Figure 5.19 demonstrates the effect of maternal education for infants following long birth intervals.

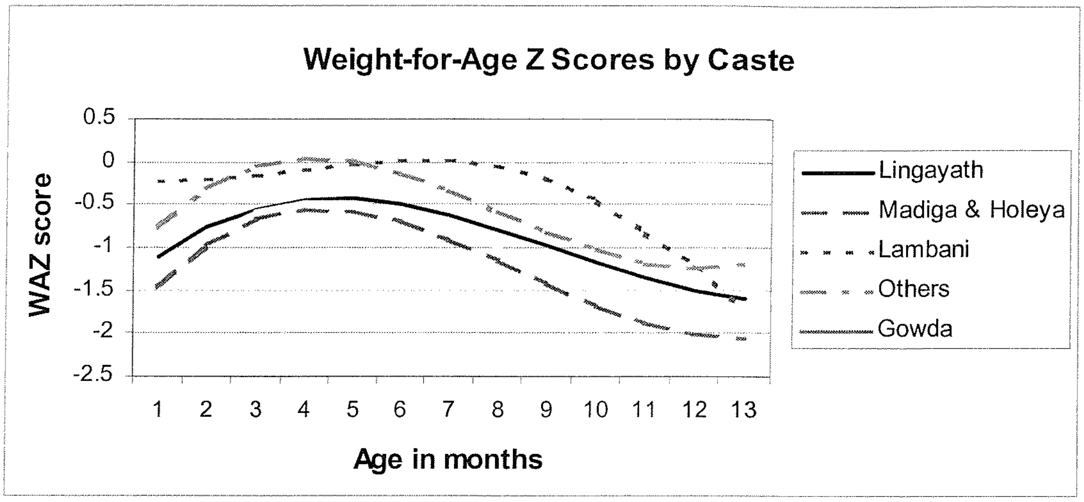
A relatively large positive interaction was evident between short birth intervals and maternal education at primary level, and a negative interaction between short birth intervals and maternal education at high school level. Figure 5.20 demonstrates that for infants following short birth intervals, there is little difference in the estimated WAZ scores by maternal education at primary, middle or uneducated levels. If, however, the mother received high school education the estimated WAZ score is shown to be significantly lower.

Other factors significantly associated with infant WAZ scores include first born infants, the season in which the infant was born, the caste of the head of household, paternal education and maternal occupation. First born children demonstrated low WAZ scores in comparison to infants who were of second or higher birth order, and who followed a birth interval of 2 years or more. Table 5.7 shows that the average WAZ score first born children was approximately 0.5 of a standard deviation lower, and that the effect was constant throughout the year.

Infants who were born in the monsoon seasons demonstrated lower WAZ scores than those born in the winter season (January and February). The effect of a birth during the NW monsoon (October and December) was particularly severe with the estimated WAZ score being one standard deviation below that of infants born during the winter. Birth during the SW monsoon was associated with a decrease in WAZ score of 0.4 of a standard deviation.

Infants of families belonging to the Lambani caste demonstrated a pattern of WAZ scores over the year that is particularly unique in comparison to the infants of families belonging to the other castes (Figure 5.21). At birth the estimated WAZ score of the Lambani infants were over one standard deviation higher than that of the Gowda infants (reference caste). Indeed the WAZ score at birth was considerably higher than that of all the other castes. The significant interactions with time, time squared and time cubed result in a pattern whereby a relatively high estimated WAZ score was maintained by the Lambani infants throughout the first nine months of the year. The WAZ scores decline sharply towards the end of the year however. This is a stark contrast to the estimates shown for the other castes whereby the decline in WAZ score occurs much earlier at approximately 4 months and is much less acute.

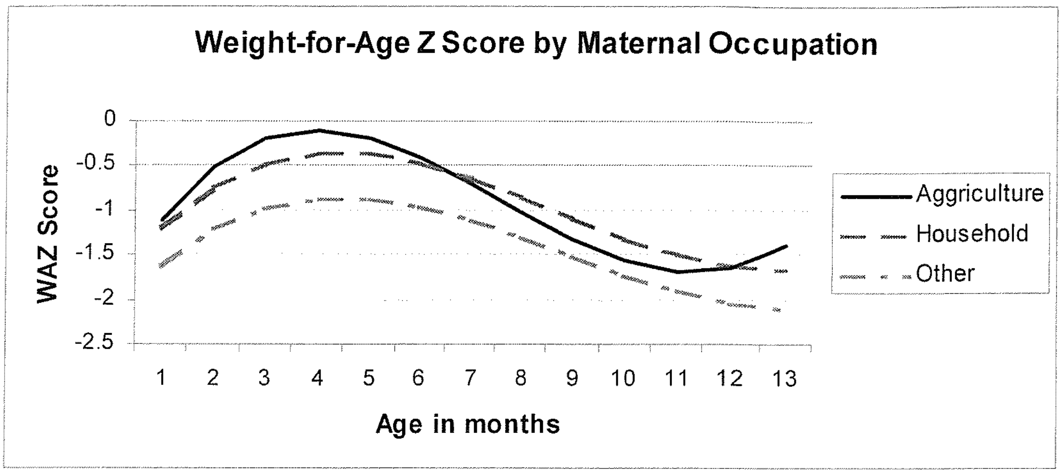
Figure 5.21



The estimated WAZ score of infants whose fathers received middle school education were significantly higher than infants of fathers who were uneducated (by 0.5 of a standard deviation). There was no interaction with time and thus the effect is constant throughout the year. The estimated WAZ scores of infants whose fathers received primary or high school education WAZ not significantly different from that of infants whose fathers are uneducated.

Finally, the change in WAZ score, over the year, was different for infants whose mothers undertook agricultural work as their primary occupation compared to infants whose mothers undertook household work. Although the WAZ scores at birth were similar, the estimated score of infants whose mothers undertook agricultural work showed an initial increase before the subsequent decline during the second half of the year. By the end of the year the WAZ scores had levelled off and begun to increase again. For infants whose mothers primarily undertook household work the increase in early infancy was much less marked and the subsequent decline less severe. These patterns of change in WAZ score are similar to those shown by the preceding birth interval. The change in WAZ score associated with agricultural employment, for example, is similar to that associated with long birth intervals and that associated with household occupation is similar to that associated with short birth intervals.

Figure 5.22



A number of variables were excluded from the model as they were not significantly associated with WAZ scores after controlling for the variables in the model. These included

- the premature delivery of the index child
- the gender of the index child
- maternal and paternal age
- the parity of the mother
- the village in which the infant resides
- variables representing the socio-economic status of the household (i.e. value of household possession, land and livestock ownership)
- the survival status of the previous sibling
- the number of children aged less than five years within the family
- the season in which the weight was recorded.

5.10 Discussion

5.10.1 Weight-for-Age Z score at Birth

The results show that, on average, the infants in these villages have low birth weights in comparison to the reference population (Figure 5.14). It is likely, therefore, that the weight gain of the infants is compromised during the fetal period as a result of a nutritionally poor intrauterine environment. (See discussion of racial differences in growth potential in section 2.4.1.) This reflects the inadequate nutritional intake of the mothers, the high energy expenditures required for daily activities, and possibly the incidence of morbidity. Also, fasting for short periods of time is a common practice amongst women in these rural villages, as it is in the rest of Karnataka, and this practise often continues during pregnancy. Also it is custom for women to deliberately reduce food intake during the last trimester, to influence the growth, or weight gain, of the infant. One reason commonly reported for this was a preference for small babies to promote easy delivery. Other women, however, reported that larger babies are healthier so it is necessary to reduce food intake during pregnancy so that there is room in the stomach for the baby to grow (Hutter, 1998). Any deliberate reduction in food intake is likely to exacerbate the nutritional disadvantage suffered by the infant.

5.10.2 Birth Interval Effects

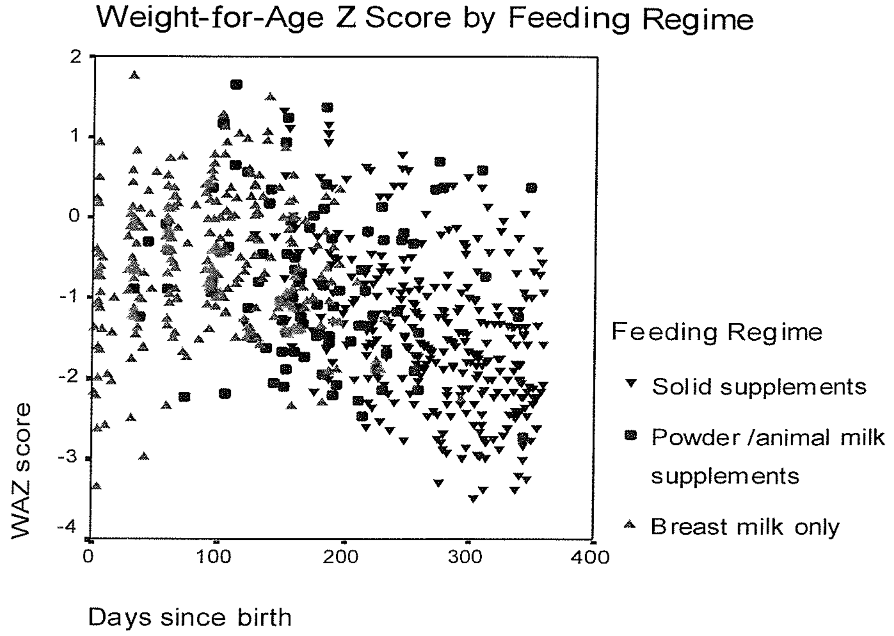
No difference was found between the WAZ scores at birth, of infants following short birth intervals compared to those following long birth intervals. This suggests that the prenatal conditions of these children were similar regardless of the length of the preceding birth interval. There is no evidence, therefore, that maternal depletion resulting from close birth spacing, affects the weight gain of the fetus. However, as these women are already likely to be under-nourished it is possible that their body has adopted compensatory mechanisms to maximise their nutritional status. Prentice and Prentice (1988) found that the maximum decrease in birth weight associated with maternal under-nourishment was 10%. They suggest that women of poor nutritional status adopt a number of physiological and behavioural strategies to meet the extra energy requirements of pregnancy. Fat reserves are mobilised, for example, and the metabolic rate is decreased.

For infants following long birth intervals the WAZ score increases sharply over the first three months indicating that the babies thrive during early infancy. Supplementary data concerning the breast-feeding behaviour of women in these villages shows that although occasional supplementary liquids or foods are given during this early period, breast-milk is the major source of nutrition for the infants. From around four to five months supplements in the form of powdered milk, animal milk and solid foods are introduced, and make a make a more substantial contribution to the overall diet. The benefits of breast-feeding during the first few months of life are widely documented as providing for the specific nutritional and digestive requirements of an infant, as well as providing antibodies to protect against infection (Jelliffe and Jelliffe, 1978 and Savage et al., 1992).

The first three to four months after delivery is characterised in rural south India by culturally prescribed practises. This period is termed "banathana" and the woman the "bananthi". Both mother and infant are thought to be vulnerable during bananthana and prone both natural and supernatural origins of disease. Traditional practises are thus adopted as protective measures. These include confinement to a warm dark room with access limited to immediate family or carers only, sponging or body bath for both mother and infant, complete rest with no work or household tasks, food intake restricted to bland food only and fluid restrictions. The whole house is cleansed and new pots brought during second half of first month postpartum marking the end of the ritual pollution period (Kilaru et al., 2000). The dietary and fluid restrictions are clearly not beneficial to the mother or infant at this time, however some women report that on their doctor's advice they have forgone this part of the tradition. The seclusion and enforced rest could well promote the nutritional wellbeing of the mother and allow her more time for her to attend to her babies needs. It is possible, therefore, that babies thrive during early infancy as a result of these traditional practises.

The decline in the WAZ scores of the infants during the second half of the year coincides with the introduction of milk and solid food supplements (Figure 5.22). The change in WAZ scores suggest that the dietary requirements of the children are not fully met during this period, either in terms of the type of foods given or the quantity. Although the production of breast-milk increases during the first six months post-partum in order to meet the requirements of the infant, it declines over in the second half of the year and thus appropriate supplementary feeding becomes important (Griffiths, 1998). Alternatively, the prevalence of morbidity may increase amongst children at this age, suppressing the appetite and possibly preventing the full utilisation of nutrients. The increased morbidity may result from contamination of foods or from utensils used for supplementary feeding. Previous research has demonstrated that the commencement of supplementary foods for infants is associated with an increased risk of morbidity, particularly from diarrhoeal disease (WHO, 1991). At the end of the year the WAZ scores level off for infants following long birth intervals. This may reflect the increased proportion of solid foods taken within the diet and the more mature digestive and immune systems of the infant.

Figure 5.22



In contrast, infants following short birth intervals thrive less well during early infancy indicating that breast-feeding is less successful. According to the maternal depletion hypothesis the quality or quantity of breast milk could be impaired as a result of the nutritional stress placed upon the mother following close reproductive cycles. Previous research has shown that certainly in cases of severe malnutrition, milk production is compromised (Jelliffe and Jelliffe, 1978). The extent to which maternal depletion resulting from short birth intervals is likely to affect lactation is debatable but nevertheless it is possible that there is some effect especially in communities where underlying nutritional levels are uniformly poor.

An alternative argument in keeping with the sibling rivalry hypothesis is that women who have a short birth interval behave differently in terms of breast-feeding practice, as a result of time pressures or a heavy workload. It is possible, for example, that they may be more likely to commence powdered or animal milk supplementation early so that other members of the family can share child care tasks more easily. Also women with other small children to care for may be less able to partake in the tradition of bananthana.

The decline in WAZ score during the second half of the year is initially much slower for infants following short birth intervals than for those following longer birth intervals. This may reflect their comparatively low WAZ scores at three to four months of age, before the onset of the decline. Weight loss is often slower for those whose who are low in weight initially. However, infants who follow short birth intervals are clearly disadvantaged at the end of the year when the mean weight-for-age z score fails to level off as it does for infants following longer birth intervals. This could be indicative of competition for resources and for maternal care and attention as the infant progresses into early childhood.

The results show that for infants who follow short birth intervals, there is no association between maternal height and WAZ score, whilst for infants who follow long birth intervals there is a significant positive association (Figure 5.16). The genetic height potential of an individual is a characteristic partially inherited from the parents. The ability to meet this potential, however, is influenced by the health and nutritional status of the individual. Thus if an infant fails to thrive following a short birth interval, he or she may not attain this genetic potential, as growth may be stunted. This explanation accounts for the lack of association between tall mothers and high WAZ scores but does not fully account for why there is no apparent association between short maternal stature and low WAZ scores. One possible explanation posits that attaining a short predetermined stature is nutritionally less demanding than attaining a tall one, thus the disadvantages of a short previous birth interval would have only a negligible impact.

If an infant follows a short birth interval and has two or more previous siblings who have died the WAZ scores are shown to be considerably lower throughout the year (Figure 5.18). It is likely that this reflects a correlated mortality risk suffered by children within the same family. Such children share the same biological and environmental factors, which influence their welfare and ultimately their survival prospects (Curtis, 1991). It is hypothesised that these high-risk familial characteristics, exacerbate the short birth interval effect, culminating in an infant who fails to thrive.

The effect of maternal education on the WAZ scores was also shown to differ by the previous birth interval. Whilst primary education was associated with low WAZ scores for infants following long birth intervals, high school education was associated with low scores for infants following short birth intervals (Figures 5.19 and 5.20). Both these findings are contrary to previous literature which has found that maternal education at any level has a positive association with infant or child survival (Cleland and Van Ginneken, 1988 and The United Nations, 1985). As mentioned in Chapter 4, discussion concerning the pathways through which maternal education influences child mortality include: increased knowledge of child care issues, increased autonomy of women, and better access or use of health care facilities (Mosely et al., 1984 and Cleland, 1990). It is easy, however, to envisage circumstances, in which maternal education at primary level, may be a disadvantage to the infant. Qualitative research in these villages has highlighted customs which may put the infant and indeed sometimes the mother at risk. For example, branding of the infants navel to prevent colic and immersing the infant in a mixture of water and cow dung to promote respiration is common. It is often considered prestigious to follow such customs and it is possible that women educated at primary level learn of such custom but are perhaps unaware of their detrimental effects, or less able to treat the children if they become ill as a result. The fact that this relationship is not apparent for infants following short birth intervals may reflect their already low WAZ scores. It is possible that they do not survive if subjected to an accumulation of these detrimental effects. Alternatively, the mothers may pay less attention to such activities when they have other young children to care for.

In the study villages many women who have received education are married to men with no schooling or may be the only literate person in the household. Preliminary findings of the obstetric health survey suggest that the educational attainment of the woman, bears little relation to her autonomy or ability to seek health care. Access to health care facilities is largely dependant of ability to pay and even where finance is available women do not have access without the prior agreement of another family member. More generally, fieldworkers working within the area comment that maternal education appears to have little effect on a woman's status or ability to make decisions independently.

Nevertheless women's education at high school level is weakly associated with higher WAZ scores for children following long birth intervals indicating that there may be some positive effect. The strong negative interaction between high school education and short birth intervals could possibly result from a lower mortality risk suffered by infants whose mothers received high school education. These children who clearly have thrived less well, may have died had the mothers been less well educated.

5.10.3 Other Associates of Weight-for-Age Z Score

First born children were shown to have lower WAZ scores throughout the whole year in comparison to second or higher order births who followed birth intervals greater than two years. This could reflect differences in maternal age at birth between the two groups. The age of the mothers for first born children ranged between 14 and 22 years with an average of 18 years. For higher order births following a medium birth interval the age range was between 17 and 32 years with an average of 22 years. By definition the very young maternal ages at childbirth occur predominantly amongst first born children. Whilst 34% of first born children had mothers under 18 years of age, only 2.7% of higher order infants following medium birth interval infants had mothers this young. Very young ages at childbirth are known to be associated with health risks for the infant as well as the mother (NFHS for India 1992-3).

The results show that the birth of the child in the monsoon seasons was associated with lower WAZ scores than birth during the winter season and that this effect was constant throughout the whole of the first year of life (Table 5.6). This was particularly severe if the child was born during the north east monsoon. The effect of season may act directly on the nutritional status of the infant or through the maternal nutritional status. The fact that the WAZ scores are lower at birth and then remain low throughout the year indicates that the relationship acts through the prenatal nutritional environment. Had the association been direct, the effect on the WAZ score would be more transient and one might have expected a significant interaction between season at birth and the age of the child. Alternatively, the variable representing the season at the time of the weight measurement would have had greater significance.

The influence of season on the woman's nutritional status may act through a decrease in food availability and an increase in workload, thus causing a negative energy balance. Additionally flooding during the monsoon seasons often results in contamination of drinking water and more generally in greater exposure to pathogens owing the damp and less sanitary environment. Diseases such as gastro-enteritis become more prevalent.

In their longitudinal study of maternal weights in rural Bangladesh, Miller et al. (1994) found a strong seasonal effect on the women's weight measurements. Women lost weight most rapidly during the rainy monsoon seasons. In Kanakapura the Southwest monsoon occurs during the months of June, July and September, and the Northeast monsoon during the months of October, November and December. By the north east monsoon the women have already suffered nutritional stress from the Southwest monsoon. Babies born during the north east monsoon are thus more likely to suffer a deprived intrauterine environment during the third trimester (a period when weight gain is concentrated).

The WAZ scores of children of the Lambani caste were clearly different from that of the other castes. The Lambani caste is ex-nomadic with different culture and customs from other villagers. They are generally poorer, most are either landless or have only small land holdings, the value of possessions owned by the households tends to be generally lower than that of other castes. A high proportion of men are employed as wage labourers and fewer women have a primary occupation within the household, most work for wages doing agricultural work. Fairly long durations of breast-feeding are common with later introduction of supplementary foods. The comparatively high WAZ score during the first nine months is unexpected given the low socio-economic status of this caste but possibly reflects the prolonged and exclusive breast-feeding. The children lose their advantage, however, towards the end of the year when weaning is commenced. Also, fieldworkers visiting theses villages report a sudden decline in the weight of the child which coincides with the mothers return to wage labour.

The difference in WAZ score shown for all infants whose mothers undertake agricultural work reflects a similar pattern. The infants appear to thrive well during the early months when breast-feeding is more intense. Also, during this period the mother is likely to be following the custom of bananthana in which she is expected to rest and is relieved of her work. She thus has more time to spend with the child. During the second half of the year when she is likely to return to agricultural work the WAZ score of the infant shows a sharp decline.

Summary

Overall, this analysis has shown that the infants in these villages have lower WAZ scores than those of the reference population and that the relative disadvantage varies at different periods during the first year of life. It is likely that this generally reflects lower levels of nutritional intake and a higher incidence of morbidity.

The mean WAZ score at birth was found to be the same for infants following both long and short birth intervals. This suggests that prenatal conditions are not influenced by birth spacing patterns. A previous birth interval of less than two years, however, was found to be significantly associated with lower WAZ scores, particularly during early infancy and at the end of the first year. Infants following a short birth interval, thus, thrive less well during the first three to four months of life when exclusive breast-feeding is common practice. This indicates that either milk production is impaired as a result of maternal depletion or that the breast-feeding behaviour of women who have had a child following a short birth interval is different from that of women who have had a child following a long birth interval.

The comparative disadvantage of infants following short birth intervals is also demonstrated by the continued decline in the WAZ scores at the end of the first year. This could be indicative of the need to compete for resources and for maternal care and attention. An analysis of the change in WAZ scores further into childhood would be useful to investigate this relationship further.

Interactions were identified between short birth intervals and the death of the previous sibling, maternal height and maternal education. If the previous sibling died the WAZ score was lower than expected indicating that familial characteristics associated with an increased mortality risk, exacerbate the disadvantages suffered by a child following a short birth interval. The positive effect of maternal height on WAZ scores is not evident for infants following short birth intervals, indicating that these children may be failing to reach their genetic growth potential. Also the WAZ scores are lower than expected if the mother received high school education. Further research would be useful in establishing whether this relationship is evident in other populations. Other associates of WAZ score include premature births, the season in which the child was born, the caste of the household, maternal occupation and paternal education.

CHAPTER 6

Analysis of Birth Spacing and Child Mortality in Karnataka

6.1 Introduction

The analysis presented in this chapter investigates the correlates of mortality for children in the State of Karnataka, India. The 1992-93 NFHS for rural Karnataka is used, and thus the analysis is representative of the same population as that of the cross-sectional anthropometric analysis. There are two main objectives of the analysis. The first, is to facilitate an understanding of factors related to child mortality within the state and provide a wider context within which the anthopometric analyses can be interpreted. In particular the relationship between birth spacing and mortality risk is assessed. The second is to investigate the potential bias caused by the lack of information on infant deaths within the analysis of anthropometric status.

The 1992-93 NFHS for Karnataka shows that infant and child mortality declined in Karnataka over the 15 year period prior to the survey. The overall proportionate declines in mortality rates were 30% for infant mortality and 55% for child mortality. Nevertheless mortality rates remain high: 1 in 15 children born during the five years prior to the survey died during infancy and 1 in 11 children died during early childhood, i.e. between ages 1 and 5 years (NFHS for Karnataka).

The mortality risk of infants and children in developing countries results from a culmination of factors, which form the physical and pastoral environment within which the child exists. Describing the causes of mortality or explaining morality patterns within populations can thus involve understanding a complex interaction of precipitating factors. Mosely and Chen (1984) developed a framework in order to promote a greater understanding such causative relationships. This consisted of five proximate determinants through which the secondary factors function to influence mortality risk. The proximate determinants include: maternal factors (i.e. the health of mother), environmental determinants, nutrition, control of disease and propensity to injury. Many other factors influence these proximate determinants and culminate in the mortality risk of the child.

The relative contribution of the proximate determinants vary by the age of the child, however. Mortality risk during very early infancy is influenced predominantly by biological factors and thus the proximate determinant relating to the mothers health status is important in explaining mortality. During early childhood, however, social, behavioural and environmental factors become more influential and thus the remaining four proximate determinants increase in importance (Bhatia, 1989).

This analysis focuses specifically on mortality occurring during infancy and early childhood (i.e. up to two years of age). Separate analyses are conducted for deaths occurring during the neonatal period and for those occurring during the post-neonatal and childhood periods. This avoids missing significant associations as a result of the changing importance of biological and exogenous determinants with the age of the child. Section 6.2 outlines the approach adopted for these analyses and describes the logistic regression models used. A preliminary analysis of neonatal and childhood mortality in Karnataka is provided in section 3.3.3, following the description of the design of the 1992-93 NFHS. Section 6.3 presents the results of the analysis and section 6.4 a discussion of the significant associations identified. The final section of the chapter considers the potential effect of infant deaths on the analysis of anthropometric measurements in chapters 4 and 5.

6.2 Methodology

The analysis is conducted separately for children in the neonatal period (0-1 month of age) and for those in the post-neonatal or early childhood periods (1-24 months). This allows for the changing importance of biological and pre-natal factors relative to social or behavioural factors between these different periods. It may be informative to have divided the age groups further as there is a considerable change in development and behaviour of children between early infancy and early childhood. These changes may be associated with different influences of mortality risk. For example, as the child is weaned they have greater exposure to pathogens yet have immature immune systems in comparison to a child of four or five years. However, due to the relatively small numbers of deaths for these age groups within the State of Karnataka it was not possible to divide the data for these age groups. The analysis was thus conducted separately for children within the neonatal (0-1 month) and postneonatal /early childhood periods (1-24 months) only.

The data are obtained from the 1992 NFHS for Karnataka. For the analysis of neonatal mortality, the data consist of 2,810 children aged between 1 and 60 months. Children aged less than one month of age at the time of the survey are excluded as they had not completed the neonatal period and thus did not have full exposure to the risk of neonatal mortality. For analysis of mortality after the neonatal period the data consist of 1,572 children aged between 25 and 60 months. Again children less than two years of age are excluded from the data as they had not completed the full period of exposure. Children who died during the neonatal period are also excluded.

Binary logistic regression models were fitted for the two mortality periods using death as the dependant variable. The probability of death for the i^{th} individual (i.e. $Pr\,[y=1]$) is thus estimated rather than y_i itself. The probability of death for the i^{th} individual is denoted by p_i and the probability of survival by $1 - p_i$. The odds of death is represented by

$$\text{odds} = \frac{Pr[\text{death}]}{Pr[\text{survival}]} = \frac{p}{1-p_i}.$$

In order that the outcome remains between the values of 0 and 1 the probability is transformed. This is achieved via the logit link function,

$$\text{logit}\,(p_i) = \log\frac{p_i}{1-p_i}.$$

The logistic regression model has the general form:

$$\text{logit}\,(p_i) = \beta_0 + \beta_1 x^{(1)}_i + \cdots + \beta_q x^{(q)}_i.$$

(Note that q is used to denote the number of independent variables as p is used for the probability of death).

The logit model can be translated to the probability scale:

$$p = \frac{1}{1 + \exp\{-(\beta_0 + \beta_1 x^{(1)}_i + \cdots + \beta_q x^{(q)}_i)\}}.$$

or

$$p = \frac{\exp\{\beta_0 + \beta_1 x^{(1)}_i + \cdots + \beta_q x^{(q)}_i\}}{1 + \exp\{\beta_0 + \beta_1 x^{(1)}_i + \cdots + \beta_q x^{(q)}_i\}}.$$

It is assumed that the observations are independent, and that the variation in individual probabilities of death can be explained by the independent covariates.

The explanatory variables included bio-demographic characteristics of the infant and mother as well as socio-economic variables, health care utilisation and environmental factors. The distribution of the dependent and explanatory variables is shown for each data set in Appendix 6.a and 6.b. Section 3.3.3 provides a preliminary analysis of child mortality in Karnataka, describing the distribution neonatal and childhood mortality by the explanatory covariates.

Although there is a hierarchical structure within the data such that children are clustered within families, and families within villages, multilevel modelling techniques were not employed for the final models, as the parameters for the random effects were found insignificant. It is likely that this reflects the relatively rare event of death and the consequent low frequency of death clusters within the higher levels (Tables 6.1 and 6.2). It is possible therefore, that the significance of associations may be overestimated. Nevertheless, the analysis does provide a useful investigation of the relationship between short birth intervals and child mortality in the specific area of Karnataka, India.

Table 6.1 Clustering Effects of Neonatal Mortality at the Household and PSU Levels

Neonatal Deaths per Household	Frequency	Neonatal Deaths Per PSU	Frequency
1	72	1	35
2	13	2	17
3	6	3	10
4	1	4	1
5	0	5	1
6	0	6	2

Table 6.2 Clustering Effects of Early Childhood Mortality at the Household and PSU Levels

Early Childhood Deaths per Household	Frequency	Early Childhood Deaths per PSU	Frequency
1	44	1	38
2	6	2	6
3	0	3	2

6.3 Results

6.3.1 Neonatal Mortality Period

The model for neonatal mortality shows that birth spacing is significantly associated with mortality risk (Table 6.3). The odds ratio can be used to compare the odds of mortality given different values for the explanatory variables. Those following intervals of less than two years thus suffer over twice the odds of those following intervals greater than 2 years. More extreme, however, is the increased mortality risk associated with multiple births. The odds ratio shows that the odds of neonatal mortality for a child from a multiple birth is nearly five and a half times the those of a single born infant following a birth interval greater than two years.

The results also show that infants born prematurely suffer a high mortality risk. The magnitude of disadvantage is very large with such infants suffering over fourteen times the odds of infants born after at least 40 weeks gestation. Over and above the effect of prematurity, the size of the infant at birth (as reported by the mother) was also associated with mortality. A small baby suffered twice the odds of mortality as one of average size. The results also provide evidence of a correlated mortality risk between siblings. A child whose previous sibling had died had nearly four times the odds compared to a child whose previous sibling had survived.

Other significant associations included the maternal age, the gender of the child, the father's education and household density. An infant born to a mother less than 15 years of age was shown to suffer over three times the odds of neonatal mortality compared to an infant born to a mother of optimum child bearing age, i.e. between 20-24 years. Female children demonstrated a 40% reduction in odds compared to male children. Children of educated fathers demonstrated a 50% reduction in odds compared to those of uneducated fathers. Finally, children from high density households were shown to suffer a 70% reduction in odds compared to those of low density households. Household density reflects the number of household members and thus measures crowding.

Table 6.3 Parameter Estimates and Standard Errors for the Logistic Regression Model for Neonatal Mortality

Parameter	Estimate	Standard Error	Odds Ratio
Constant	-3.3333	0.4866	
Previous Birth Interval			
24 months of more	Ref		
< 24 months	0.7868	0.2673	2.1963
First birth	0.4933	0.2959	1.6377
Multiple birth	1.6974	0.4745	5.46
Size at Birth (Mother's opinion)			
Average	Ref		
Large	0.2726	0.2711	1.3133
Small	0.6899	0.2585	1.9936
Gestation at Birth			
At least 40 weeks	Ref		
Less than 40 weeks	2.6527	0.2781	14.1918
Maternal Age			
20-24	Ref		
<15	1.1442	0.5099	3.1399
15-19	0.6435	0.2738	1.9032
25+	0.5274	0.2942	1.6945
Gender			
Boy	Ref		
Girl	-0.5163	0.2113	0.5967
Death of Previous Sibling			
Survived	Ref		
Died	1.3175	0.2703	3.7341
Husbands Education			
Uneducated	Ref		
Educated (at primary level or above)	-0.6539	0.2200	0.5200
Household Density			
Low	Ref		
Average	-0.8912	0.3416	0.4102
High	-1.3007	0.4053	0.2723

Variables which were not significant at the 5% level (and were thus excluded from the model) included: prenatal health care utilisation, recent morbidity, source of drinking water and toilet facility, the standard of living index and variables relating to the mother such as education and occupation.

6.3.2 Post-neonatal and Childhood Mortality Period

Table 6.4 shows the results of the model for mortality of children between the ages of 1 and 24 months. For this period the mortality risk of children born after a short previous birth interval was not significantly different from that of children born after a longer birth interval. The relationship remained, however, for multiple births. Children of multiple births demonstrated over 5 times the odds of single births, following intervals of two years or longer. This effect was only slightly weaker than that for neonatal mortality. Maternal age also remained significantly associated with mortality for this period. The effect for maternal age at less than 15 years was in fact stronger, demonstrating a five fold increase in odds as compared to optimal maternal age for childbearing.

Two covariates were significantly associated with post-neonatal mortality although they were not so for neonatal mortality. These were the age of the child and maternal education. For the children who died the age refers to the age they would have been at the time of the survey had they survived. The age of the child was also significantly associated with post-neonatal and early childhood mortality, demonstrating a decrease in mortality risk with increasing age. Each additional month was associated with a 6% reduction in odds. Finally, if the mother received education, the mortality risk of the child was reduced. The magnitude of effect was shown to increase successively for each level of schooling but only the primary school level was significant at the 5% level. This was associated with a 63% reduction in odds.

The insignificance of many of the remaining variables could relate to the to the relatively small numbers within the categories and rare occurrence of death. One might expect for example that socio-economic status represented by the standard of living index may be related to mortality risk.

Table 6.4 Parameter Estimates and Standard Errors for the Logistic Regression Model for Post Neonatal and Toddler Mortality

Parameter	Estimate	Standard Error	Odds Ratio
Constant	-0.7702	0.6005	
Previous Birth Interval			
24 months of more	Ref		
< 24 months	0.0953	0.3650	1.1000
First birth	-0.4671	0.4274	0.6268
Multiple birth	1.6063	0.7091	4.9844
Childs Age	-0.0611	0.0147	0.9407
Maternal Age			
20-24	Ref		
<15	1.5700	0.6087	4.8068
15-19	0.3790	0.3697	1.4608
25+	-0.1245	0.3817	0.8830
Maternal Education			
Uneducated	Ref		
Primary	-1.0063	0.4824	0.3656
Middle	-1.4990	1.0238	0.2233
High	-6.8336	12.1234	0.0011

6.4 Discussion

The results show that a previous birth interval of less than two years was significantly associated with mortality during the neonatal period. Such infants suffered twice the odds of mortality than infants following longer birth intervals. After the neonatal period, however, there was little effect. For mortality during the post-neonatal and early childhood periods, the disadvantage associated with short birth intervals was very small and not significantly different from zero. These results indicate that the pathways through which short birth intervals effect child mortality function primarily through adverse circumstance during the prenatal period, delivery or early infancy. Table 6.5 shows the distribution of the age at death by the previous birth interval for infants who died during the neonatal period. It shows that deaths occurring amongst infants who follow a short birth interval are more highly concentrated immediately following birth or within the first day, than deaths occurring to infants who follow longer birth intervals. For example, 48.2% of deaths occur within the first 24 hours following the birth, compared with 36.4% for infants following long birth intervals. This concentration of early deaths even within the neonatal period suggests that prenatal factors may well be important in explaining the relationship. If maternal depletion is the causal mechanism and fetal development is compromised, the infant would be less able to cope with adjusting to the new environment following the birth, for example, the infant may be less able to maintain a constant temperature.

Table 6.5 Percentage Distribution of Age at Death by Previous Birth Interval
(Includes neonatal deaths only)

Neonatal Deaths	Previous Birth Interval			
Age at Death in Days	<24 months	24+ months	First birth	Multilple birth
0	21.4	16.7	22.6	11.1
1	26.8	19.7	21.0	33.3
2-7	28.6	40.9	43.5	33.3
8-14	16.1	16.7	6.5	11.1
15-21	7.1	6.1	6.5	11.1
Total	100.0	100.0	100.0	100.0
Number	56	66	62	18

There is little evidence in this analysis to suggest that competition between siblings or that increased exposure to infectious disease is a causal pathway increasing the mortality risk of infants following short birth intervals.

Multiple births have a large impact on the mortality risk in both the neonatal period and post-neonatal or early childhood periods. The circumstances of such infants are unique; the growth of two fetuses concurrently, places intense physiological and nutritional demands upon the mother and thus the risk of nutritional depletion is acute. Following the birth, if the infants are to be breast-fed the mother must meet the extra nutritional demands required for lactation. Additionally, she must bear the heavy work load of caring for two infants, ensuring their needs are met. Multiple births could thus be thought of as the ultimate short birth interval, amplifying the effect of both maternal depletion and competition between siblings.

The results do indeed indicate that multiple births strongly influence the survival prospects of the infant not only during the neonatal period but also during early childhood. Infants suffer around 5 times the odds of both neonatal deaths and post-neonatal and early childhood deaths. Table 6.5 shows that neonatal deaths occurring amongst multiple birth infants are less concentrated in the immediate postpartum period than for all other infants. For example 11% died at less than one day compared with 21.4% of deaths amongst infants following short birth intervals, 16.7% of deaths amongst infants following longer birth intervals and 22.6% of deaths amongst first born infants. Although 75% of the deaths are clustered within of the first week of life, a slightly higher percentage of deaths occur within the third and fourth weeks of life compared with other birth spacing groups (11% compared with 7%, 6.1% and 6.5%). The very strong effect of multiple births throughout early childhood clearly indicates that a number of underlying causal factors are likely to function within the relationship. The strong effect in the neonatal period especially in the first week of life indicates that the growth and development of the fetus is compromised during the prenatal period. The comparatively low percentage immediately postpartum could reflect a higher incidence of miscarriage or abortion within multiple birth infants. The strong disadvantage demonstrated for infants of multiple births continues during early childhood, indicating that competition for resources and for care may be acute with siblings so close in age.

The detrimental effect of short birth intervals and multiple births is over and above that of premature births and the small size of babies at birth. The results show that premature babies have an increased risk of mortality during the neonatal period. The magnitude of effect is very large with odds at 14 times those of infants born over 40 weeks gestation. This reflects their immature development and consequent inability to cope within the outside environment at birth. Similarly, small size is at birth is significantly associated with mortality. Such infants suffer nearly twice the odds of mortality compared to average or large babies. This effect is in addition to that reflected by the small size of premature births and is likely to indicate failure to thrive and possibly immature development. The relationships between post-neonatal or childhood mortality and both premature births and small size at birth, were found to be insignificant.

Maternal age was found to be associated with both neonatal and childhood mortality. If the mother was less than 15 years of age the child suffered 3 times the odds of mortality during the neonatal period and 4.8 times the odds during the post-neonatal or childhood period. If the mother was aged between 15-19 years the infant suffered nearly twice the odds during the neonatal period, but was not a significantly more likely to die during the post-neonatal period. The relationship between young maternal age and infant mortality has been well documented in previous literature (Ladislav 1972; Nortman 1974). Explanations posit that the bodies of teenage women are not biologically mature and therefore are not fully equipped to cope with childbearing. The results of this analysis support this hypothesis and that the effect continues throughout the teenage years although it is most acute in those less than 15 years of age.

The very strong association between maternal age at under 15 years and post-neonatal or childhood mortality suggests that behavioural factors also function within the relationship in addition to the biological ones. Such young teenage girls may be less capable at caring for a baby and are likely to suffer very low status within the marital household and have limited autonomy. Although many girls get married in India at young ages, they do not move to the marital household, or consummate the marriage until much later. It is possible that such young pregnancy occurs to girls who are sent early to the marital household and are thus less well cared for by their own natal household. It is common practice for women to return to the marital household for the birth of their first baby and research has found that this practice is associated with a lower mortality risk for the infant. It is posited that the young mother and infant benefit from the experience of the women of their own family (Stephenson, 1999). Girls who are sent to the marital household at very early ages may be less likely to return to the natal household for the birth of their babies.

Other significant correlates of neonatal mortality include gender, death of the previous sibling, husbands education and household density. Girls demonstrate a 40% decrease in the odds of mortality during the neonatal period compared boys. This gender difference has been previously identified in analyses and has been attributed to the stronger constitution of baby girls (Stephenson, 1999). Other analyses, however, have identified a higher than expected mortality rate girls during infancy and early childhood and have suggested this may result from a preference for boys owing to the patrilineal system within the community. Girls may therefore be less well cared if they became ill and may be less likely to receive health care (Griffiths, 1998). There is no evidence in this analysis of such gender preference. This behaviour is perhaps more acute in northern states where traditional customs remain an integral way of life.

The death of the previous sibling was associated with nearly 4 times the odds compared to infants whose previous sibling survived. This effect has been identified in previous literature (Curtis, 1992) and represents correlation in mortality risk between siblings. Siblings share common biological, socio-economic and behavioural circumstances which influence their survival prospects. Such factors include genetic inheritance, the health constitution of the mother, competence of the mother and immediate family in providing adequate childcare and the physical environment. This effect is not significant in the post-neonatal period possibly as a result of a selective effect, i.e. those children exposed to a high mortality setting tend to die early on during the neonatal period .

Infants of educated fathers demonstrated a 50% reduction in the odds of mortality compared to infants whose fathers who were uneducated. This could reflect a higher socio-economic status associated with education. It is also possible that educated fathers are more aware of the health needs of their children and are more likely to seek health care if they are ill. The attitudes and beliefs of educated fathers may also differ in that they are less likely to follow traditional customs which place women in a more subservient or low status position. The mother would therefore be in a better position to care for the children.

Household density was also shown to be associated with mortality risk. This variable relates to the number of persons per room and indicates levels of overcrowding. A negative relationship was found between household density and neonatal mortality, with the odds of neonatal death 60% lower in households of average density and 70% lower in households of high density compared to those of low density. This finding is contrary to previous research which, has found that over-crowding within the household was associated with higher mortality because disease transmission was exacerbated (Timeaus and Lush, 1995 cited in Stephenson, 1999). It is possible, however, that in households of high density, the infant benefits from childcare and support from other family members.

Although maternal education was not associated with mortality risk during the neonatal period it was significantly associated with post-neonatal and early childhood mortality. The benefits of maternal education in reducing the risk of child mortality have been well established (Cleland & Van Ginneken, 1988 and The United Nations, 1985). As mentioned in Chapters 4 & 5, a focus of analysis in academic literature has concerned the pathways through which maternal education is transferred to the welfare of the child. Authors hypothesise that education is associated with different behaviour and attitudes of the woman and the way that she is viewed by society. A more educated woman may have a greater awareness of issues concerning nutrition, hygiene and sanitation, for example. She may gain greater autonomy, confidence and ability to communicate her wishes or concerns. Educated women are less likely to commence child bearing at a very early age and tend to have fewer children. These factors are known to influence infant survival (Mosely and Chen, 1984 and Cleland, 1990). Another hypothesis concerns the association of maternal education with economic status; United Nations (1985) for example state that "approximately half the gross effect of mothers education could be attributed to economic advantage". Overall it seems that education equips the woman, to exploit her own particular circumstances, in a way which is beneficial to the welfare of her children.

The age of the child was also associated with the mortality risk of children between the ages of 1 and 24 months. Only children aged between 24 and 60 months were included in this analysis and thus all the children had been exposed to the full mortality period (i.e. 1 to 24 months). For the children who died the age refers to the age they would have been at the time of the survey had they survived. The results therefore indicate a cohort effect whereby children born further back in time have a lower probability of mortality.

Summary

A previous birth interval of less than two years was found to be significantly associated with mortality risk during the neonatal period but not during the post-neonatal or childhood periods. The results, therefore, suggest that the pathways through which short birth intervals effect child mortality function primarily through adverse circumstances during the prenatal period, delivery or early childhood. A closer examination of the timing of neonatal deaths by the previous birth interval, show that for infants following short birth intervals deaths occur immediately following birth or within the first day. This indicates that fetal development is compromised and that the infant is thus less able to cope in the outside environment following the birth. There is little evidence in this analysis to support the sibling rivalry hypothesis.

Multiple births were also significantly associated neonatal mortality. The impact was considerable, demonstrating a five fold increase in the odds of mortality which persisted during the post-neonatal and early childhood periods. Multiple births could be thought of as the ultimate short birth interval, amplifying the effect of both maternal depletion and competition between siblings. Over and above the effect of short birth intervals and multiple births, premature births and small size at birth were associated with an increase neonatal mortality risk. It is likely that these factors also reflect the immature development of the infant and decreased ability to adjust to the outside environment upon birth.

Other factors found to be associated with neonatal mortality included maternal age, gender, the death of the previous sibling, paternal education and household density. Very young maternal age at birth was associated with increased mortality risk as documented in previous research. Girls demonstrated a lower mortality risk than boys, possibly reflecting their stronger constitution during this early period. The significance of the death of the previous sibling indicates that children within a family suffer a correlated mortality risk owing to shared circumstances. Finally, paternal education and high household density were also found to be associated with an increased mortality risk. These factors may reflect socio-economic status and availability of support for child care activities.

Maternal education was associated with post-neonatal and childhood mortality but not with neonatal mortality. It is possible that educated women have a greater ability to exploit their circumstances to the benefit of their children and that this is of greater benefit during early childhood when weaning is commenced and the child becomes mobile, rather than during very early infancy.

6.5 The Potential Effect of Infant Deaths on the Analysis of Anthropometric Measurements

Using the results of the analysis of infant and child mortality in Karnataka (presented in the previous sections of Chapter 6) this section considers the potential bias in the analyses of anthropometric assessment (presented in Chapters 4 and 5), caused through the exclusion of observations for children who have died. Owing to the retrospective nature of the cross-sectional data, weight measurements would obviously not be available for such children. If the anthropometric status of children who subsequently died were different from those who survived, the average WAZ scores described in the anthropometric analysis could be misleading, if they were assumed to be representative of all children. In this case the results would be applicable only to surviving children.

Longitudinal data often has the advantage that observations are attained until the time of death, but for the survey used in this analysis such data were unavailable. This was mainly because most deaths to children under one year of age occurred during the first month of life, with a high concentration soon after birth or within the first week. It was not possible for the field workers to visit households within this short time period owing to the logistical limitations of travel within these rural villages. Both analyses of anthropometric assessment in this thesis, thus, suffer a potential bias caused through the self-selective nature of the outcome variable. This section assesses the effect of this bias and considers the implications for the results, particularly for the effect of birth spacing on infant weight measurements.

WAZ scores are influenced by the height of an individual, as well as muscle and fat constitution. The general size of the infant will thus be related to their WAZ score. Table 6.1 shows that the size of the infant at birth (as reported by the mother) was significantly associated with neonatal mortality. If the infant was reported to be small at birth the probability of death was twice that of an infant reported to be of average size. This indicates that there may well be a higher concentration of infants with low WAZ scores amongst those who died in the neonatal period. In this case the WAZ scores would be lower than estimated in the cross-sectional and longitudinal athropometric analyses (Chapters 4 and 5) during the neonatal period.

It is possible, however, that the mothers of infants who died were more likely to report the baby as being small as they associate the infant with ill-health. Data were available for the weight measurements of the infant at birth, for some individuals within the survey. The weight measurements were recorded by health workers following delivery of the infant and were attained from the mother during the survey. Table 6.6 shows that the average weight at birth calculated from the recorded measurements was in fact lower for infants reported to be small at birth compared to those reported to be of average size or even large, although the magnitude of difference was minimal. This suggests that the variable "size at birth" as reported by the mother may well be reasonably accurate.

Table 6.6 Average Recorded Weight at Birth by Reported Size of Child at Birth

Reported Size of Child at Birth	Average Recorded Birth weight (Kg)	Number	Standard Deviation
Large	2.52	223	1.23
Average	2.25	226	1.17
Small	2.06	121	0.84
Total		570	1.17

Source 1992-93 NFHS for Karnataka

Table 6.7 shows the average recorded birth weight by neonatal death. The mean birth weight of infants who subsequently died was lower than that for surviving infants, although not significantly so. The infants for whom weight measurements at birth were recorded may not be fully representative of the sample as a whole, however. In order to have their weight recorded they must have been delivered in a health care setting, or at least with health workers present. It is possible that such infants come from families who have greater access to health care facilities and who received antenatal care. Such infants may thrive better than those who did not receive health care and thus attain greater weight measurements.

Table 6.7 Average Recorded Birth Weight by Neonatal Death

Neonatal Mortality	Average Recorded Birth Weight (Kg)	Number	Standard Deviation
Survived	2.33	556	1.16
Died	1.85	14	1.45
Total		570	1.17

Source 1992-93 NFHS for Karntaka

Nevertheless the higher concentration of small, or low birth weight infants amongst those who died shown in these cross-tabulations, does indicate that the true average WAZ score may well be lower than that estimated in Chapters 4 and 5 during this early period. The effect would be greatest at birth and during the very early neonatal period when the concentration of deaths is highest (Table 6.3). An effective assessment of bias after the neonatal period would be only possible if data were available concerning the weights of the children prior to their death. However, the magnitude of effect is likely to be less acute than that for the neonatal period, owing to the lower rates of death at each individual month of age.

In order to assess the effect of this bias, within the relationship between short birth intervals and WAZ scores, it is necessary to consider a three-way relationship between short birth intervals, size at birth, and mortality. If there is a high concentration of infants with low WAZ scores amongst those following short birth intervals, and a greater probability of death amongst those infants, then the WAZ scores of infants following short birth intervals would be over-estimated in the anthropometric analysis. The analysis of neonatal mortality (Table 6.3) does indeed show a significant association between both a short previous birth interval and small size at birth, with mortality risk. However Table 6.8, shows that a lower percentage of children following short birth intervals were reported to be small at birth as compared to those following longer birth intervals.

Table 6.8 Percentage Distribution of Size at Birth by Previous Birth Interval

	Previous Birth Interval			
Size of Child at Birth	<24 months	24 + months	Multiple	First birth
Small	25.4	26.6	53.5	30.4
Average	33.4	34.7	34.9	36.3
Large	41.2	38.7	11.6	33.3
Total	100	100	100	100
Number	551	144	43	826

Source 1992-93 NFHS for Karnataka

Also Table 6.9 shows a slightly lower average recorded weight measurement at birth, for infants following a short birth intervals, compared to those following longer birth intervals, but the magnitude of difference is minimal. It thus appears that the effect of the previous birth interval is unaffected by any bias caused through the omission of data for infants who have died in the neonatal period.

Table 6.9 Average Recorded Birth Weight by Previous Birth Interval

Previous Birth Interval	Average Recorded Birth Weight (Kg)	**Number**	Standard Deviation
<24 months	2.20	93	1.15
24+months	2.30	226	1.19
Multiple	2.45	5	1.66
First births	2.37	246	1.16
Total		570	

Source 1992-93 NFHS for Karnataka

Summary

The anthropometric analyses shown in the previous chapters potentially suffer bias because observations for children who have died are not available. If the anthropometric status of such children was different from those who survived the average WAZ scores estimated by the anthropometric models may be inaccurate. The analysis of infant mortality for the state of Karnataka shows that the size of the child, as reported by the mother, is associated with neonatal mortality risk, but not with post-neonatal or early childhood mortality. In this case the WAZ scores for children aged less than one month would be lower than those shown by the estimated scores attained from the anthropometric analyses. The effect is likely to be most acute for the early neonatal period as deaths are highly concentrated during the early period following the birth.

Data is only available for the size and weight of the infants at birth, for children who died. It is not possible, therefore, to assess bias after the neonatal period effectively. The magnitude of such bias is likely to be small, however, owing to the considerably lower mortality rates for individual months during the post-neonatal period and the less vulnerable constitution of the child.

The potential impact of this bias on the relationship between short birth intervals and WAZ scores can be investigated by considering a three-way relationship between short birth intervals, size at birth and mortality risk. The analysis of infant mortality in Karnataka does indeed show a significant association between short birth intervals and mortality risk during the neonatal period. Cross tabulations, however, fail to provide evidence that small size at birth or low birth weight babies are more highly concentrated amongst infants following short birth intervals than amongst those following longer intervals. This suggests that the relationship between short birth intervals and WAZ scores would be unaffected by the omission of data for children who subsequently died.

CHAPTER 7

Short Birth Intervals and Child Mortality in India

7.1 Introduction

This chapter uses the NFHS for the whole of India to investigate the causal mechanisms within the relationship between birth spacing and the mortality of children, under two years of age. Interactions within the relationship are analysed to identify the extent to which other explanatory covariates mediate the effect of short birth intervals. The analysis also provides a wider context in which to interpret the analyses of Karnataka and indicates the extent to which the previous results are generalisable.

The analysis of infant mortality for Karnataka was limited in that the data set was small given the relatively rare event of death. This meant statistical analyses were limited in gaining strength of inference across individuals, particularly for the post-neonatal and early childhood period. Some correlates of mortality and interactions between covariates may, therefore, have appeared insignificant when in fact a relationship did exist. This is particularly so for interactions between covariates where cross tabulation results in smaller numbers of cases within some categories. Interactions are likely to be informative in explaining how the mechanisms of the relationship between short birth intervals and child mortality function and thus explanatory power will have been lost in the previous analysis. The NFHS for the whole of India includes approximately 90,000 individuals and thus facilitates a detailed examination of such interactions for key age groups of children during infancy and early childhood. Data for both urban and rural areas was included in the analysis.

A further limitation of the previous analysis is that although the data is hierarchical in structure it was not feasible to conduct multi-level models. Associations may, therefore, have been incorrectly identified and others overlooked. This again relates to the small numbers of deaths occurring within the separate age groups. Three levels are included within this analysis to control for the clustering at the mother and village levels.

Section 7.2 describes the data used and explains how it relates to the smaller NFHS for the State of Karnataka. The selection of individuals included in the data for this analysis is outlined. Section 7.3 describes the multi-level models used, and section 7.4 presents a preliminary analysis of mortality by the age groups analysed and by the previous birth interval. The results of the models are presented in section 7.5, which is followed by a discussion.

7.2 The Data

The data used is the 1992-93 Indian National Family Health Survey (NFHS). The NFHS for India was undertaken by the Ministry of Health and Family Welfare, New Dehli, with the objective of providing both state-level, and national-level, estimates for demographic and health indices, including infant and child mortality. It was intended that as well as providing information for policy makers, the survey would provide high quality data for researchers undertaking analyses on various population and health topics (1992-93 NFHS for India).

A further objective of the NFHS was to provide a source of data for inter-state comparisons of demographic and health analyses. Uniform methods in questionnaire design, sampling techniques, data collection and analysis were thus employed across the different states. The study design of the NFHS for Karnataka, as described in section 3.2, thus applies to the survey for the whole of India.

The target population for the survey was ever-married women aged 13-49, with data collected at three levels: the individual level, the household level, and the village level. Data was collected for each of the twenty-four states of India and the National Capital Territory of Delhi, containing ninety-nine percent of the total population (IIPS 1993). This analysis uses the data for the whole of India, and thus analyses the results of 89,777 individual and 80,652 household interviews. The survey collected data on household socio-economic and environmental conditions, full birth histories, individual bio-demographic characteristics, and the utilisation of health services. It thus allows a range of potential correlates of under-two mortality to be examined.

First births have been excluded from the data, such that this analysis models only those with a previous birth interval. The influence of birth spacing behaviour on under-two mortality is examined through the modelling of mortality in three age groups: neonatal (0-1 month), post-neonatal (1-7 months) and early childhood (8-24 months). These age categories were selected firstly to capture key developmental periods during early childhood, but secondly to avoid difficulties with age heaping inherent within the data.

(See Stephenson, 1999 for demonstration of age heaping NFHS for India.) Age heaping occurs when respondents report ages rounded to given figures, for example 6 months, 12 months and 18 months. If an age category consisted, say, of children aged 1 to 6 months, some would be incorrectly allocated owing to this miss reporting of exact age. The analysis was truncated at two years to focus on the early childhood period, when physiological development is particularly marked, for example, when the child is weaned and becomes mobile. This also has the advantage that age at death is recorded in months, providing a more specific analysis, whilst for older children age at death is recorded in years.

Three data sets were created and separate analyses conducted for each mortality period. This avoids the necessity of fitting interactions with the age of the child in order to account for the changing determinants of mortality. Very complex models incorporating three way interactions would then be required to explore mediating factors within the relationship between birth intervals and infant mortality. As with the analysis of child mortality in Karnataka, each data set included only those children who had full exposure to the mortality period. Also, children who died before the mortality period, under investigation, were removed from the data. For the analysis of neonatal mortality the data consists of children born between one month and five years before to the survey, and includes 42,798 individuals. The sample for post-neonatal mortality includes children born between six months and five years before the survey and includes 36,371 individuals. Finally the sample for the early childhood mortality period consists of children born between two and five years before to the survey and includes 23,488.

7.3 Methodology

The hierarchical structure of the data is the same as that for Karnataka, discussed in section 4.2. A multilevel logistic modelling approach is therefore used including the child as level one, the mother as level two, and the primary sampling unit as level three. This methodology is employed to account for the correlation in the risk of both mortality and birth spacing behaviours between siblings, and to identify unobserved influences on mortality and birth spacing behaviour at the woman and primary sampling unit levels. The variance components model for a continuous response variable is described in section 4.3. For this analysis the variance components model is used with the logistic link to allow for the binary distribution of the outcome variable, death. The model can be represented by the equation

$\text{logit}\,(p_{ijk}) = \beta_0 + \beta_1 x^{(1)}{}_{ijk} + \cdots + \beta_p x^{(p)}{}_{ijk} + e_{ijk} + u_{0jk} + v_{0k}$,

where p_{ijk} is the probability of dying for the i^{th} child, in the j^{th} household and the k^{th} PSU. $\beta_1, \cdots, \beta_p$ is a range of unknown regression coefficients for the corresponding covariates $x^{(1)}, \cdots, x^{(p)}$ demonstrated by the individual child. e_{ijk} is a zero mean random variable representing the deviation of the *ith* individual from the predicted outcome. u_{0jk} is the departure of j^{th} households (in the k^{th} PSU) intercept from the predicted outcome and v_{0k} is the departure of k^{th} PSUs intercept from the predicted outcome. The distribution of the random effects is assumed to be normal, with mean equal to zero.

To interpret the random effects model, the parameter estimates are interpreted as odds ratios. However, in the random effects model the odds ratios are referred to as an average odds ratios, because they are specific to the household and PSU of that particular individual. The probability of death for particular child, for example, depends on both the observed covariates associated with that child and the unobserved cluster effects.

Children from multiple births were excluded from the analysis as siblings would suffer an increased, and thus correlated, risk of mortality, over and above that caused through the shared circumstances of siblings from singleton births (see Chapter 6). A separate multilevel, logistic model was fitted for each of the three mortality periods, with a dichotomous outcome for mortality. The previous birth interval was categorised as less than 18 months, 18-36 months and 36+ months. Eighteen months rather than 24 months was used to define short birth intervals as this provides a more focused analysis, and the effect of age heaping is less acute than at 24 months.

7.4 Preliminary Analysis

Table 7.1 shows the distribution of neonatal, post-neonatal and early childhood deaths within each data set. Nearly 4% of infants died in the first month of life, 2% between ages 1 and 7 months and 3% between ages 8 months and 2 years. The 1992-93 NFHS for India reported mortality rates of 49 per 1,000 live births for neonatal mortality, 30 per 1,000 for post-neonatal mortality (age 1-12 months) and 33.4 per thousand for childhood mortality (age 1-5 years). These rates include first born children and those from multiple births, both of which suffer higher mortality risk than second or higher order, singleton births. The distribution shown for the samples are thus as would be expected.

Table 7.1 Distribution of Neonatal, Post-neonatal and Early Childhood Deaths within Each Data Set Analysed

Mortality Period	Percent Died	Total Children Within Sample
Neonatal (under 1 month)	3.7	42,798
Post-neonatal (1-7 months)	1.8	36,371
Childhood (8-24 months)	2.9	23,488

Source 1992-93 Indian NFHS

Table 7.2 shows the distribution of the length of the previous birth interval for each mortality period analysed. Around 13% of infants included in the data for the analysis of neonatal mortality followed intervals of less than 18 months. That is 5,468 children. Twelve and a half percent, or 4,543 children, followed short birth intervals, in the post-neonatal period, and 13.7%, or 3,208, children in the early childhood period. A significant association between short birth intervals and mortality risk would thus effect a considerable number of children.

Table 7.2 Distribution of Previous Birth Interval within Each Data Set Analysed

Previous Birth Interval	Percent of Total Sample
Neonatal Period	
<18 months	12.8
18-36 months or more	49.8
36+	37.4
Total cases	42,798
Post-neonatal Period	
<18 months	12.5
18-36 months or more	50.7
36+	36.8
Total cases	36,371
Early Childhood Period	
<18 months	13.7
18-36 months or more	52.6
36+	33.8
Total cases	23,488

Source 1992-93 Indian NFHS

Table 7.3 shows the percent distribution of mortality by the previous birth interval. For all three mortality periods a higher proportion of children following birth intervals of less than 18 months died, compared to children following longer birth intervals. Indeed the proportion of deaths is shown consistently to decrease with each successive interval length. Tables 7a, b and c in the appendix show the percentage distribution of children by the explanatory variables for each mortality period.

7.3 Distribution of Mortality by Previous Birth Interval

	Previous Birth Interval		
	<18 months	18 – 36 months	36+ month
Neonatal Mortality			
Died	6.6	3.6	2.9
Survived	93.4	96.4	97.1
Post-neonatal Mortality			
Died	4.0	1.8	1.2
Survived	96.0	98.2	98.8
Early Childhood Mortality			
Died	5.5	3.0	1.7
Survived	94.5	97.0	98.3

Source 1992-93 Indian NFHS

Columns add to 100% for each mortality period

7.5 Results

The relationship between birth spacing and mortality risk was examined for children during the neonatal period (less than 1 month), the post-neonatal period (1 to 7 months) and during early childhood (8 to 24 months). Tables 7.4, 7.5 and 7.6 display the results of these models. Although some factors were significantly associated with mortality risk for all three periods, others were important in only the post-neonatal and/or neonatal periods. It is likely that this reflects changes in the relative importance of biological and social factors in determining mortality risk during infancy and childhood.

The length of the preceding birth interval was significantly associated with mortality risk in all of the periods analysed. Short birth intervals (less than 18 months) were associated with an increased risk of mortality when compared to medium birth intervals (18 to 36 months). This was particularly marked in the post-neonatal period, when the odds of mortality were found to increase by 237%. This compares with an increase of 84% in the neonatal period, and 71% in the toddler/ childhood period. Long birth intervals (greater than 36 months) showed only minimal, insignificant effects on mortality risk.

Table 7.4 Results of Multilevel Model of Neonatal Mortality

Parameter	Estimate	Standard Error	Odds Ratio
Constant	-3.07	0.241	
Maternal Age Group			
<20	Ref		1.000
20-24	-0.231**	0.075	0.794
25-29	-0.135	0.082	0.874
30-34	0.135	0.093	1.145
35+	0.226	0.116	1.254
Gestation at Birth			
40 weeks or more	Ref		1.000
Premature	2.072**	0.089	7.941
Don't know	0.386	0.362	1.471
Weight at Birth			
Heavy	Ref		1.000
Average	-0.777**	0.064	0.460
Low	-0.021	0.07	0.979
Standard of Living Index			
Rich	Ref		1.000
Upper middle	0.209	0.215	1.232
Middle	0.217	0.199	1.242
Lower middle	0.511**	0.196	1.667
Poor	0.593**	0.201	1.809
Household Density			
Low	Ref		1.000
Average	-0.606**	0.115	0.546
High	-0.94**	0.126	0.391
Very high	-1.633**	0.32	0.195
Water Supply			
Other	Ref		1.000
Piped	0.18**	0.058	1.197
Received Tetanus Injection			
Yes	Ref		1.000
No	0.351**	0.08	1.420
Received Antenatal Care			
Yes	Ref		1.000
No	-0.21**	0.08	0.811
Location			
North	Ref		1.000
South	-0.189**	0.073	0.828

Continued below

Table 7.4 continued

Interactions

Birth Interval * Survival Previous Sibling			
<18 mths / Survived	0.712**	0.079	2.038
<18 mths / Died	1.476**	0.085	4.375
18 - 36 mths / Survived	Ref		1.000
18 - 36 mths / Died	0.696**	0.092	2.006
36+ mths / Survived	-0.268**	0.07	0.765
36 + mths / Died	0.056	0.15	1.058
Birth Interval * Maternal Education			
<18 mths / Illiterate	1.142**	0.109	3.133
< 18 mths/ Primary	0.611**	0.148	1.842
< 18 mths / High	0.599**	0.221	1.820
18 - 36 mths / Illiterate	0.341**	0.102	1.406
18 –36 mths / Primary	Ref		1.00
18 - 36 mths / High	0.061	0.19	1.063
36+ mths / Illiterate	-0.038	0.11	0.963
36+ mths/ Primary	-0.007	0.139	0.993
36+ mths / High	-0.612**	0.251	0.542
Random Effects			
Woman level	0.079	0.047	
Psu level	0.313	0.122	

Table 7.5 Results of Multilevel Model of Early Post-neonatal Mortality

Parameter	Estimate	Standard Error	Odds Ratio
Constant	-4.904	0.455	
Gestation at Birth			
40 weeks +	Ref		1.000
Premature	0.95**	0.196	2.586
Don't Know	-0.031	0.605	0.969
Weight at Birth			
Heavy	Ref		1.000
Low	0.228*	0.113	1.256
Average	-0.356**	0.098	0.700
Breast feeding			
Breast feed	Ref		1.000
Not Breast Fed	1.608**	0.166	4.993
Standard of Living Index			
Rich	Ref		1.000
Upper Middle	0.576	0.429	1.779
Middle	0.645	0.402	1.906
Lower Middle	0.841*	0.397	2.319
Poor	1.002*	0.402	2.724
Household Density			
Low	Ref		1.000
Average	-0.315	0.204	0.730
High	-0.534*	0.217	0.586
Very High	-0.506	0.381	0.603
Received Tetanus Vaccine			
Yes	Ref		1.000
No	0.236**	0.087	1.266
Location			
North	Ref		1.000
South	-0.347**	0.118	0.707
Marital Status (Mother)			
Married	Ref		1.000
Separated	1.312**	0.337	3.714
Widdowed/Divorced	0.116**	0.37	1.123
Interactions			
Birth Interval * survival of previous sibling			
< 18 mths / Survived	0.89**	0.111	2.435
< 18 mths / Died	0.94**	0.159	2.560
18 - 36 mths / Survived	Ref		1.000
18 - 36 mths / Died	0.441**	0.15	1.554
36+ mths / Survived	-0.368**	0.107	0.692
36+ mths / Died	0.2	0.211	1.221

Table 7.5 continued

Birth Interval * maternal education			
< 18 mths/ Illiterate	1.34**	0.171	3.819
< 18 mths/ Primary	0.864**	0.233	2.373
< 18 mths / High	-0.367**	0.603	0.693
18 - 36 mths / Illiterate	0.55**	0.159	1.733
18 -36 mths / Primary	Ref		1.000
18 - 36 mths / High	-0.422	0.371	1.449
36+ / Illiterate	0.108	0.171	1.186
36+ / Primary	-0.014	0.228	1.256
36+ / High	-0.474	0.418	1.519
Random Effects Terms			
Woman level	0.034	0.105	
PSU level	0.369	0.288	

Table 7.6 Results of Multilevel Model for Early Childhood Mortality

Parameter	Estimate	Standard Error	Odds Ratio
Constant	-3.787	0.407	
Gestation at Birth			
40 weeks +	Ref		1.000
Premature	1.036**	0.216	2.818
Don't Know	1.029*	0.403	2.798
Weight at Birth			
Heavy	Ref		1.000
Low	-0.053	0.117	0.948
Average	-0.507**	0.094	0.602
Received Tetanus Vaccine			
Yes	Ref		1.000
No	0.234**	0.088	1.264
Location			
North	Ref		1.000
South	-0.657*	0.132	0.518
Interactions			
Birth Interval * Gender			
< 18 mths / Female	1.088**	0.133	2.968
< 18 mths / Male	0.496**	0.148	1.642
18 - 36 mths / Female	0.342**	0.109	1.408
18 - 36 mths / Male	Ref		1.000
36+ mths / Female	-0.332*	0.148	0.717
36+ mths / Male	-0.389**	0.146	0.678
Birth Interval * Maternal education			
< 18 mths/ Illiterate	1.284**	0.186	3.611
< 18 mths/ Primary	0.538	0.303	1.713
< 18 mths / High	-0.185	0.447	0.831
18 - 36 mths / Illiterate	0.647**	0.175	1.910
18 -36 mths / Primary	Ref		1.000
18 - 36 mths / High	-1.046**	0.377	0.351
36+ / Illiterate	0.004	0.192	1.212
36+ / Primary	0.057	0.263	1.301
36+ / High	-1.395**	0.534	1.706
Random Effects Terms			
Woman level	0.162	0.106	
PSU level	0.125	0.259	

The relationship between birth spacing and mortality risk was found, however, to be influenced by other covariates, including maternal education, the survival status of the previous sibling, and the gender of the index child. The interaction between birth interval and maternal education was shown to be consistent across all three age groups (Figures 7.1, 7.2 & 7.3). For children of illiterate women the effect of a short birth interval was found to be particularly severe. Such infants demonstrate between 3 and 4 times the odds of mortality compared to infants who follow a medium birth interval (18 to 36 months) and whose mother gained primary. This is considerably higher than would be expected given the independent effects of birth interval and maternal education. In the post-neonatal period and in early childhood the adverse effect of a short birth interval is negligible for infants of women who gained high school education.

An interaction was also identified between the previous birth interval and the survival status of the previous sibling. This was only significant, however, in the neonatal and early post-neonatal periods. During the neonatal period the probability of mortality for those following a short birth interval was greater than would be expected if the previous sibling died (Figure 7.4). Such an infant would suffer over 4 times the odds of mortality than one whom followed a medium birth interval and whose previous sibling survived.

The direction of the interaction is different for the post-neonatal period (Figure 7.5). In this case the increase in the odds of mortality for an infant who follows a short birth interval and whose previous sibling died, is less than would be expected given the independent effects of the two covariates.

In the early childhood period (8 to 24 months) the gender of the index child interacts with the effect of birth interval such that the adverse effect of a short birth interval is particularly severe for a girl (Figure 7.6). The increase in the odds of mortality for a girl who follows a short birth interval rather than a medium birth interval is 256%. For a boy the increase is only 64%. The gender difference in mortality risk disappears completely for those children who follow intervals of 36 months or more.

Figure 7.1

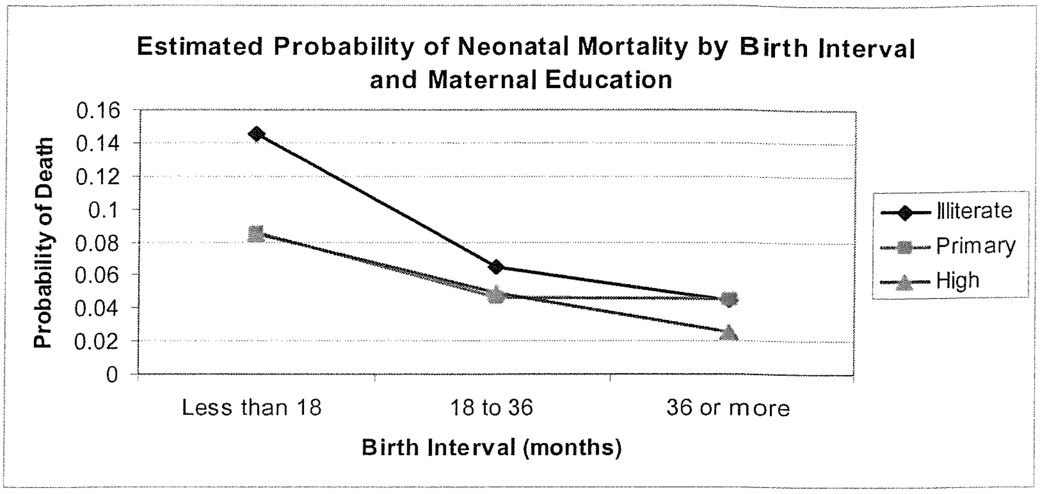


Figure 7.2

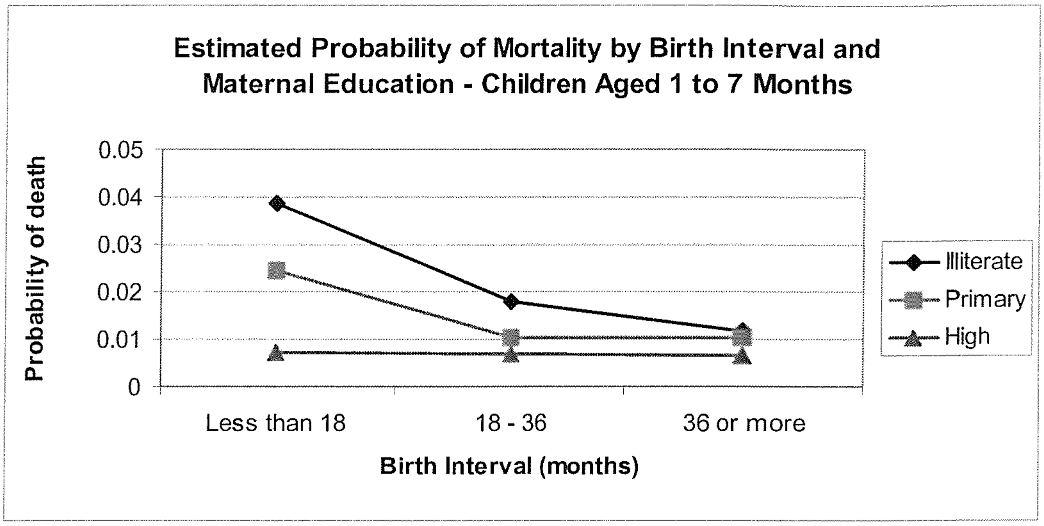


Figure 7.3

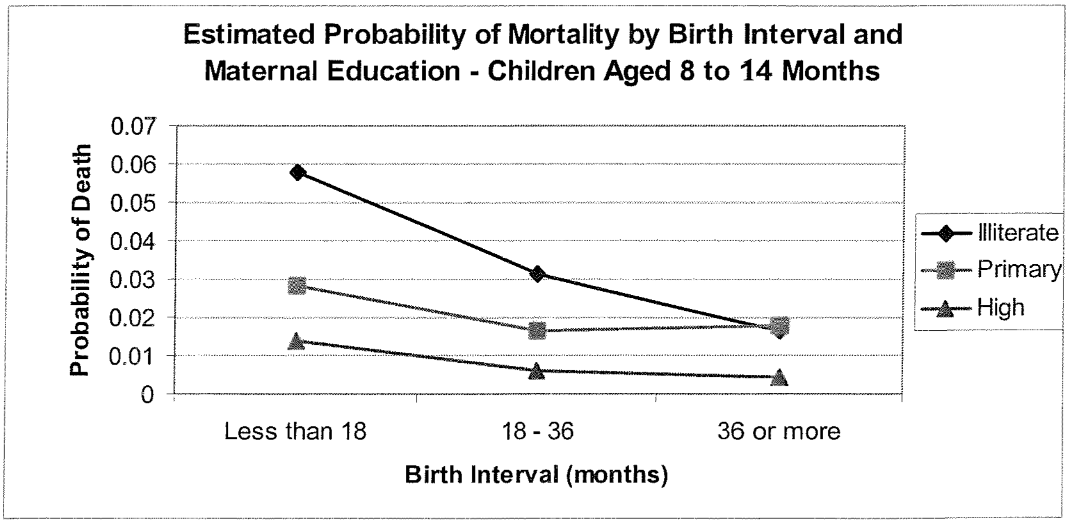


Figure 7.4

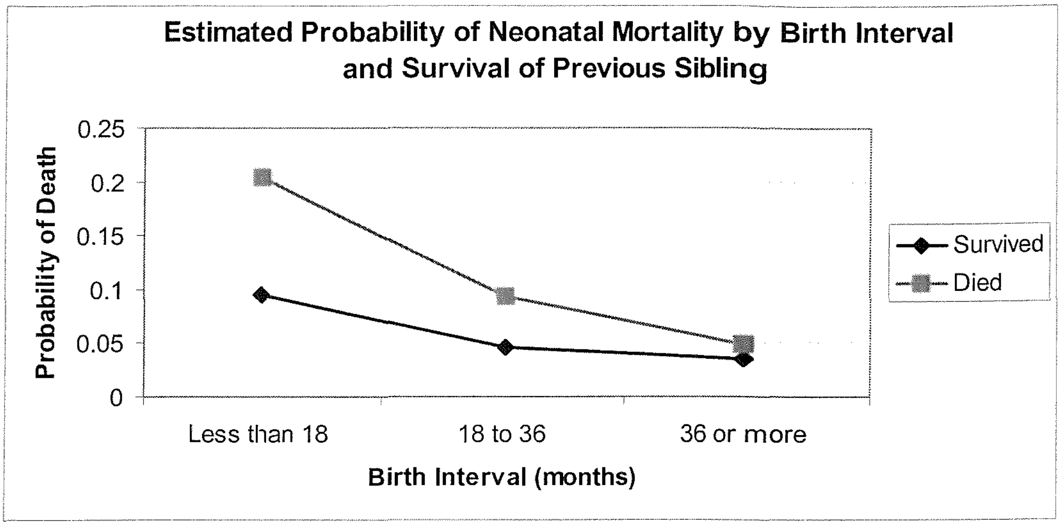


Figure 7.5

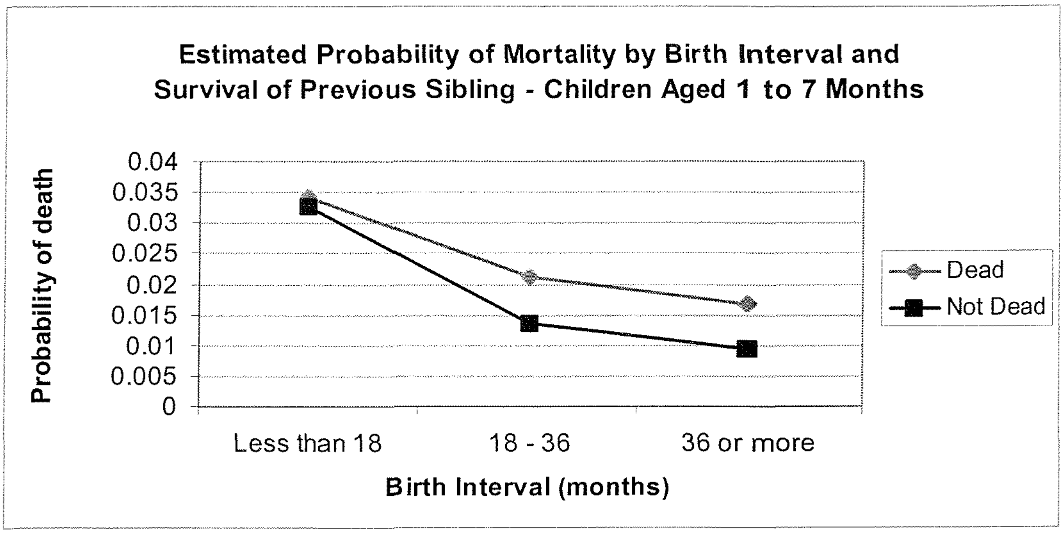
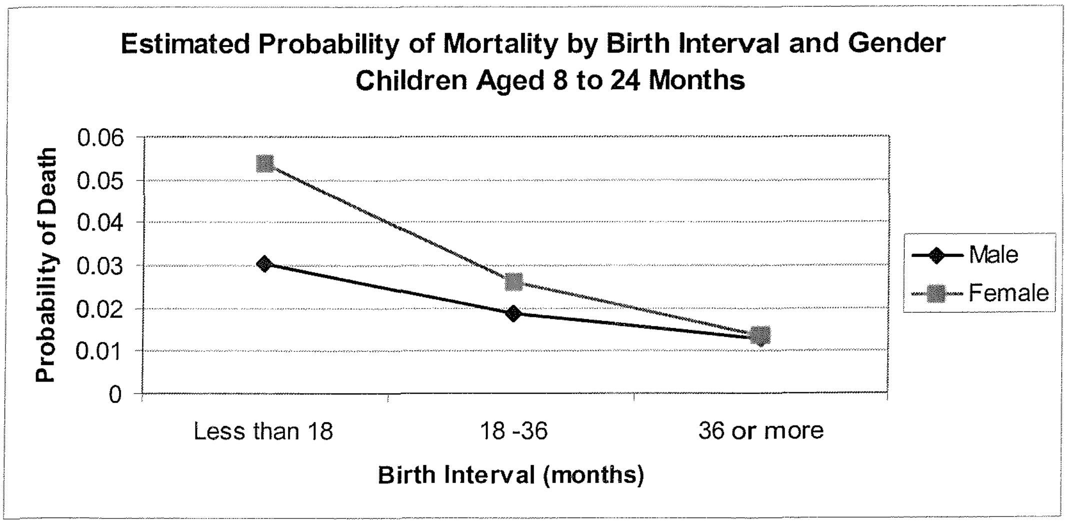


Figure 7.6



Other correlates of mortality risk included bio-demographic, socio-economic and health care related variables. Gestation at birth, birth weight, geographical location, and whether the mother received a tetanus injection during pregnancy were significantly related to the risk of mortality in all three of the time periods. Children who are born prematurely experience nearly eight times the odds of neonatal mortality compared to children who were born after a full term gestation. This increase reduces for children in the post-neonatal and early childhood period although they still experience 2.5 to 3 times the odds. Aside from the effect of gestation, the weight of the infant at birth is also associated with the risk of mortality. In the neonatal period the odds of mortality reduces by 56% if the infant is of average weight compared to being underweight. This reduction declines successively in the subsequent age groups (38% for post-neonatal and 30% for childhood) but the effect of birth weight remains significant.

Children living in southern India have a lower mortality risk than those living in the north. This differential becomes progressively more marked for each successive age group. Living in the south rather than the north is associated with a 17% reduction in mortality odds in the neonatal period, a 29% reduction in the post-neonatal period, and a 48% reduction in the early childhood period.

Whether or not the mother received a tetanus injection during pregnancy was also an important determinant of mortality in all three periods. If no vaccine was given an increase in odds of 42% occurred in the neonatal period and approximately 27% in the post-neonatal and childhood periods.

The two main variables representing socio-economic status, the standard of living index and household density were significantly related to mortality risk only in the neonatal and post-neonatal periods. Generally the effects were shown as expected with those of a lower standard of living suffering an increase in mortality risk compared to those of middle or higher levels. Having a low, rather than high, standard of living was associated with a greater influence in the odds of mortality for infants in the post-neonatal period than those in the neonatal period. The standard of living index was calculated according to the number and value of different household amenities (See Stephenson (2000) for a full description of its construction).

Contrary to expectation household density displayed a negative relationship with the risk of mortality. Those from households of very high density were associated with a lower mortality risk than those of very low density. This was particularly marked in the neonatal period, with a decrease in the odds of mortality of 81%.

Maternal age and type of water supply were important only in the neonatal period. A decrease in the odds of mortality was evident for infants of women aged 20-24 when compared to those aged less than 20 years. Finally those with piped water to the household showed a small decrease in mortality risk compared to those with other sources.

7.4 Discussion

7.4.1 Short Birth Intervals and Child Mortality

The results of this analysis confirm a strong relationship between short birth intervals and the mortality risk of children during all three periods analysed. The relationship was particularly strong in the post-neonatal period, however, and was weakest during the early childhood period. In accordance with literature which attributes neonatal deaths to biological causes and post-neonatal or childhood deaths to exogenous causes, this would indicate that although maternal depletion has a role within the relationship, behavioural factors are the more dominant pathway, particularly during the most vulnerable, early postnatal period. The weaker relationship during the early childhood period could, in part, reflect the self-selective nature of mortality in the post-neonatal and early childhood periods. Only the stronger infants would be exposed to mortality after the neonatal period as they have to survive the neonatal period to be exposed to post-neonatal mortality. Similarly, for the early childhood mortality period, children have to survived both the neonatal and post-neonatal periods.

These results are contrary to those for the analysis of child mortality in the State of Karnataka (Chapter 6). The results of that analysis showed that the effect of a previous birth interval of less than 24 months, was significantly associated with mortality risk only in the neonatal period, and indeed was not significant for the post-neonatal or early childhood periods. It is possible that this reflects the relatively small numbers of deaths after the neonatal period.

7.4.2 Interactions with the Previous Birth Interval

A significant interaction was identified between maternal education and birth spacing such that infants who followed a short birth interval and had an illiterate mother suffered an unexpectedly high risk of mortality during all three periods. If, however, the infant had a mother who gained high school education the risk of mortality after the neonatal period was no more than would be expected for infants following longer birth intervals. As mentioned in the previous chapters maternal education is though to influence mortality risk through a number of pathways. Katherine and Walker (1991), for example, note that maternal education acts as a catalyst which allows a range of economic factors to become effective, providing the mother with functional autonomy and the ability to utilise health services outside the home. In addition, it is suggested that maternal education produces a more rational and greater use of preventative and curative medical services, due to the increased awareness and independence that education may provide (Grossman, 1972). Hence, these characteristics associated with higher maternal education may act to prevent a short birth interval from leading to under-two mortality. An educated mother may be more likely to seek health care for her child or during pregnancy, and may thus be more able to seek care for a child suffering from a secondary infection. Alternatively, maternal education may act as a proxy for socio-economic status. Those with higher educational attainment, and hence higher socio-economic status, may have greater resources, which in turn lessens the effect of sibling rivalry for limited resources, and offers a greater nutritional resource to prevent maternal depletion syndrome.

The results suggest that the effect of being illiterate acts in a different way to the effect of being educated to high school level. The unexpectedly high risk of mortality suffered by infants of illiterate women shown for all the periods, suggests that the detrimental effects of a short birth is exacerbated by the disadvantages of a mother being uneducated. These disadvantages influence mortality during each of the periods analysed. Conversely, the reduction in the short birth interval effect, after the neonatal period, for women with high school education, confirms that behavioural factors associated with high school education are of the benefit of the children. As this pattern is not evident during the neonatal period, however, it appears that these behavioural factors are not relevant during the prenatal and early neonatal period. This supports the hypothesis that biological factors are important in determining infant welfare during this period.

No interaction was identified between the standard of living index, which represents the socio-economic status of the household, and birth spacing. This is a more direct indicator of economic welfare than maternal education and it is, thus, likely that the effect of maternal education primarily relates to autonomy and behavioural factors rather than an association between maternal education and socio-economic status.

The results showed that the survival status of the previous sibling also influenced the detrimental effect of short birth intervals. If the previous sibling died, the index child suffered an unexpectedly high risk of mortality in the neonatal period. This association has been identified in previous literature and has been attributed to the correlated risk of mortality suffered by children within the same family (Curtis, 1992). Such children share similar biological and environmental factors, which may influence their survival prospects. The combination of the adverse effect of a short birth interval and the increased familial risk, culminate in the unexpectedly high risk of mortality shown by the interaction.

In contrast, during the post-neonatal period the death of the previous sibling significantly reduces the effect of short birth intervals. This could indicate that competition between siblings, or exposure to infectious disease, is a causal mechanism and that the death of the previous sibling removes this effect. The benefits gained by the removal of competition, are greater during the post-neonatal period than the increased mortality risk of the family. This interaction is not significant in the childhood period, however, again indicating that effects seem to be stronger in the more vulnerable early post-neonatal period. The change in the direction in the mediating effect of the death of the previous sibling has documented in previous research (Curtis, 1992; Alam, 1995).

During the childhood period the gender of the index child influences the birth interval effect, such that girls born after a short birth interval suffer a much greater increase in mortality risk than a boy. Authors who have analysed gender differences in mortality rates have found that differentials are often large between the ages of one and five years

(Waldron, 1983; D'Souza and Chen, 1980, cited in Griffiths, 1997). It has been suggested that this reflects the practise of gender preference, whereby less priority is given to a girl, particularly if resources are scarce. It has been found, for example, that girls are less likely to be taken to a health care centre for treatment of illness than boys (Hill and Upchurch, 1995). Also, analyses which have investigated intra-household resource allocation within developing countries, have found evidence of "investment strategy" whereby children who provide the greatest returns receive preferential treatment when resources are scarce (Behraman, 1988; Ralston, 1997). Male children were found to be valued more highly than female children (Ralston, 1997) and older children more so than younger children. This was particularly so if births were closely spaced. A girl following a short birth interval is thus likely to be given lower priority than a boy. As the interaction is only significant in the childhood period, it is apparent that this effect becomes acute as the child is weaned and thus may relate primarily to nutritional intake.

7.4.3 Other Significant Correlates of Mortality

Other significant correlates were in keeping with the results of the analysis of Karnataka in Chapter 6. Premature delivery and small size at birth were associated with higher mortality risk for all three period analysed, although the effect was strongest in the neonatal period for both. This relationship is likely to reflect the immature, or compromised, development of the infant, at birth, and inability to adapt to the outside environment. Clearly, the disadvantage continues during early childhood. Failure of the mother to receive a tetanus injection during pregnancy was also associated with a higher mortality risk, for all periods of the analysis. This could reflect health care use of the family and thus more general welfare.

Children who lived in the northern states of India suffered higher mortality than their southern counterparts, and this effect became increasingly strong for each successive period analysed. Such geographical disparities have been previously identified and have been attributed to economic factors, welfare provision and a greater adherence to traditional customs which limit the status and autonomy of women (Grffiths, 1998).

The economic welfare of the household, measured by the standard of living index, was found to be negatively associated mortality in the neonatal and post-neonatal periods but not during childhood. This possibly reflects maternal nutrition during pregnancy and lactation, as well as the environment and resource availability of the infant. The lack of association during the early period is not as expected but could reflect a selective effect where the more vulnerable children die during early infancy. As found in the analysis of Karnataka, household density was negatively associated with mortality risk. It is thus likely that the variable reflects factors such as the availability of childcare rather than crowding or general welfare.

Finally maternal age at birth was associated with neonatal mortality such that infants of teenage or older women were at increased risk. This is in keeping with the results of previous literature and with the analysis of mortality in Karnataka (Chapter 6).

Summary

This analysis has shown that there is a strong relationship between the length of the preceding birth interval and the risk of mortality amongst children in India, up to the age of two years. The relationship was significant for all the mortality periods analysed, but was shown to be strongest in the post-neonatal period. This suggests that although maternal depletion has a role within the relationship, behavioural factors are the more dominant pathway, particularly during the more vulnerable early post-neonatal period.

The analysis has used interaction terms to explore the causal mechanisms behind the birth interval, mortality relationship. Maternal education was found to interact with birth intervals, such that children following a short birth interval and of illiterate women suffered an unexpectedly high mortality risk. Maternal illiteracy thus exacerbated the adverse effect of a short birth interval. Conversely, the adverse effect of a short birth interval was minimised if the mother received high school education. The mediating effect was only apparent during the post-neonatal and early childhood periods, however, indicating that behavioural associations with high school education offset the birth interval effect.

The death of the previous sibling also demonstrated a mediating effect within the relationship between short birth intervals and child mortality. The effect varied by the period of mortality under analysis. During the neonatal period, a child who followed a short birth interval and whose previous sibling died showed an unexpectedly high risk of mortality. It is likely that a correlated mortality risk occurs between siblings and that this high risk factor exacerbated the short birth interval effect. During the post-neonatal period, however, a child who followed a short birth interval and whose previous sibling died demonstrated a lower risk of mortality. It is possible that for this age group of children the benefit of not having to compete for resources outweighs the family correlated risk of mortality.

Finally the effect of a short birth interval was found to be more acute in the early childhood period for girls than for boys. This may reflect the practise of gender preference and investment strategies in resource allocation. A girl following a short birth interval would be of least value for future returns.

CHAPTER 8

Summary and Conclusions

8.1 The Objectives and Overall Achievements of the Thesis

The association between short birth intervals and child mortality has been well established and persists across many countries of different socio-economic and cultural setting. In theory this excess mortality is avoidable through the adoption of appropriate family planning practices. Birth intervals of less than 24 months remain highly prevalent, however, despite initiatives by family planning programs to promote the spacing of births for maternal and child health. It is important, therefore, that knowledge is generated concerning the mechanisms of the relationship so that the harm suffered by mothers and their children, as a result of short birth intervals, can be minimised. Although much academic research has sought to quantify and explain the relationship, many uncertainties remain concerning its causal pathways.

The main objective of this thesis has thus been to investigate the causal pathways within the relationship between short birth intervals and child survival. The analysis of child health, rather than mortality, has provided a more direct and sensitive indication of circumstances, which are disadvantageous to the wellbeing of the child. Weight measurements were used as a proxy for infant health, reflecting both long and short-term welfare. The observations, expressed as WAZ scores, represent the relative advantage or disadvantage of the sample population in comparison to a reference population.

Two analyses of anthropometric assessment were conducted, one using cross-sectional data and the other using longitudinal data. Each approach provided specific strengths, in terms of analytical and explanatory power. The larger sample attained by a cross-sectional survey was perhaps more representative of the population of Karnataka, India. In addition, it included children across a wider age range, and thus enabled the analysis of birth interval effects into early childhood. The longitudinal approach, on the other hand, allowed the dynamics of change over the first year of life to be assessed, and thus provided greater explanatory power. The surveys were both conducted within the State of Karnataka, so could be used to compliment each other.

This research also includes an analysis of child mortality in the State of Karnataka. This was conducted for main two reasons. Firstly, to provide a wider context in which to understand birth interval effects and secondly, to assess the potential bias caused by the lack of information on infant deaths within the analysis of anthropometric status. The analysis was limited in its ability to meet the first objective, as strength of inference was lost owing to the relatively rare event of death. This was particularly so for the analysis of post-neonatal and early childhood mortality. The final analysis of child mortality within the whole of India has overcome this problem. It has enabled a detailed examination of interactions within the relationship between short birth intervals and infant mortality, for specific age groups of children during infancy and early childhood. This has illuminated key mediating factors within the relationship thus enhancing the understanding of causal mechanisms.

8.2 Summary of Results

8.2.1 Cross-sectional Analysis of Weight-for-Age Z Scores

The results of the cross-section analysis of anthropometric assessment show that the children of rural Karnataka are considerably less well nourished than the reference population. The average WAZ score at birth is lower and this deficit increases for successive age groups during infancy before stabilising at around -1.5 standard deviations. This indicates that many children receive a comparatively poor nutritional intake and suffer a higher prevalence of disease.

Short birth intervals are significantly associated with WAZ scores, although the effect varies with the age of child. For children under one year of age, there is little difference between those following short and long birth intervals. A negative association increases in magnitude, however, for children aged between 12 and 36 months. This indicates that exogenous factors associated with short birth intervals are detrimental to the welfare of the child. It is intuitive that the detrimental effect of such factors are likely to become more acute for children during later infancy and early childhood, as the nutritional requirements become more complex and as the child becomes mobile increasing exposure to pathogens and to physical danger. However, with cross-sectional data, age, or time effects cannot be disentangled from cohort effects and thus the analysis is limited in its capacity to support such a hypothesis.

Other significant covariates included breast-feeding behaviour and the introduction of solid foods, recent incidence of diarrhoea, size at birth, place of delivery, maternal education, death of the previous sibling, number of children under 5 years of age within the household and type of household construction. Interactions between the previous birth interval and the other covariates were insignificant. A multilevel model was used for the analysis in order to account for the hierarchical structure of the data. The unexplained variance was found to be significantly correlated at the household level, indicating that the nutritional status of children within households tend to be similar even after controlling for the explanatory variables at this level. Nevertheless, variation at the child level accounts for by far the greater proportion of total variation.

8.2.2 Longitudinal Anthropometric Analysis

The longitudinal analysis of weight measurements also showed that the infants in the study villages had lower WAZ scores than those of the reference population. The relative disadvantage varied, as the children progressed through their first year of life. For infants following long birth intervals the WAZ score increased sharply over the first three months indicating that the babies thrive well during early infancy. This may reflect the predominance of breast-feeding and possibly a strong adherence to the cultural practice of bananthana, which promotes seclusion of the woman and infant following the birth and ensures a period of rest. After approximately four months, however, the WAZ scores show a steep and consistent decline.

The mean WAZ score at birth for infants following short birth intervals was similar to that for infants following long birth intervals. This suggests that prenatal conditions associated with birth spacing do not influence the weight gain of the fetus. A previous birth interval of less than two years, however, was significantly associated with lower WAZ scores during early infancy and at the end of the first year. Infants following a short birth interval, thus, appear to thrive less well during the first three to four months of life. This could indicate that either milk production is impaired, or that the breast-feeding behaviour is different from that of women who had a longer birth interval. The disadvantage suffered by infants following short birth intervals is also demonstrated by a continued decline in the WAZ scores at the end of the first year. This could be indicative of the need to compete for resources and for maternal care and attention.

Interactions were identified between short birth intervals and the death of previous siblings, maternal height and maternal education. If two or more previous siblings had died, the WAZ score was shown to be lower throughout the year. It is likely that this reflects a correlated mortality risk suffered by children within the same family. Such children share the same biological and environmental factors, which influence their welfare and ultimately their survival prospects. It is hypothesised that these high-risk familial characteristics, exacerbate the short birth interval effect, culminating in an infant who fails to thrive.

Also for infants who follow short birth intervals, there is no association between maternal height and WAZ score, whilst for infants who follow long birth intervals there is a significant positive association. The genetic height potential of an individual is a characteristic partially inherited from the parents, but the ability to meet this potential is influenced by the health and nutritional status of the individual. The results therefore indicate that infants following a short birth interval, fail to thrive and thus do not attain their genetic growth potential.

Finally the effect of maternal education on the WAZ scores was also shown to differ by the previous birth interval. Whilst primary education was associated with low WAZ scores for infants following long birth intervals, high school education was associated with low scores for infants following short birth intervals. Both these findings are contrary to the results of previous literature, which has found that maternal education at any level has a positive association with infant or child survival. It is possible, however, that primary education is associated with support for traditional customs, which are detrimental to the welfare of the child and that infants following short birth intervals do not survive the accumulation of these detrimental influences. Alternatively, the mother may pay less attention to such traditions when they have other young children to care for. The strong negative interaction between high school education and short birth intervals could possibly result from a lower mortality risk suffered by infants whose mothers received high school education. These children who clearly have thrived less well, may have died had the mothers been less well educated.

Other significant correlates of WAZ scores in the longitudinal analysis included first born infants, the season of birth, the caste of the head of household, paternal education and maternal occupation. For this analysis, it was necessary to use a modelling technique which accounted for the correlation between of the repeated observations for individuals within the data. A covariance structure was evident whereby the correlation between such observations decayed with an increasing time lag, and also with the age of child.

8.2.3 Comparison of the Cross-sectional and Longitudinal Models for Child Weight-for-Age Z scores

This section compares the results of the longitudinal and cross-sectional models of anthropometric measurements of children in Karnataka. The longitudinal analysis would be expected to have greater scope in explaining temporal effects. However, the number of individuals included in the survey is relatively small owing to financial and logistical limitations of collecting repeated observations for each individual. Strength of inference across individuals may, therefore, be lost and significant associations may be missed. The cross-sectional analysis, on the other hand, includes a greater number of individuals and would thus have greater statistical power to identify factors associated with WAZ scores.

Table 8.1 compares the results of the longitudinal and cross-sectional models of WAZ scores. In both models a cubic model of WAZ scores by the age of the child was highly significant. Clearly the age of the child is very important in explaining the variation in WAZ scores. Figures 8.1 and 8.2 compare the estimated WAZ scores of the average child by age for each analysis. The estimated WAZ score at birth is considerably lower in the longitudinal data than in the cross-sectional data. The longitudinal analysis, however, demonstrates an increase in WAZ score during the first 3 to 4 months following birth, whilst the cross-sectional data demonstrates a decline. This could reflect particular circumstances or behaviour peculiar to the community within these villages. For example it could be that the cultural practices such as fasting during pregnancy and bananthana (see section 5.10 for description) are adhered to more strictly, than in Karnataka as a whole. Both practices could have an impact on the weight change of the fetus or infant.

Table 8.1 Comparison of Results for the Cross-sectional and Longitudinal Models for WAZ Scores

a) Main Effects Significant in Both Models

Parameter	Cross-sectional	Longitudinal
Age in Months		
Age	↑	↑
Age squared	↓	↓
Age cubed	↑	↑
Previous Birth Interval		
LBI (24 months or more)	Ref	Ref
SBI (< 24 months)	↑	↑
First birth	↓	↓
Interaction with Age		
SBI x Age	↓	↓
SBI x Age squared	NS	↑
SBI x Age cubed	NS	↓
First birth x Age	NS	↓
First birth x Age squared	NS	↑
First birth x Age cubed	NS	↓
Maternal Education		
Illiterate	Ref	Ref
Primary	↑	↓
Middle	↑	↓
High	↑	↑
Sibling deaths		
Number of deaths / two plus died	↑	↓
Interaction with Age		
Deaths x Age	↓	NS
Deaths x Age squared	↑	NS

b) Significant in Cross-sectional Model Only

Parameter	Cross-sectional	Longitudinal
Size at Birth (Mothers opinion)		
Average or large	Ref	
Small	↓	NS
Recent Morbidity		
No diarrhoea	Ref	
Diarrhoea in past two weeks	↑	NS
Interact with Age		
Diarrhoea x Age	↓	
Diarrhoea x Age squared	↑	NS
Diarrhoea x Age cubed	↓	NS
Hospital Delivery		
No	Ref	
Yes	↑	NS

Continued below

Table 8.1 (b) Continued

b) Significant in Cross-sectional Model Only

Parameter	Cross-sectional	Longitudinal
Children within Household		
Under 5 years	↓	NS
Feeding		
Not breastfeeding	Ref	
Breastfeeding	↑	U
Weaning appropriate for age	Ref	
Not appropriate for age	↓	U
Interaction with Age		
Breastfeeding x Age	↓	U
Breastfeeding x Age squared	↑	U
House Construction		
Katcha	Ref	
Pucca	↑	U
Semi pucca	↑	U

c) Significant in Longitudinal Model Only

Parameter	Cross-sectional	Longitudinal
Season at Birth		
Winter		Ref
Summer	NS	↓
SW Monsson	NS	↓
NE Monsoon	NS	↓
Maternal Occupation		
Housework/ child care		Ref
Agricultural work	NS	↑
Other	NS	↓
Interaction with Age		
Agricultural work x Age	NS	↑
Agricultural work x Age squared	NS	↓
Agricultural work x Age cubed	NS	↑
Other x Age	NS	↓
Other x Age squared	NS	↑
Other x Age cubed	NS	↓
Paternal Education		
Illiterate		Ref
Primary	NS	↓
Middle	NS	↑
High	NS	↑
Caste		
Gowda		Ref
Lingayath	NS	↑
Madiga & Holeya	NS	↓
Lambani	NS	↑
Others	NS	↑

Table 8.1 (b) Continued

c) Significant in Longitudinal Model Only

Parameter	Cross-sectional	Longitudinal
Interaction with age		
Lingayath x Age	NS	↓
Lingayath x Age squared	NS	↑
Lingayath x Age cubed	NS	↓
Madiga & Holeya x Age	NS	↓
Madiga & Holeya x Age squared	NS	↑
Madiga & Holeya x Age cubed	NS	↑
Lambani x Age	NS	↓
Lambanix Age squared	NS	↑
Lambanix Age cubed	NS	↓
Others x Age	NS	↓
Others x Age squared	NS	↑
Others x Age cubed	NS	↑
Mothers Height		
Difference from average	NS	↑
Interaction with Age		
Maternal height x Age	NS	↑
Interactions between covariates		
SBI x Maternal Height	U	↓
SBI x Death of Previous Siblings	NS	↓
SBI x Maternal Education		
Primary	NS	↑
Middle	NS	↑
High	NS	↓

Key: Ref – Reference category, NS – Not significant, U – Unavailable

Arrows indicate direction of significant effects

Figure 8.1

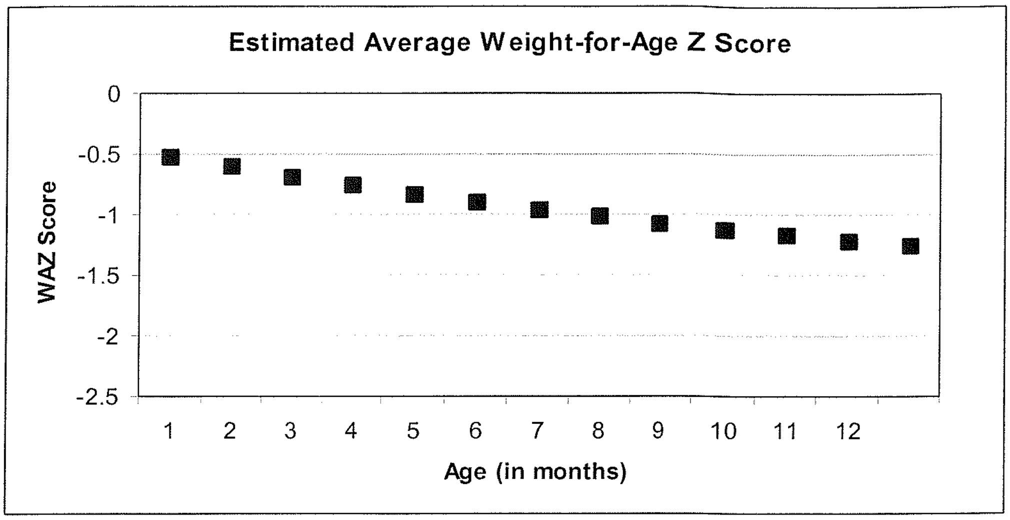
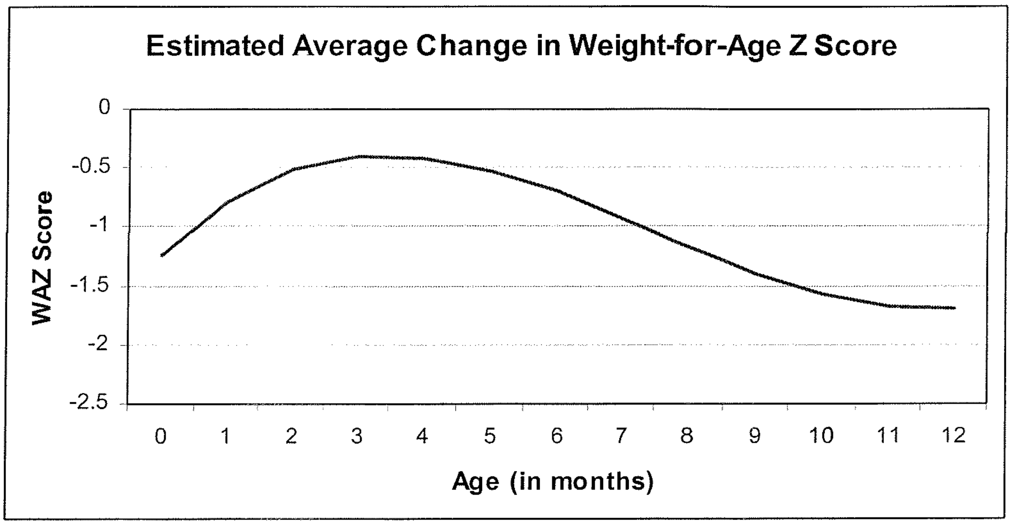


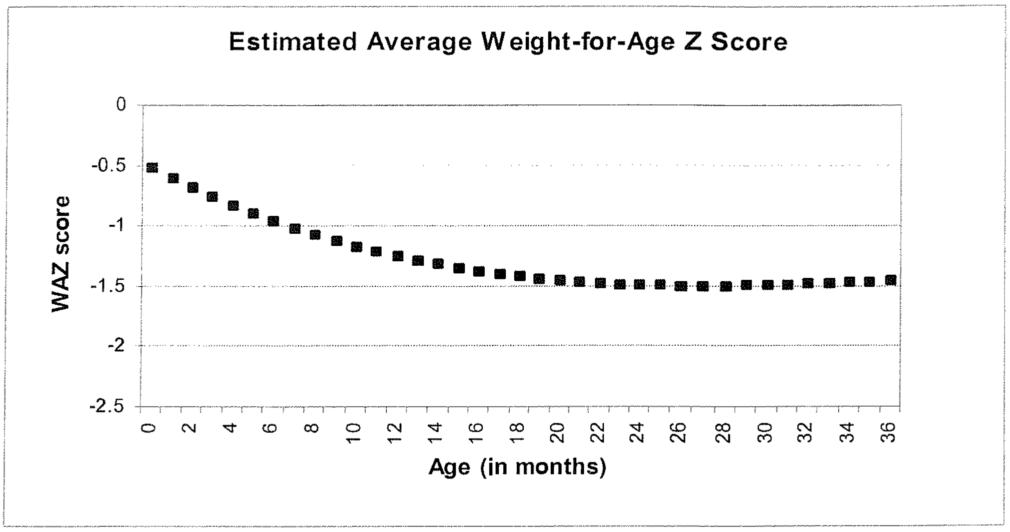
Figure 8.2



Alternatively the difference in the weight curves shown in figures 8.1 and 8.2 could result from a cohort effect. The longitudinal data consists of a cohort of infants born within a given time period. The lower average birth weight of the infants in the longitudinal study could, therefore, have occurred because food availability was poor whilst the cohort of mothers where pregnant. This situation might occur though crop failure, for example. The cross-sectional analysis averages across cohorts so would be relatively unaffected by such an event.

Both models demonstrate a decline in WAZ score over the second half of the year, so that the nutritional status is poorer, relative to the reference population, at the end of the first year of life, compared to that at birth. The effect is evident in both analyses strongly indicating that the exogenous circumstances in which the children exist are detrimental to nutritional status during late infancy. This is a period of time when most children are weaned form breast milk to solid foods and when they become more mobile. Figure 8.3 shows the average WAZ scores, estimated in the cross-sectional analysis, for children between the ages of 0 and 36 months. The decline in WAZ scores becomes much less acute for each successive age group between 12 to 24 months and then stabilises for children between the ages of 24 and 36 months. This pattern is supported by the longitudinal analysis in which the decline in WAZ scores stabilises at months 11 to 12.

Figure 8.3



Short birth intervals were significantly associated with WAZ scores in both models thus confirming the importance of birth spacing as an associate of infant and child nutritional status. Additionally an interaction between short birth intervals and the age of the child was significant in both models, although interactions with the quadratic and cubic terms for age were only significant in the longitudinal analysis. This reflects the different shape of the curve in the longitudinal analysis for those following short birth intervals compared to those following longer intervals. Figures 8.4 and 8.5 demonstrate the effect of short birth intervals on the WAZ scores in both analyses. The estimated average WAZ score at birth was unaffected by the previous birth interval, in both models, suggesting that any difference in the intrauterine environment has little effect on fetal weight gain. Alternatively, it is possible that such effects are masked by the higher mortality risk of infants following short birth intervals. In the cross-sectional data there is little birth interval effect for those aged between 0 and 12 months. For the longitudinal data, however, the average WAZ score for infants following short birth intervals fails to increase during the very early months as it does for those following longer intervals. Also at the end of the first year of life the average WAZ score continues to decline for infants following short birth intervals, whilst it levels off for those following long intervals.

Figure 8.4

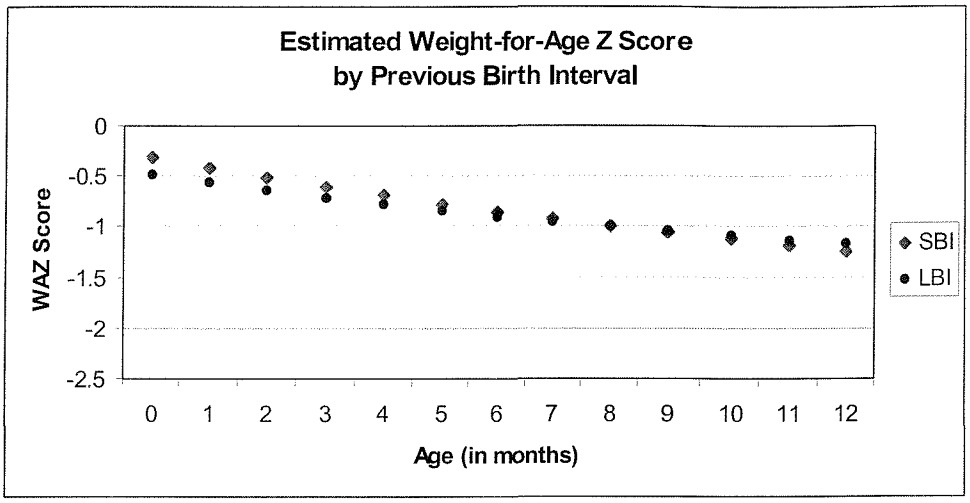
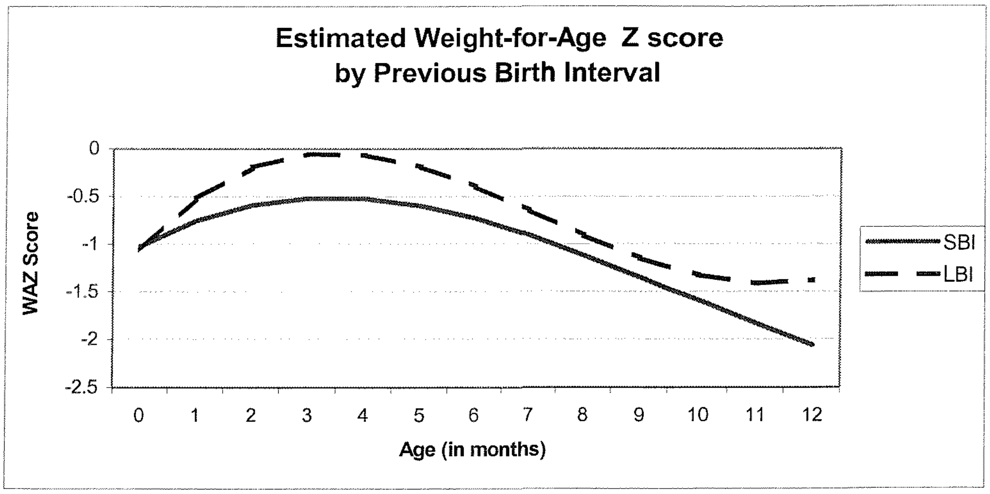
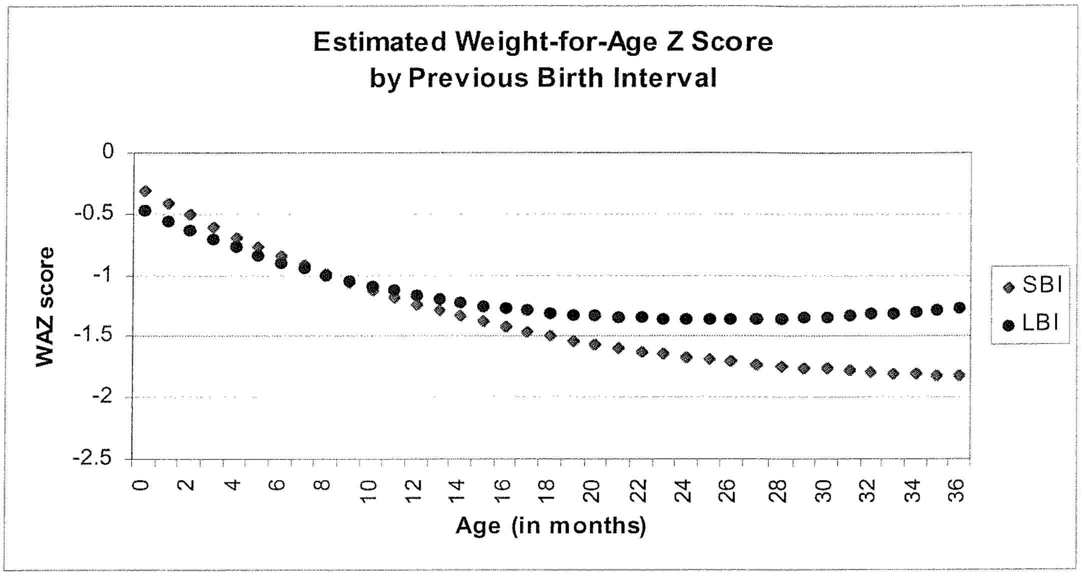


Figure 8.5



This again gives some support to the patterns shown by the cross-sectional data for children in their second and third years of life, indicating that it may not be unreasonable to interpret the curves as change in WAZ score. Figure 8.6 shows that for children aged between 24 to 36 months, the average WAZ score of those following short birth intervals continues to decline with age, increasing the deficit between those following longer intervals. The fact that the difference is particularly marked during late infancy and early childhood in both analyses strongly supports the hypothesis that competition between siblings is an important mechanism within the relationship between short birth intervals and child health.

Figure 8.6



Other covariates which were significantly associated with WAZ scores in both models included first births, maternal education and the death of previous siblings. These factors are also clearly important determinants of WAZ scores. An interaction between first births and the age of the child was evident in the longitudinal analysis and between the death of previous siblings and the age of the child the cross-sectional analysis. A possible reason why the interaction between the death of previous siblings and the age of the child was not significant in the longitudinal analysis, is that the data includes observations for the first year of life only. The difference in effect by the age of the child age is greatest for children between the ages of 18 to 24 months (See Figure 4.10). The difference in effect by the age of the child may not have been great enough to appear significant for children of 12 months or less.

Covariates which were significant only in the cross-sectional analysis included size at birth, recent morbidity, hospital delivery and the number of children under 5 years within the household. It is possible that for these factors, the lack of significance in the longitudinal data reflects the lack of power across individuals and they would indeed have been significant if a larger sample had been used. Additionally the size of the infant at birth may not be significant in the longitudinal data because observations for the WAZ scores soon after birth were included, and the serial correlation was accounted for in the modelling technique used. Factors related to the genetic growth trajectory of individuals will thus be weaker in a longitudinal analysis.

It was expected that the longitudinal analysis would be sensitive to recent morbidity as the data included repeated observations for individuals. Measurements before and after the episode of morbidity were thus included. The insignificance of recent morbidity in the model, however, may reflect the time period used to represent "recent". In the longitudinal analysis information was recorded for episodes of morbidity since the previous observation (approximately one month), whilst for the cross-sectional data episodes of morbidity were recorded for the previous two weeks only. Wasting is very transient in nature (see section 2.8) and thus infants would be likely to recover any deterioration the WAZ score soon after the illness.

Data were unavailable in the longitudinal analysis for the feeding regime of the infant. Variables representing breast-feeding behaviour and the age at weaning, were however, significantly associated with WAZ scores in the cross-sectional data. Nutritional intake and how appropriate it is for the age of the child are clearly likely to be an important determinants of nutritional status and would be expected to be significant in a longitudinal analysis.

Covariates which were significant only in the longitudinal analysis included season at birth, maternal occupation, paternal education and caste. It is possible that for these variables the particular circumstances of children living within the villages of Kanakpura are different to those of children in Karnataka as a whole and the association is lost in the larger data set. The villages of Kanakpura are fairly near Bangalore, for example, there may be opportunities for more educated fathers which improve their socio-economic status and general welfare. The cross-sectional analysis provides an average across areas and across cohorts, so is more generalisable.

Alternatively the longitudinal aspect of the data may be more sensitive in identifying particular correlates. Season at birth, for example, incorporates a strong time element; the external environmental characteristics which accompany a given season, clearly effect the nutritional status of children at specific periods of development. The repeated observations of longitudinal data are likely to have greater sensitivity since the data also includes observations for the same individuals at other seasons also.

For maternal occupation a strong interaction with the age of the child was significant so that infants of mothers who were agricultural workers demonstrated a very different pattern of weight change compared to those whose mothers worked primarily in the household or in other occupations (Figure 5.22). It is possible that this strong time element within the relationship could only be captured in longitudinal data.

Finally for the variable representing caste, different classifications were used in the longitudinal and cross-sectional data. The cross-sectional data used categories for broad groups of caste i.e. whether scheduled or unscheduled. The longitudinal data, however, included categories for individual caste groups. Classifications of individual caste groups will provide a less diluted representation of specific characteristics than the broader aggregate categories. Additionally, as with maternal occupation there was a strong interaction between caste and the age of the child. Again it is possible that longitudinally collected data is better placed to capture these effects.

The mothers height was significantly associated with WAZ score in the longitudinal analysis but was unavailable in the cross-sectional data. This variable would be expected to be a significant correlate of nutritional status since it reflects not only the genetic characteristics of the mother but also long term socio-economic welfare. It is likely that it would be significant if included in the cross-sectional data.

Finally interactions were identified between short birth intervals and the covariates; maternal education and the death of pervious siblings in the longitudinal analysis but not in the cross-sectional analysis. This is contrary to expectation as it was expected that the larger sample size of the cross-sectional data would provide greater statistical strength with which to identify such effects.

8.2.4 Infant and Child Mortality in Karnataka

The analysis of child mortality in Karnataka showed that a previous birth interval of less than 2 years was significantly associated with neonatal mortality risk but not with post-neonatal or childhood mortality. The results of this analysis, therefore, suggest that the pathways through which short birth intervals effect child mortality function primarily through the prenatal period, or very early infancy. A closer examination of the timing of neonatal deaths by the previous birth interval, showed that for infants following short birth intervals, deaths occur immediately following birth or within the first day. This indicates that fetal development is compromised and that the infant is less able to cope with the outside environment following the birth.

Over and above the effect of short birth intervals, premature births and small size at birth were associated with an increase neonatal mortality risk. It is likely that these factors also reflect the immature development of the infant and decreased ability to adjust to the outside environment upon birth. Other significant associates of mortality in Karnataka included the child's age, gender, maternal age, maternal education, paternal education and density of the household. Although the data was hierarchical in structure, multilevel models were not employed owing to the relative rarity of death and the small numbers occurring within clusters.

The results of the anthropometric analyses potentially suffer bias because observations for children who have died were not available. The analysis of infant mortality for the state of Karnataka shows that the size of the child at birth, as reported by the mother, was associated with neonatal mortality risk. In this case the WAZ scores for children aged less than one month would be lower in reality than shown by the estimated scores attained from the anthropometric analyses. If a three-way relationship existed between short birth intervals, WAZ scores and mortality, then the results shown for the effect of short birth intervals would also be biased. The analysis of mortality identified a relationship between short birth intervals and neonatal mortality risk but the cross tabulation of the previous birth interval by the size of the infant at birth provided no evidence of an association between short birth intervals and WAZ score. This suggests that the results shown for the birth interval effects may be unaffected by the lack of information on children who subsequently died.

For an effective assessment of bias after the neonatal period is only possible if data is available concerning the weights of the children before death. The magnitude of effect is likely less than that for the neonatal period, however, owing the lower prevalence of mortality.

8.2.5 Infant and Child Mortality in India

The analysis of child mortality for the whole of India showed a significant relationship between the length of the preceding birth interval and the risk of mortality amongst children in all three of the periods analysed, i.e. neonatal, early post-neonatal and early childhood. The relationship was shown to be strongest in the post-neonatal period, however. This suggests that although prenatal conditions are likely to function within the relationship, exogenous factors of are also of considerable importance, particularly during the vulnerable early post-neonatal period.

The analysis has used interaction terms to explore the causal mechanisms within the birth interval, mortality relationship. Maternal education was found to interact with birth intervals, such that children following a short birth interval and of an illiterate mother suffered an unexpectedly high mortality risk. Maternal illiteracy, thus, exacerbated the adverse effect of a short birth interval or vice versa. Conversely, the adverse effect of a short birth interval was minimised if the mother received high school education. The mediating effect was strongest during the post-neonatal and early childhood periods, however, indicating that behavioural associations with maternal education influence the birth interval effect.

The death of the previous sibling also demonstrated a mediating effect within the relationship and again the effect varied by the period of mortality under analysis. During the neonatal period, a child who followed a short birth interval and whose previous sibling died showed an unexpectedly high risk of mortality. It is likely that a correlated mortality risk occurs between siblings and that this high risk factor exacerbated the short birth interval effect. During the post-neonatal period, however, a child who followed a short birth interval and whose previous sibling died demonstrated a lower risk of mortality. It is possible that for this age group of children the benefits of not having to compete for resources, or for maternal care and attention, outweigh the increased familial mortality risk. The effect of a short birth interval was also found to be more acute in the early childhood period for girls than for boys. This may reflect the practice of gender preference and investment strategies in resource allocation. A girl following a short birth interval would be of least value for future returns and thus deserve lower priority in resource allocation. The results of these interactions suggest that children following short birth intervals are more vulnerable than those following longer intervals, such that an accumulation of less favourable circumstances culminates in an unexpectedly high mortality risk whilst more favourable circumstances dilute any disadvantage suffered.

Other correlates of mortality in India included gestation at birth, birth weight, geographical location, maternal age, whether the mother received a prenatal tetanus injection, the socio-economic status of the household, household density and the availability of piped water to the household. Multilevel models were used for this analysis to control for the hierarchical structure within the data. Levels were included to account for clustering within families and villages. Clustering was significant at the village level for neonatal mortality but was insignificant in the models for post-neonatal and early childhood mortality.

8.2.6 Comparison of the Models for Infant and Child Mortality for the State of Karnataka and for India

This section compares the results of the models for mortality in the state of Karnataka (Chapter 6) and for the whole of India (Chapter 7). The analysis for Karnataka provided a wider understanding of infant health and survival within the state, thus complimenting the anthropometric analyses. The data used is considerably smaller than that used for the analysis of India as a whole and is more specific in its representation. The results are applicable only to individuals who live within the economic, social and environmental circumstances characteristic of Karnataka. As mortality is a relatively rare event this analysis may be expected to miss significant associations owing to the lack of statistical power. This is particularly so for associates of mortality during the post-neonatal and early childhood periods. The data set for India as a whole is large, facilitating an extensive and detailed investigation of factors associated with mortality, including interactions between covariates. The results of the analysis are much more generalisable representing a population of diverse socio-economic and cultural settings.

Table 8.2 shows a comparison of results for the models of neonatal mortality in Karnataka and India. Short birth intervals were significant in both models confirming their association with neonatal mortality. Other variables which were significant in both models included the size of the infant at birth, premature delivery, young maternal age at birth, the death of the previous sibling and household density. These factors are also clearly important determinants of mortality, indeed their association with early childhood survival has been well documented in previous literature (Mosely and Chen, 1984; Bhatia, 1989; United Nations, 1991)

Variables, which were only significant in the model for India, included maternal education, type of water supply and whether the mother received antenatal care. These variables may have been missed in the analysis of Karnataka owing to the lack of statistical power and possibly a weaker association. They relate more closely to socio-economic welfare and behavoural factors, whilst those significant in both models relate more closely to bio-demographic factors. The relative importance of bio-demographic associates of mortality during the neonatal period and socio-economic factors during later infancy and early childhood have been well documented (Bhatia, 1989). Interactions between short birth intervals and covariates for maternal education and the survival of previous siblings were also significant in the model for India but were insignificant in the model for Karnataka. It is likely that the greater statistical power attained by the large sample size included in the data for India as a whole has facilitated the analysis of more complex associations.

Two covariates were significantly associated with neonatal mortality only in the analysis for Karnataka. These included the gender of the infant and paternal education. These associations may specifically reflect characteristics of population of Karnataka and have become lost in the diversity of the population characteristic included in the data for the whole of India. Female infants, for example, are known to have a lower mortality risk during the early neonatal period owing to their more robust constitution (Griffiths, 1999). Cultural practises within India, however, commonly favour male children and can lead to discrimination against female infants (Griffiths, 1999). Some populations within India adhere more closely to such cultural traditions and behaviours than others. In these states the more robust constitution of the female infant may be counteracted by the disadvantage caused by gender discrimination.

Table 8.2 Comparison of Results for the Analyses of Neonatal Mortality in Karnataka and India

a) Effects Significant in Both Models

Parameter	Karnataka	India
Previous Birth Interval		
LBI (24 months or more)	Ref	Ref
SBI (< 24 months)	↑	↑
First birth	NS	U
Multiple birth	↑	U
Size at Birth (Mothers opinion)		
Average	Ref	Ref
Small	↑	↑
Large	NS	↑
Gestation at Birth		
Full term	Ref	Ref
Premature	↑	↑
Maternal Age at Birth		
<20 years	↑	↑
20+ years	Ref	Ref
Death of Previous Sibling		
Survived	Ref	Ref
Died	↑	↑
Household Density		
Low	Ref	Ref
Average	↓	↓
High	↓	↓

b) Effects Significant in the Model for Karnataka Only

Parameter	Karnataka	India
Gender		
Boy	Ref	Ref
Girl	↓	NS
Paternal Education		
Uneducated	Ref	Ref
Educated (at primary level of above)	↓	NS

Continued below

Table 8.2 continued

Parameter	Karnataka	India
c) Effects Significant only in the Model for India		
Maternal Education		
Illiterate	NS	↑
Primary / middle	NS	Ref
High	NS	NS
Standard of Living Index		
Rich		Ref
Upper middle		NS
Middle	U	NS
Lower middle		↑
Poor		↑
Water Supply		
Other	Ref	Ref
Piped	NS	↑
Received Antenatal Tetanus		
Yes	Ref	Ref
No	NS	↑
Received Antenatal Care		
Yes	Ref	Ref
No	NS	↓
Location		
North	Ref	Ref
South	U	↓
Interactions		
Short Birth interval * Survival Previous Sibling	NS	Sig
Short Birth Interval * Maternal Education	NS	Sig
Random Effects		
Family Level	NS	NS
Community Level	U	Sig

Key				
	Ref -	Reference category	NS -	Not significant
	Sig -	Significant	U -	Unavailable

The significance of paternal education may reflect specific opportunities available to educated men within Karnataka and thus reflect socio-economic welfare. The analysis for India includes a standard of living index, which would provide a more direct representation of socio-economic status. This was not included in the analysis for Karnataka.

The models for mortality during post-neonatal and childhood periods were combined in the analysis for Karnataka owing to the small sample size and the relative rarity of death during this period. Significant covariates included the age of the child, multiple births, maternal age at birth and maternal education. Short birth intervals were not significantly associated with mortality risk in this period. The significance of the age of the child most likely reflects the wide age range of children included in the analysis and the changing mortality risk between early infancy and childhood. The remaining covariates are clearly important associates of child mortality for the population of Karnataka.

The models for the analysis for India were conducted separately for the neonatal, early post-neonatal and childhood periods. Short birth intervals were significantly associated with mortality risk in all three periods. This is contrary to the results of the analysis for the state of Karnataka, in which the relationship was only significant in the neonatal period. Karnataka is a relatively forward state in terms of development and welfare provision. Other states demonstrate much lower attainment in welfare indicators (see section 1.4). If short birth intervals cause the child to become more vulnerable, the accumulation of such disadvantage may culminate in the increased mortality risk for infants during the post-neonatal and early childhood periods. For Karnataka these wider circumstances are less disadvantageous and thus the effect of a short birth interval is less likely to culminate in death. Such children do fail to thrive, however, as shown by their comparatively low nutritional status in Chapters 4 and 5.

This hypothesis is supported by the significance of interactions evident within the models for India. As with the neonatal mortality period the mortality risk is particularly high for an infant who follows a short birth interval and whose mother is illiterate, but is average for an infant whose mother attained high school education. Similarly the post-neonatal mortality risk of a child following a short birth interval is exceptionally high if the family has a history of child deaths. Finally, childhood mortality risk is considerably more severe for a girl following a short birth interval than a boy. Clearly the accumulation of such risk factors compound upon each other multiplying the mortality risk.

8.3 Conclusion

The analyses of child nutritional status show that the socio-economic and environmental circumstances of the children of Karnataka cause them disadvantage in terms of nutritional status in comparison with the reference population. This is particularly so during late infancy when the deficit in weight attainment increases before stabilsing during early childhood.

Short birth intervals are clearly important as an associate of child nutritional status although the effect varies with the age of the child. Little difference was evident in the birth weight of infants by the previous birth interval. This suggests that any difference in the intrauterine environment resulting from maternal depletion does not influence the weight gain of the fetus. The disadvantage suffered by infants following short birth intervals, however, is demonstrated by an increasing deficit in weight attainment at the end of the first year of life and continuing into early childhood. Exogenous factors associated with short birth intervals are clearly detrimental to the welfare of the child causing failure to thrive. This becomes particularly acute during late infancy as the nutritional requirements become more complex and as the child becomes mobile, increasing exposure to pathogens and physical danger.

The analyses of child mortality confirmed the relationship between short birth intervals and neonatal mortality. The early timing of these deaths suggests that the prenatal environment may well affect infant develop even though weight gain remains unaffected. These infants are clearly vulnerable during the early neonatal period and are less able to adapt to their environment following birth. The analysis of mortality within India also demonstrated a significant association between short birth intervals and mortality after the neonatal period and indeed the relationship was found to be strongest during the early post neonatal period.

Furthermore the risk of mortality was found to be unexpectedly high if a child who followed a short birth interval, was also exposed to other disadvantageous circumstances. For example, if the mother was illiterate or if the infant was of female gender (where male children have higher status). The increase in mortality risk was found to be considerably greater than the independent effects of these factors, indicating that the accumulation of such circumstances exacerbate, the detrimental effect of one another. Conversely a child following a short birth interval, who enjoyed more favourable circumstances, did not suffer a higher mortality risk than those following longer birth intervals. The anthropometric analyses did indicate, however, that such infants fail to thrive suffering lower nutritional status.

8.4 Policy Implications

There are some important policy implications to these findings. Short birth intervals are highly prevalent in India; 27% of second or higher order births follow an interval of less than 24months and 12% follow very short intervals of less than 18 months. This research has confirmed the strong association between short birth intervals and neonatal mortality in Karnataka, as well as with the nutritional status of surviving children during late infancy and early childhood. For India as a whole, short birth intervals were also found to be associated with mortality in the post-neonatal and early childhood periods as well as the neonatal period. Although the main focus of this thesis has been to provide information so that the harm suffered by children, as a result of close birth spacing may be reduced, the need to promote birth spacing as a preventative measure should not be overlooked. The most widely used method of contraception, in India, is female sterilisation. Furthermore, it has been conducted at relatively early ages so that childbearing has become concentrated into the early adulthood years. The importance of spacing births should thus be widely promoted in the provision of family planning programmes.

In order to reduce the harm suffered by children who follow short birth intervals health interventions could be targeted in the follow ways:

- The provision of adequate nutrition for women during pregnancy.

The results demonstrated the strong association between short birth intervals and neonatal mortality. Further investigation indicated that even within the neonatal period the deaths tend to be concentrated soon after birth. The prenatal environment thus compromises fetal development so that the infant is less able to cope with the outside environment upon birth. Initiatives that promote maternal nutrition could take the form of education in dietary requirements during pregnancy and of the negative effects of traditional practices which severely limit food and fluid intake, such as fasting. Additional supplementations would help the very poorly nourished, where resources are scarce. Also initiatives which relieve the women of some of the heavy physical work during pregnancy would also be beneficial.

- The promotion of child welfare during the post-neonatal and early childhood periods for infants who follow short birth intervals.

The diffusion of knowledge concerning the vulnerability of children following short birth intervals should be promoted. This would enable individuals to take measures themselves to protect such children. Informal discussion groups held within the villages of Kanakpura, have indeed shown that in some communities extra support is provided by other family members for such child. Additionally, welfare initiatives designed to promote child nutrition should recognise the disadvantage suffered by children following short birth intervals and thus focus their activities appropriately. Programmes which provide forms child care (i.e. nursery schools), for example, could provide relief for a mother from the heavy workload of having to care for young children, closely spaced in age.

- Targeting welfare initiatives at less advantaged children

The results also showed that the mortality risk was unexpectedly high if a child who followed a short birth interval was also exposed to other circumstances, which were disadvantageous to child survival. The accumulation of such circumstances, were found to exacerbate the effects of one another such that the increased risk of death was considerably greater than would be expected given the individual effects. These included maternal illiteracy, families with previous experience of child deaths and female gender. Welfare programmes could thus function efficiently by focusing on closely spaced children from more disadvantaged households. Those children from more advantaged circumstances (i.e. maternal education at high school level) were not shown to suffer an increased mortality risk associated with short birth intervals but the analysis of anthropometric assessment showed that they failed to thrive and demonstrated particularly low WAZ scores. Health interventions should thus monitor children following short birth intervals, even if they come from households of higher socioeconomic status and target them for services aimed at promoting child nutrition.

8.5 Future Research

This research has advanced the understanding of the mechanisms through which short birth intervals affect child health and survival status. One approach used has been to analyse the weight change of children throughout the first year of life. Longitudinal data provides a valuable source of information since temporal effects within relationships can be examined. It therefore has considerable potential in terms of explanatory scope. The longitudinal analysis in this thesis has suffered a number of limitations, however. Firstly the data included observations for infants throughout the first year of life only. The results showed that the effect of birth interval on the nutritional status of infants became more acute during late infancy. Indeed the cross-sectional analysis showed a continuing decline in WAZ score for infants following short birth intervals for children between the ages of 12 to 36 months. It would be useful to repeat this analysis using repeated anthropometric measurements for children over a longer time period including early childhood years.

Additionally a strength of longitudinal data for the analysis of anthropometric assessment is that weight measurements can be attained for children who subsequently died thus ruling out any associated bias. For this data observations for child who died were unavailable and assessment of the bias could lonely be conducted using indirect methods. Since short birth intervals are associated with both mortality risk, and low WAZ scores during childhood, it would be instructive to conduct a three-way assessment to make a more direct analysis of this effect.

Finally data concerning the feeding regime of the infant was collected at different time points to the anthropometric assessment and suffered considerable missing data. This made it impractical to use. Breast-feeding behaviour and the timing of weaning would have a direct impact on the weight attainment of the infant and are thus likely to be important correlates of nutritional status. Furthermore changes such behaviour may be associated with short birth intervals.

The data concerning recent morbidity also posed similar problems. The respondents were asked if the infant had suffered morbidity since the previous visit. Since the observations were recorded monthly, and since some observations were missed for many individuals, the timing since the episode was very imprecise. Longitudinal data would be expected to be efficient in capturing effects of morbidity on nutritional status, since it includes observations both before and after the event. Again, episodes of morbidity may be related to short birth intervals and explain their association with nutritional status. Future analyses should, therefore, seek to attain accurate data concerning these factors.

The analyses of infant and child mortality showed that the association between short birth intervals and mortality risk was significant in the neonantal, post-neonatal and early childhood periods in India but in only the neonatal period in Karnataka. This could be because the data for Kanataka lacked statistical power for the post-neonatal and early childhood periods. Alternatively, it could reflect the relatively prosperous socio-economic setting in Karnataka, compared to many other Indian states, which is more favourable to child welfare. It would be informative to compare similar anaylses for other Indian states and investigate the relationship by the level of economic and social development attained.

This research has also highlighted the complexity of the relationships involved between short birth intervals and child health and survival. There is a need for considerably more research in order to gain a full understanding of how the harm suffered by such children may be minimised. This thesis has focused on the impact of birth spacing on the nutritional status and mortality risk of children. As the mechanisms of the relationship cannot be directly defined and thus assessed in their capacity to explain the relationship, it would be informative to conduct further investigation into the effects of short birth intervals on alternative outcomes associated with the potential mechanisms. These may include factors such as incidence of morbidity, the type of morbidity suffered, breastfeeding behaviour, the timing of weaning and the use of healthcare facilities.

Qualitative research may also be useful as a means of exploring the women's experiences and perceptions concerning birth spacing and may help to identify behavioural factors which mediated within the relationship.

APPENDIX

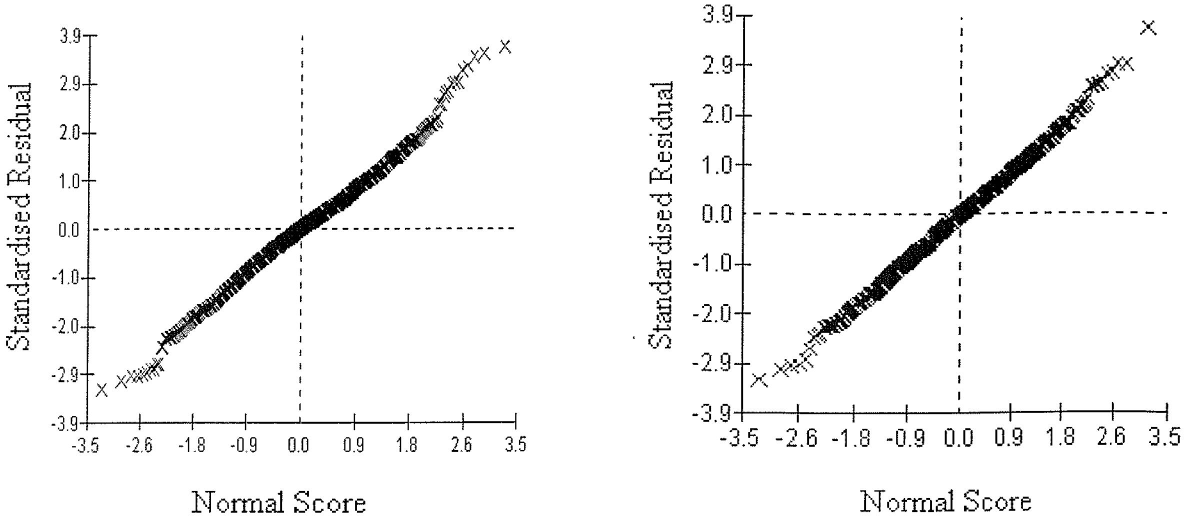
Table 4.a Parameter Estimates and Standard Errors for the Ordinary Least Squares Model for Weight-for-Age Z Scores

Parameter		Estimate	Standard Error
Constant		-3.70828	0.61227
Age in Months			
Age		0.13820	0.06998
Age squared		-0.00288	0.00302
Age cubed		0.000007	0.00005
Previous Birth Interval			
24 months or more		Ref	
< 24 months		0.16475	0.16769
First Birth		-0.19249	0.07713
Size at Birth (Mothers opinion)			
Average or large		Ref	
Small		-0.40579	0.06830
Feeding			
Not breastfeeding		Ref	
Breast-feeding		3.16046	0.58662
Weaning appropriate for age		Ref	
Not appropriate for age		-0.18831	0.06871
Morbidity			
No diarrhoea		Ref	
Diarrhoea in past two weeks		0.80659	0.54257
Hospital Delivery			
No		Ref	
Yes		0.19918	0.07640
Maternal Education			
Illiterate		Ref	
Primary		0.36152	0.08235
Middle or High		0.47539	0.11033
Sibling deaths			
Number of deaths		0.32460	0.16264
Interactions with age			
Previous Birth Interval			
Short birth interval:	Age	-0.01930	0.00800
Feeding			
Still breastfeeding:	Age	-0.28266	0.05308
	Age squared	0.00550	0.00119
Morbidity in last 2 weeks			
Diarrhoea:	Age	-0.26200	0.11926
	Age squared	0.01677	0.00718
	Age cubed	-0.00030	0.00013
Sibling deaths			
Number of deaths:	Age	-0.04880	0.01938
	Age squared	0.00124	0.00049

Table 4.b Parameter Estimates and Standard Errors for the Variance Components Model for Child Weight-for-Age Z Scores

Parameter		Estimate	Standard Error
Constant		-3.67772	0.60083
Age in Months			
Age		0.14409	0.06843
Age squared		-0.00330	0.00295
Age cubed		0.00001	0.00004
Previous Birth Interval			
24 months or more		Ref	
< 24 months		0.16992	0.16262
First Birth		-0.21468	0.07493
Size at Birth (Mothers opinion)			
Average or large		Ref	
Small		-0.40059	0.06697
Feeding			
Not breast-feeding		Ref	
Breast-feeding		3.14389	0.57608
Weaning appropriate for age		Ref	
Not appropriate for age		-0.19223	0.06790
Morbidity			
No diarrhoea		Ref	
Diarrhoea in past two weeks		0.80683	0.53439
Hospital Delivery			
No		Ref	
Yes		0.19852	0.07562
Maternal Education			
Illiterate		Ref	
Primary		0.36506	0.08287
Middle or High		0.44149	0.11047
Sibling deaths			
Number of deaths		0.33996	0.15979
Interactions with age			
Previous Birth Interval			
Short birth interval:	Age	-0.02078	0.00779
Feeding			
Still breast-feeding:	Age	-0.28614	0.05206
	Age squared	0.00565	0.00116
Morbidity in last 2 weeks			
Diarrhoea:	Age	-0.26539	0.11745
	Age squared	0.01717	0.00707
	Age cubed	-0.00032	0.00012
Sibling deaths			
Number of deaths:	Age	-0.05131	0.01907
	Age squared	0.00131	0.00048
Random Effects			
Child level		0.65136	0.06412
Household		0.22436	0.06383

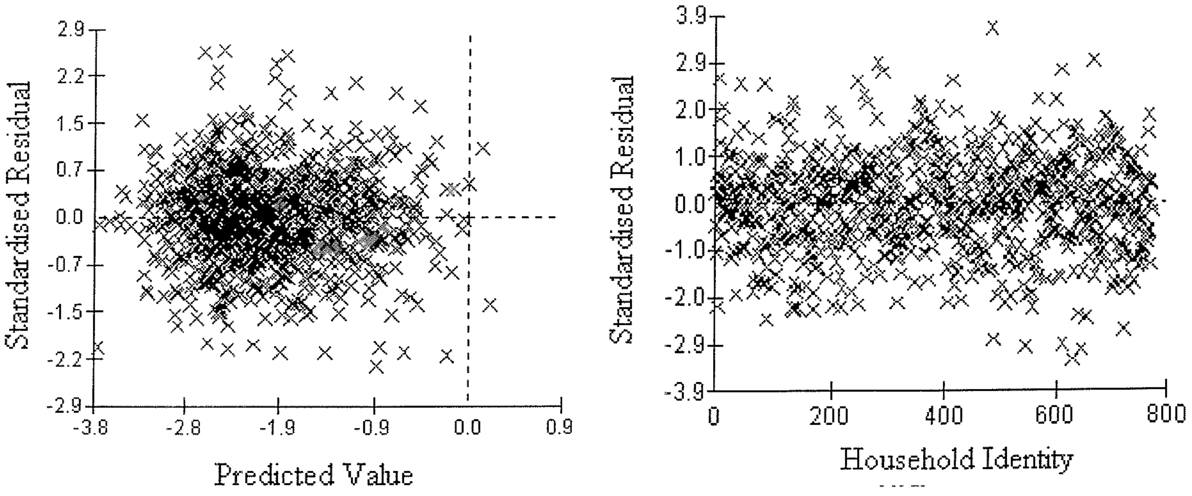
Figure 4.a Standardised Residuals by Normal Scores



Child level

Household Level

Figure 4.b Standardised Residual by Fixed Part Prediction



Child Level

Household Level

Table 6.a Percentage Distribution of Children aged 1-60 Months by Neonatal Death and Explanatory Covariates

	%
Neonatal Death	4.3
Individual Characteristics	
Previous birth interval	
<24 months	19.6
24 months or more	49.5
First birth	29.4
Multiple birth	1.5
Gender	
Male	51.3
Female	48.7
Size at birth	
Small	27.9
Average	34.9
Large	37.2
Premature birth	3.2
Received antenatal care	64.5
Given iron during pregnancy	73.9
Given tetanus during pregnancy	75.4
Born in Hospital	33.2
Never breast fed	4.5
Morbidity in previous 2 weeks	
Diarrhoea	8.6
fever	15.9
Previous sibling died	8.3
Household Characteristics	
Source of drinking water	
To residence	24.7
Public	75.3
Type of toilet facility	
None	73.6
Own Flush	10.6
Shared Flush	3.5
Pit/Bucket	12.3
House construction	
Katcha	34.8
Pucca	13.2
Semi-pucca	52
Household density	
Low	5.6
Average	68.7
High	25.7

	%
Standard of Living Index	
Poor	15.4
Rich	1.9
Upper middle	6
Middle	20.8
Lower middle	55.3
Maternal Characteristics	
Age	
<15	2.8
15-19	32.8
20-24	35.4
25+	29
Education	
None	64.4
Primary	17.7
Middle	6.2
High or College	11.8
Occupation	
Housework	57.9
Administration	1.2
Service / Agriculture	39.7
Professional	1.1
Marital Status	
Married	98.4
Separated	0.8
Widowed	0.8
Religion	
Hindu	82
Muslim	15.1
Other	2.8
Caste	
Scheduled caste	12.7
Scheduled tribe	5.2
Other	82.1
Consanguinity	
Married to cousin	27.8
Married to other relative	10
Not relative	62.2
Paternal Characteristics	
Education	
None	42.5
Attended School	57.5
Occupation	
Farming	78.4
Administration	17.6
Professional	2.9
Other	1.1
Total number of children = 2,810	

Table 6.b Percentage Distribution of Children aged 24-60 Months by Early Childhood Death and Explanatory Covariates

	%		%
Early Childhood Death	3.6	Standard of Living Index	
Individual Characteristics		Poor	15.1
Previous birth interval		Rich	1.8
<24 months	20.5	Upper middle	6.6
24 months or more	49.2	Middle	19.7
First birth	28.9	Lower middle	55.2
Multiple birth	1.3	**Maternal Characteristics**	
Gender		Age	
Male	51.0	<15	3.0
Female	49.0	15-19	31.7
Size at birth		20-24	35.7
Small	25.3	25+	29.6
Average	35.2	Eductaion	
Large	39.4	None	65.3
Premature birth	1.8	Primary	17.5
Received antenatal care	61.6	Middle	6.1
Given iron during pregnancy	72.3	High or College	11.1
Given tetanus during pregnancy	72.8	Occupation	
Born in Hospital	32.9	Housework	54.4
Never breast fed	1.5	Adiminstration	1.6
Morbidity in previous 2 weeks		Service / Agriculture	42.9
Diarrhoea	4.9	Professional	1.1
fever	12.6	Marital Status	
Previous sibling died	8.1	Married	98.0
Household Characteristics		Separated	1.0
Source of drinking water		Widowed	1.1
To residence	26.0	Religion	
Public	74.0	Hindu	81.4
Type of toilet facility		Muslim	15.5
None	72.0	Other	3.2
Own Flush	11.6	Caste	
Shared Flush	3.4	Scheduled caste	12.7
Pit/Bucket	13.0	Scheduled tribe	5.9
House construction		Other	81.4
Katcha	34.5	Consanguity	
Pucca	13.8	Married to cousin	27.9
Semi-pucca	51.7	Married to other relative	9.9
Household density		Not relative	62.2
Low	5.6	**Paternal Characteristics**	
Average	68.7	Education	
High	25.7	None	43.3
		Attended School	56.7
		Occupation	
		Farming	77.8
		Administration	18.3
		Professional	2.7
		Other	1.3
		Total number of children = 1,572	

Table 7.a Percentage Distribution of Children aged 1-60 Months by Neonatal Explanatory Covariates

	%
Individual Characteristics	
Previous birth interval	
<18 months	12.8
18-36 months or more	49.8
36+	37.4
Gender	
Male	51.5
Female	48.5
Size at birth	
Small	18.3
Average	58.2
Large	12.9
Never Breast-fed	1.5
Premature birth	2.3
Received antenatal care	54.1
Given iron during pregnancy	44.4
Given tetanus during pregnancy	52.7
Born in Hospital	20.4
Previous sibling died	11.1
Household Characteristics	
Place of Residence	
Urban	26.0
Rural	74.0
South	20.1
North	79.9
Water Supply	
Piped	29.5
Other	70.5
Type of toilet facility	
None	70.5
Own Flush	13.0
Shared Flush	3.7
Pit/Bucket	12.8
Household density	
Low	4.1
Average	70.4
High	23.8
Very high	1.6
Standard of Living Index	
Poor	20.7
Rich	2.5
Upper middle	7.7
Middle	20.6
Lower middle	47.5
Maternal Characteristics	
Age	
<19	16.3
20-24	38.5
25-29	27.2
30-34	12.3
35	5.8
Education	
None	66.0
Primary	24.4
Middle or higher	9.5
Total number of children = 42,798	

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