Home Thermal Environment and Body Temperature Patterns in Babies

THESIS PRESENTED FOR THE DEGREE OF
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DEDICATION

I wish to dedicate this thesis to my mother who has on numerous occasions inspired me to continue. She has been a substitute mother to my very young children, and a help in home maintenance to us all. Thank-you.

Also to my friends Jane and Charlie who during these years of study lost their precious third daughter Alice Rose to Sudden Infant Death Syndrome. Their courage will always be an inspiration to our family. Such loss reinforces the need for further understanding about the precise physiological mechanisms of the developing infant.

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FOREWORD

Over Centuries the way in which babies are nurtured has depended on tightly adhered to beliefs and customs that became established within the culture of the day. For many generations these practices have been handed on as frameworks to follow, such as the practice of swaddling, which is still used in some communities today.

"What we do know, however is that the baby, male or female, started life by being swaddled.

When the child is born He must be swaddled.

(The Treatise of Walter de Biblesworth)

Swaddling involved bandaging the baby's body from neck to enclosing the arms and legs in a solid bundle, apparently owing to a fear that the limbs might get damaged or even fall off by careless handling unless thus protected".

(Cunningham P, Buck A, 1965)

Family group. Swaddled baby carried by mother, small child on another woman's back, boy in loose tunic following the father. 1320. (*Queen Mary's Psalter.*)

Today the scientist, armed with growing knowledge of paediatric physiology, is trying to prescribe the exact formula for the optimal care of the developing infant. The question remains as to whether we can arrive at any justification for such a formula, and how far it will diverge from the courses of action passed on from generation to generation.

CHAPTER ONE

INTRODUCTION

The health of any individual, infant or adult, is determined by a complex interaction between constitution and environmental influences, which is even less well understood in babies than in adults. There is no shortage of epidemiological evidence linking infant morbidity and mortality to features of the home environment provided by parents, and a plethora of assumptions have been made about how these features might actually affect a baby's health, but there is very little evidence as to the mechanism of their effects (Morris JN, 1990).

Cold conditions in winter have long been associated with increased mortality and morbidity in children (Wynn M, Wynn A, 1975), although we do not know how or why. The very words used to describe minor illness, a`chill', a`cold', carry connotations of the association with temperature. Folklore describes the child born in winter as

> "A child born in January will be laborious".
> *Quoted in the encyclopedia of superstitions, folklore, and the occult*
> *sciences of the world 1903.*

Seasonal variations in mortality have been noted for some time,

> "As for the season, in spring and full summer, children and young people do
> best" *Hippocrates (LLoyd GER 1978).*

This thesis sets out to examine, by means of detailed physiological measurements on babies, the interaction between one aspect of the home, the thermal environment, and the physiology of babies. The objective being to determine how babies react to the extremes of environment normally encountered, and whether these conditions might be harmful.

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1.1 THE CHANGING PATTERN OF CHILD HEALTH.

Infant mortality is considered to be a sensitive indicator of the health of a population. Although infant mortality rates fell during the first decade of the twentieth century, prior to the Boer war in 1906 Dr George Newman, (Medical Officer For Health For Finsbury), wrote,

" ..though the general death rate is decreasing the Infant Mortality rate is not declining. This means that whilst during the last half century, a time of marvellous growth of science and of preventative medicine, human life has been saved and prolonged, and death made more remote for the general population, infants still die every year much as they did in former times. Indeed in many places it appears as if they die in greater numbers, and more readily than in the past"

(Newman G, 1906).

Government Committees were investigating reasons for unfitness of recruits to the Boer War, which resulted in detailed analysis of infant mortality being produced by the Registrar General. Local Government boards were set the task of investigating the possible impact on infant mortality of antenatal influences, employment of women, domestic and social conditions, and bottle feeding (Macfarlane M, Mugford M 1984). Many of the same questions are still being discussed today.

Recently the infant mortality rate (deaths of live born infants under one year of age per 1,000 live births) has fallen from 17.7 in 1971, to 9.4 in 1984 and reached 7.7 in 1990, the lowest ever recorded in England and Wales (OPCS, 1990). The two components of infant mortality are neonatal deaths (deaths at less than 28 days after live births) and post–neonatal deaths (deaths at ages 28 days or over, but under one year of age). There has been a fall in neonatal mortality from 10.6 per 1,000 live births in 1975, to 4.5 in 1990. The post–neonatal mortality rate has fallen although less steeply and regularly, from 4.8 per 1,000 live births in 1975 to 3.2 per 1,000 in 1990, after fluctuating near 4.0 between 1983 and 1987, (OPCS, 1990). Trends in

mortality of infancy and childhood reveal an overall fall, but on further analysis show differing patterns. In 1986 a rise in post-neonatal mortality prevented the continued fall in infant mortality. The rate of post-neonatal deaths has recently stabilised, and remains resistant to further fall.

Post-neonatal mortality is due to malignant disease, respiratory disease, congenital malformations, accidents, and unexplained death or Sudden Infant Death Syndrome (SIDS), often referred to as cot death (Pharoah POD, 1986). Between 1983-1989 the death rate for all of these groups fell, with the exception of SIDS, which rose to a maximum of 2.13 per 1,000 live births in 1982, falling to 1.95 per 1,000 live births in 1984, 1.9 in 1989, and 1.5 in 1990. Between 1985-6 a rise in infant mortality was due to a 16% rise in the number of deaths attributed to cot deaths (Limerick S, 1988). Deaths from congenital malformations have remained steady from 1974-1984 and were 0.5 per 1.000 live births in 1990. Deaths from accidental causes were 0.1 per 1,000 live births in 1990, with deaths from respiratory causes, a rate of 0.3 per 1,000 live births in 1990.

Interpretation of childhood morbidity is confused by limitations on data sources. Hospital admissions seem to reflect alterations in diagnostic criteria, and fail to account for multiple admissions (eg changes in neoplasms). The incidence of diseases especially infectious have changed, with improved medical management leading to the survival of many children who would otherwise have died, especially in cases of cystic fibrosis, diabetes melitis, and renal failure. However there is an increasing prevalence of children living with chronic disease, disability and handicap (Graham.P 1987). Many argue that childhood infections have decreased in all developing countries, but there exists a complacency about infectious disease with the changes of human behaviour. This may be especially relevant to changes associated with air travel, sexual habits, macro-scale urbanization into office blocks, schools, and day care centres (Hall S,1986).

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Sudden infant death syndrome

SIDS the largest category of post-neonatal deaths accounts for half the deaths in the post-neonatal period. We do not have any full understanding of its aetiology, as it occurs in apparently normal healthy infants suddenly and inexplicably at home. The infant is put to bed only later to be discovered dead (Gold E, et al 1961). There are virtually no deaths attributed to SIDS during the first week post-natally, when other categories of infant mortality are at a maximum. The peak incidence is between the 9th and 20th weeks, with a maximum in the third month. Cot deaths then decrease so that 90% have occurred by the age of 6 months (Frederick J, 1974: Petersen DR, 1988). SIDS or cot death, is defined precisely as:

"the sudden death of an infant or young child which is unexpected by history, and in which a full post mortem examination fails to demonstrate an adequate cause of death".

(Beckwith JB, 1970).

This definition was promulgated in 1969 at the second International Conference on SIDS, and despite continued debate has continued to be used throughout the world for want of an alternative. Recent revision of the definition at the National Institute of Health USA in 1989 has included death'under one year of age'. The term SIDS, or cot death, was accepted as a registrable cause of death in England and Wales in 1970, and was included as an International Classification of Disease in 1971. The UK rates are similar to those in the USA (Standfast SJ, Jereb, Janerich DT, 1980), but higher than those for Sweden (Norvenius SG, 1987) Finland (Rintahaka PJ, Hirvonen J, 1986) and Hong Kong (Davies DP, 1986). These deaths have therefore assumed increasingly greater significance in recent years, becoming a focal point for paediatric research world wide.

At postmortem, although there is no apparently lethal pathology, there are common findings. These include recent responses to infection in the lungs from evidence of intrathoracic petechiae and pulmonary oedema (Gold E, et al 1961), associated with minor illness a few days before death (Carpenter RG, Shaddock CW, 1965: Gilbert

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RE, Fleming PJ, Azzaz Y, Rudd PT, 1990). There is sometimes evidence of pre-existing hypoxia identified from increased muscle mass in the pulmonary arteries (Naeye RL, 1973) and right ventricle (Valdés-Dapena MA, et al 1980), the presence of a smaller thymus than normal (Sinclair-Smith C, Dinsdale F, Emery J, 1976), extra-medullary erythropolesis (Naeye RL 1974) and increased periadrenal brown fat (Valdés-Dapena MA, Gillane MM, Catherman R, 1976).

Cot deaths were previously identified as deaths attributed to accidental smothering or inhalation of vomit, many pathologists in the mid-twentieth century attributing them to respiratory deaths to avoid parents being subjected to an inquest, mandatory for a diagnosis of unnatural deaths. Difficulties arose from variations in the reliability of a medical history, thoroughness of postmortem examination, and debate on what is considered an "adequate cause of death". The definition is based on diagnosis by exclusion and subjective evidence. There is now greater acceptance of data from diagnosis, associated with developments in paediatric pathology, which has clarified interpretation of mortality statistics during the last ten years. However, it remains a diagnosis of probability assessment rather than an irrefutable fact (Petersen DR, 1988).

Factors associated with post-neonatal mortality
There are two types of factors which influence post-neonatal mortality and morbidity. First factors directly affected by the infants' home environment and family, environmental factors and second those which are not, constitutional factors.

Some categories of post-neonatal deaths are irrefutably influenced more by one factor than the other, for example genetic anomalies are undoubtedly a constitutional factor of inheritance and as such remain beyond parental control, whereas infanticide is undoubtedly environmental, practised as a social institution in some types of society. But for other categories such as respiratory deaths the influence is an interaction of varying degrees between the environment and the biological make up of the infant. A child exposed to cigarette smoke who has some predisposition to allergy is more likely to develop asthma than a child without such a predisposition. The influence of

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constitutional factors may remain outside the reach of medical science, accounting for a residual pool of deaths which are resistant to further reduction. Environmental factors are accessible, through health educational campaigns which seek to inform parents of factors which prevent illness and reduce the risk of death.

Identification of environmental risk factors generally occurs without a full understanding of the effect upon the biological mechanisms of the baby which lead to an increased risk of death or disease. Although environmental factors have been well documented for some categories of post-neonatal death, especially SIDS, relatively little is known about the interaction between the identified environmental risk factor and the physiological make up of the developing infant. Despite a wealth of information no real grasp of the issues that distinguish acknowledged health differentials have had an impact upon improving mortality statistics. In particular many of these facets of the social environment have not been attributed to biological causality. The state of the art can best be described by J.N Morris,

> "There has been little work on psychosocial or inequalities away from poverty and deprivation eg the superiority of social class 1 over 2 and of 3 over non-manual. And there has been disappointing little advance in understanding of social biological interactions. Experimental approaches, for instance with mothers and under fives in the inner cities are notably few. Morbidity data confirm the picture but are much scarcer than mortality "
>
> (Morris J N 1990).

1.2   CONSTITUTIONAL FACTORS

Congenital anomalies are obviously inherited or developmental and therefore constitutional. Examples are cystic fibrosis, and congenital malformations of the cardiovascular system such as ventricular septal defects. In 1990 they accounted for 0.5 deaths per 1,000 live birth's (OPCS 1990). Advances in medical neonatology has enabled many seriously ill babies to survive the first four weeks of life only to die in

the post-neonatal period (Pharoah POD 1986).

Heredity has been considered as a factor in SIDS as they have occurred in first cousins, and twins. Detailed analysis however, has not found any evidence to support a hypothesis that a single gene defect causes cot death. The data do not preclude the possibility that several genes each with a small defect may interfere with the normal maturation process at a critical point (Petersen DR, 1988). Several studies have identified a higher rate of cot death in siblings of SIDS than infants at large (Irgens LM, Skjaerven R, Petersen DR, 1984). There are many rare inherited metabolic disorders which have been attributed to death in infancy such as the enzyme deficiency of medium chain acyl coenzyme A dehydrogenase, identified in 5% of SIDS (Duran M, et al 1986).

Different rates of SIDS have been identified in ethnic groups. In Birmingham, England, a significantly lower risk for cot deaths occurred after controlling for maternal age, social class, and birth weight in Asians (Kyle D, et al 1990). Differences in the incidence in cot deaths have been identified in New Zealand between Maori infants (7.4/1000 live births, 1986) and non-Maori children (3.6/1000 live births, 1986) (Borman B, Fraser J, de Boer G, 1988: Mitchell EA, et al 1993: Gantley M, Davies DP, Murcott A, 1993). Such work appears to indicate a race protective element.

Gender is another constitutional factor. More males die, especially of SIDS (Golding J, Limerick S, Macfarlane A, 1985). The first report of this was in 1956 in Ohio, where analysis of 126 cases of cot death revealed slightly more males (55%), to females (45%) (Adelson L, Kinney ER, 1956), later verified in cot deaths and other forms of infant mortality (Froggatt P, Lynas MA, MacKenzie G, 1971). Multiple pregnancy, has been associated with an increased risk for cot death, especially twins, found to be twice as susceptible to cot death than expected by chance (Beal SM, 1972). Constitutional factors relating to parents have been identified in cot deaths, with conflicting evidence to suggest a risk decrease for maternal blood group A (Prostestos CD, Carpenter G, McWeeny PM, Emery JL,1973; Carpenter RG, Gardiner A, Emery JL, 1979).

1.3   ENVIRONMENTAL FACTORS

Examination of environmental factors implicated in infant morbidity and mortality cannot begin without reference to social class which is identified as playing a large part in the environmental circumstances in which a baby is nurtured. Mortality still varies with social class, despite the supposed narrowing of class differences in the mid–1970's (Graham P, 1987).   For all categories of post neonatal deaths in 1989, higher rates of death occurred in the lower social classes. For Sudden Infant Death Syndrome there were 2.7 deaths in social class 5, compared to 0.9 deaths in social class 1, excluding children outside of marriage with a rate of 2.5 (Appendix A1 OPCS 1990 by Social Class).

Social class and post–neonatal mortality.
Social class represents an attempt to classify or group individuals into strata or classes, and is often linked to the work of Karl Marx, who described two classes relating economically to the means of production. In 1911 in Britain, the Registrar General used a hierarchical classification of social class based on occupation. This grouped people according to the skill required for, and social standing of their work. It was revised in 1921, and has been modified at periods since. Information on occupation as a basis for assigning social class is collected at census and at registration of births and deaths.

Assessed by paternal occupation the term social class remains too rigid to tease out many factors of influence. It falls to grasp many issues in modern society which relate more to what an individuals income or standard of living means in the social context of society, and as such, has been criticised. But occupation as a concept of social class offers data that can be compared over considerable time, providing a frame work from which other measures can be assessed.

Evidence concerning the disproportionate distributions of mortality rates within the population was highlighted in 1977 by the Research Working Group on Inequalities in

Health. It resulted in the Black Report published in August 1980. The Report examined the official statistics of England and Wales, highlighting the steep gradient of mortality and life expectancy in 1970-72, from professional social class 1 through to semi-skilled social class 4 and unskilled social class 5 (Townsend P, Davidson N, 1982). It stated that inequalities in mortality among infants reflected that of adults, and concluded that,

> "much we feel, can only be understood in terms of the
> more diffuse consequences of the class structure".
>
> (Black Report 1980)

The established inequality of health was found to be widening despite the National Health Service and Welfare State Services, which raised fundamental questions about health.

The Black Report found that life chances were largely responsible for the measured differences in health between social classes, and these could be described as material conditions of life, income, housing and working environment. It pointed to socioeconomic poverty and deprivation as vital descriptors of social class which cause premature death and decreased life expectancy. Social class identified differentials in attitude, use of health service and access to care, diet, unemployment rates and working environment, stressful life events, religion, housing, income and education. More recent studies confirm decreasing health and life expectancy from the higher to lower social classes, with additional information to support this claim regarding housing tenure, car ownership, educational status and the loss of early working years (Goldblatt P, 1989: Blane D, Smith D, Bartley M, 1991).

Environmental factors and child health

A baby's environment is controlled by its parents, who are faced with a range of choices which encompass every aspect of care, including feeding and clothing. Some environmental risk factors are directly associated with social class behaviours such as cigarette smoking and bottle feeding, but other choices such as that of thermal

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environment and sleeping position of newborns, are less clearly related.

Cigarette smoking has been known to vary with social class since the first report of the Royal College of Physicians in 1962. Although there has been a recent reduction in smoking throughout the classes, this has not been seen in the manual classes and among young women (OPCS 1990). Maternal smoking is significantly associated with lower social classes and lower educational achievement (Haste FM et al, 1990).

Smoking has been identified as a factor of influence for respiratory deaths and SIDS. Exposure to cigarette smoke in the home environment has been associated with an increased risk for SIDS (Murphy J.F, Newcombe R.G, Silbert J.R 1982). Maternal smoking during pregnancy is an independent risk factor for SIDS, with odds ratios reported to be 1.5 and 5.0 (Golding J, Limerick S, Macfarlane A 1985: Mitchell EA, Becroft DO, Barry DMJ, 1991). In Finland a longitudinal study of 1,819 children followed to fourteen years of age, identified children born to mothers who smoked had a higher incidence of respiratory disorders, were shorter, and had a lower educational ability than children born to mothers who did not smoke. The mothers themselves were found to enjoy poorer health (Rantakallio P, 1983). Positive dose relationships have been found between the number of cigarettes the mother smoked and the proportion of children with enuresis, temper tantrums, speech problems, repeated accidents, episodes of wheezing, bronchitis, pneumonia, ear infection and squint (Golding J, 1986).

Biological associations of smoking continue to be investigated (Michael H et al 1992) with critical influence identified for the developing fetus in utero, and postnatally for the newborn. The detrimental effects of maternal smoking upon the fetus include growth retardation, associations with accidental antepartum haemorrhage, prolonged rupture of the membranes, pre-term delivery and perinatal death (Golding J, 1986), and have been directly related to a maternal diet lacking in Vitamin C (Haste FM et al, 1990), zinc (Swanson CA, King JC, 1987), and folate (Hibbard BM, 1975), resulting in a low birth weight infant (Rush D, 1974). The need for good health during pregnancy has been well documented in health prevention to reduce cot deaths (Golding J, Limerick

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S, Macfarlane A, 1985). Maternal smoking has been associated with maternal anaemia and cot death, where a low packed cell volume was an important predictor among heavy smokers of SIDS victims, not identified in non-smokers (Bulterys MG, Greenland S, Kraus JF 1990). Interactions exist between the environmental factor of maternal smoking and diet and the mechanism of chronic fetal hypoxia.

Pollution from cigarette smoke, and other toxins in the home or urban environment are risk factors for respiratory disease, but the biological interactions are unclear. A relationship exists between croup, bronchitis and pneumonia, with air pollution from gas cookers (nitrogen dioxide), parental smoking, inner city residence, and overcrowding (Leeder RS, et al 1976: Colley JR, Douglas JWB, Reid DD, 1970: Strachan DP, Elton RA, 1986). Passive cigarette smoking by the baby increases its chances of respiratory disease especially in children pre-disposed to asthma (Anderson HR, 1986). Further work is required to understand how passive smoking effects the infant to establish if this effect is mediated through a vulnerability to respiratory disease.

Maternal diet varies between social classes. Recent evidence reveals that all sections of the population have reduced their fat intake (Gregory J, Foster K, Tyler H, Wiseman M, 1990), but dietary differences between manual and non-manual classes identify low intakes of fruit resulting in low levels of vitamin C, less carotene, less fibre, and a higher dietary level of sodium and potassium in manual classes (Williams DDR, Bingham SA, 1986).

The effects of maternal nutrition on the developing fetus have been associated with increased risk for post-neonatal morbidity and mortality, with some understanding of the biological interaction. The developing embryo during its first 8 weeks, requires an environment containing hormones and nutrients in more ideal concentrations than are necessary later in pregnancy. Any imbalance has been directly associated with the quality of maternal diet at conception and congenital malformations (Wynn M, Wynn A, 1981). Mothers with poor nutrition, being underweight, are at risk of delivery to a low birth weight infant, with malformations. This was witnessed at its extreme,

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following the food shortages in Holland in 1944–5 (Stein Z, Susser M, Saenger G, Marolla F, 1975). Inadequate levels of folic acid and vitamins in the diet at conception are associated with neural–tube defects in the developing fetus (Smithells RW, et al 1980).

Parental choices of infant feeding have been implicated in post–neonatal mortality and morbidity. Bottle feeding has been linked with respiratory infection in childhood and a predisposition to ischaemic heart disease in later life (Barker DJL, Osmond C, 1987). Early work identified more cot deaths in infants who were bottle fed than breast fed (Froggatt P, Lynas MA, MacKenzie G 1971; Emery JL, Carpenter AG 1974). Breast feeding was seen as a mechanism to reduce infant morbidity and mortality with acknowledged physiological and psychological benefits to mother and child. The physiological benefits relate to colostrum as the ideal milk for adjustment from placental to oral feeding, with its rich source of antibodies. The constituents of breast milk include easily absorbed fats, the correct relationship of calcium to phosphorus (Lealman GT, 1976), and the iron binding protein lactoferrin and vitamin B_{12} binding protein, which reduce gastro–intestinal problems (Ragnhild G, 1973). Psychologically maternal bonding of mother to infant is enhanced by the process of breast feeding (Blehar MC, Leiberman AF, Ainsworth MDS 1977).

In 1946 the benefits of breast feeding were highlighted due to an increase in bottle fed infant mortality from gastro–intestinal disorders (Douglas JWP, 1950). The concern about bottle feeding arose from evidence of hypernatraemia in victims of cot death, due to the increased proportion of sodium in cows milk to breast milk, at a time when bottle milk consisted of dried powdered cows milk. A prospective study of children at risk of SIDS in Sheffield in 1973–9, led to further realisation of widespread practice of over concentration of bottle feeds, and the risk of hypernatraemia (Carpenter RG, et al 1983). The factor which appeared important was not breast versus bottle feeding, but correct reconstituted powdered milk by mothers who chose to bottle feed. Earlier fears for bottle feeding debated hypersensitivity to cows milk from milk aspiration, although this has not been substantiated (Parish WE, Barrett AM, Gunther M, Camps FE, 1960).

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Evidence suggests that breast feeding ensures a steady rate of growth, with more obesity in bottle fed then breast fed infants (HMSO 1981). Slow weight gain has been considered as a factor present prior to SIDS. Recent work identified that SIDS infants gained weight more slowly overall, but the weight gain of breast fed SIDS differed little from survivors, with bottle fed victims having considerably slower growth prior to death than controls (Williams SM, Taylor BJ, Ford RPK, Nelson EAS, 1990). Recent physiological associations indicate that breast fed babies develop a mature temperature rhythm earlier than bottle fed infants, seeming to suggest that breast fed infants make maturational developmental advances earlier than bottle fed infants (Lodemore MR, Wailoo MP, Petersen SA, 1992).

Despite research confirming the benefits of breast feeding (DHSS 1980; Fomon SJ, Filer LJ, Anderson TA, Ziegler EE, 1979; Wharton BA, 1982) mothers still chose to bottle feed. A surge in the popularity of breast feeding in the early 1970's failed to continue into the 1980's, with a decline in the early 90's (DHSS 1988). Factors influencing the choice of breast feeding, include higher social class (Coles EC, Cotter S, Valman HB, 1978) and mothers' higher educational level (Emery JL, Scholey S, Taylor EM, 1990). These factors are linked to the mother's background environment, attitudes, beliefs, her experience and those of her partner, mother and friends (Artemis P, Simopoupos MD, Gilman D, Graves MD, 1984). Other influences involve the role of nursing staff in the maternity hospital linked to maternal confidence gained prior to discharge post–delivery (Buxton KE, et al 1991). Duration of feeding is again linked to social class, mothers educational level, maternal confidence, a return to work within 6 months of delivery, infants with a demanding nature, problems with feeding and early supplementation of formula milk (Howard H, et al 1985).

Preventive measures to reduce the incidence of cot death include advice to mothers to breast feed. The Sheffield intervention programme which focused on Health Visitor interventions to reduce cot death reported a 24% subsequent improvement in the cot death rate, due to an increase in breast feeding (Carpenter RG, et al 1983). Recently results from a New Zealand study have seen a notable fall in SIDS from an intervention programme that advocated a supine sleeping position with avoidance of

overheating, reduction in maternal smoking, and breast feeding (Mitchell EA, Becroft DMO, Barry DMJ, 1991).

Establishing any biological link with the environmental factors of smoking, and infant feeding, remains fraught by the combination of social class factors often present. Often it is unclear whether the associations are biological in nature or a proxy for maternal behaviour. In many instances several environmental factors interact together or an interaction occurs between the environmental influence and some constitutional element. Indeed poor composition of artificial milk leading to biochemical changes associated with mild uraemia, have been associated with 'sub-optimal' mothering (Mason JK, Harkness RA, Elton RA, Bartholomew S, 1980). The influence of bottle feeding has been claimed to be a marker of something concerning the parental care package rather than metabolic action of the feed type (Frederick J 1974). Factors often combine poor socioeconomic status, young maternal age, multiparity, unemployed partners or social class 5 and 6, life stress, (Murphy JF, Newcombe RG, Gilbert JR, 1982) and use of dangerous drugs (Rajegowda BK,et al 1978). Such a combination of associations carry an increased risk of SIDS, small for dates babies (Bergman AB, Wiesner LA, 1976), premature babies born before the 37th week of gestation (Petersen DR, Van Belle G, Chin NM, 1979), obstetric problems such as preterm delivery and a low birth weight infant (Carpenter RG, Gardner A, Emery JL, 1979). In 1985 the DHSS multi-centre study into Post Neonatal Mortality confirmed features of cot deaths to be linked with, "young maternal age, mother's smoking, short inter-pregnancy intervals, short gestation and low birth weight, special care baby unit admission, and less breast feeding" (McLoughlin A. 1988).

Detaching individual environmental factors from social interactions leads to a confusion regarding the pathway of causality in morbidity and mortality. These types of interactions also occur with constitutional factors. Some social behaviours are reinforced by the environmental practice of the group but have a constitutional element. Indeed certain autosomal recessive conditions occur in groups such as the Pakistani practice of consanguineous couples (Chitty L.S. Winter R.W. 1989). Socioeconomic status, not a genetic factor, was found to be the cause of a higher

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proportion of cot deaths in black Americans (Harper R M, Hoffman JF, 1988). In California the increased incidence of SIDS was found to be related to whether the mother was born in America or Mexico, suggesting some culturally related care practice from the environment to be the determining factor, and not race (Grether JK, Schulman J 1989).

The environmental risk factor of babies sleeping position, has recently been associated with SIDS. This factor does not appear to be clouded by social class interactions. Parents place their newborn infants to sleep either in the prone position, with the head to one side, or laterally on the left or right side, or supine lying on the back. Parents behaviour is the product of tradition, fashion, their interpretation of the infant's preference, a fear that the infant might choke or be smothered, and advice of various sources including medical personnel. One of the difficulties of testing any hypothesis on a preferred position is the degree of change a baby may exert from the original position selected by the parent when placing the baby down for sleep.

The prone position had been fully investigated in the preterm infant where it was found to be optimal for developing physiological mechanisms (Martin RJ, Herrell N, Rubin D, Fanaroff A, 1979; Dhande VG, Katwinkel J, Darnall RA, 1982). Evidence supported the prone position as a soothing influence for distressed babies, allowing them to settle more easily and cry less (Brackbill Y, Douthitt TC, West H, 1973). This was a strong factor for advocating the prone position for babies with colic (Illingworth RS 1954).

Early research found no evidence to favour one position more than another (Froggatt 1970; Bergman AB, Ray CG, Pomeroy MA, Wahl PW, Beckwith JB, 1972). The infants position on discovery of death had been studied by epidemiologists and forensic scientists. The first hypothesis linked suffocation to sleeping position, where infants were found to be face down in their cots (Bowden KM, 1950). However autopsy reports failed to find evidence of suffocation as the mode of death (Davison WH, 1945; Werne JJ, Garrow I, 1953). Attention focused on countries where babies are predominantly nursed in the supine position, such as Hong Kong, which identified

low rates of cot death (Davies DP, 1985). In the Netherlands the prone position was challenged and felt to carry a risk where a change from a previous practice of nursing babies prone to supine produced a lowering of SIDS rates (de Jonge GA, Engelberts AC, Koomen-Liefting AJM, Kostense PJ, 1989).

Recent work continues to question tradition, since the 70's, in this country to nurse infants in the prone position, as evidence for a reduction in SIDS in New Zealand has been linked with a change from prone to supine sleeping (Mitchel EA, Becroft DMO, Barry DMJ, 1991). The New Zealand study is part of a preventative initiative to improve child care practice that demands also a reduction in cigarette smoking and the practice of breast feeding, both well documented environmental factors in infant mortality.

The biological implications for a prone position and a risk for SIDS is unknown. Recently it has been suggested that sleeping prone increases a risk of hyperthermia in warm sleeping conditions (Nelson EAS, Taylor BJ, Weatherall IJ 1989). Further work has found some evidence to suggest a relationship between infant bedding overheating and position for babies in their first months of life, who are unable to adjust their bedding, and maybe at risk of being totally covered especially by duvets (Fleming PJ et al, 1990).

The home thermal environment has been implicated in infant mortality and morbidity. Lack of warmth and the presence of damp has been found to be associated with respiratory disease in children (Burr ML et al, 1989: Martin CJ, Stephen DP, Hunt SM, 1987) and to be associated with lower socioeconomic groups and poverty (Lowry S 1989). Evidence for cold and damp effecting health with the risk of hypothermia especially to the elderly is well documented (Lowry S 1989).

More babies die in winter (Wynn M, Wynn A 1975). A recent analysis revealed that for each degree Celsius by which the winter is colder than average, there are about 8,000 excessive deaths (Curwen M, Devis T 1988). The risk of SIDS in infants aged 3 to 5 months, is greater in the winter (Beal SM, 1983). Taking into account the

variation of birth rates throughout the year does not change the strong clustering of deaths from January to March (Zoglo DP, Lucky DW, Freiker AL, 1979). This suggests that cold weather somehow affects illness.

Descriptive studies of SIDS reveal a winter excess in most countries (Fredrick J, 1973: Dwyer T, Ponsonby A–LB, Newman N M, Gibbons LE, 1991). Early research into cot deaths had identified an increased incidence in the cold months of the year in both the northern and southern hemispheres (Valdés–Dapena 1967: Froggatt et al 1971: Steele K Kraus Langworth 1967). Falls in climatic temperature are associated with SIDS where daily changes in the weather were identified four to six days prior to the death in England and Australia (Murphy MFG, Campbell MJ, 1987: Campbell MJ, 1989). The peak occurrence of cot death coincides with minimum overnight temperatures (Bonsar RS, Knight BH, West RR, 1978) and the possibility of cold exposure is suggested by the greater number of cot deaths in winter months. The regional incidence of SIDS in Australia and New Zealand is inversely related to mean annual temperature (Hassall IB, 1987). There remains no firm link between the troughs in weather and peak in incidence of cot death. A whole line of evidence suggests that more babies die when the weather is cold– why might that be? Several explanations are possible: First babies may be too cold, second they could suffer from the infections which occur in winter, or third, they could die paradoxically from being over protected against the cold. The mechanism of temperature control in babies has recently become a focal point in cot death research.

Temperature control

Man maintains an almost constant body temperature within a narrow range despite sizable variations in environmental temperature. Body temperature varies from the deeper structures of the liver, brain and viscera, known as the core temperature, to the periphery of the body or shell, comprising the muscles, limbs and skin surface. The peripheral temperature is usually lower then the core temperature providing a gradient for heat transfer from the core to the periphery. The normal range of deep body temperature in man at rest is 36–37.5°C, a `set range' allowing critical functions of the body core to continue within a narrow temperature band. The `set point' is the

level of temperature above or below which adjustments in heat gain and loss are made. A state of hypothermia occurs when body temperature is below 35°C, and of hyperthermia when the temperature is above 38°C.

In health this homeostasis in man is maintained by balancing heat gain and heat loss (Du Bois E.F 1938). There are many factors which change body temperature and play a part in heat balance. Heat gain is due to heat produced in the body by metabolic activity, and heat gained from the environment such as sitting in the sun or in front of a hot fire. The production of heat by cellular metabolism tends to increase the body temperature. Some organs such as the heart and liver produce constant heat whereas skeletal muscles make a variable contribution according to whether the body is resting or exercising. Basal metabolic rate (BMR) is the rate of metabolism of a starved individual resting in a warm environment, and is not easily defined in children (Sinclair JC, Scopes JW, Silverman WA, 1967). It varies according to age, body size and gender. BMR increases during the first week of life, until one year of age subsequently declining into adulthood and old age. BMR similarly declines with body mass so that individuals with a large body mass produce less heat per kilogram of body weight than small (Heim T, 1981). Ingestion of food also increases the metabolic rate. This stimulus of food to the metabolism is known as the 'specific dynamic action of food' (Lusk G, 1930).

Heat loss takes place principally from the skin by convection, conduction, radiation, and the evaporation of water from sweating. Conduction of heat is defined as the transfer of heat energy down a temperature gradient by the exchange of kinetic energy from one particle to the next without a change in the position of these molecules (Mitchell D, 1974). Conductive heat loss depends upon skin contact, and as the skin is mostly surrounded by air, a good insulator, and rarely in contact with heat conducting surfaces, conduction plays a small part in heat loss. It has been estimated that for babies lying with body contact on a mattress only 5% of non-evaporative heat loss is by this method (Hey EN, Katz G, 1970). Convection is heat exchange promoted by air movement, defined as the bulk movement of congregations of particles at different temperatures (Mitchell D, 1974) and is continually occurring.

Radiation of heat is the loss or gain of heat by exchange of electromagnetic energy. The nature of the surface determines how much of the Incident energy is absorbed and what fraction of the maximum possible energy is emitted. Very dark skin absorbs about 82% of the sun's radiation, very fair skin 62%, but these values are modified by any clothing worn (Bray JJ, et al 1986). Exchanges of heat with the ambient environment by radiation, convection and conduction can be gains or losses according to the direction of the temperature gradient. Where the ambient environment is colder than the surface temperature heat will flow from the body core to the periphery. The surface temperature may vary in form, from the skin of a naked man to the outer surface of clothing in an insulated man. Insulation of the body will play a role in the degree of heat flow, and is affected by body fat, clothing and wrapping. Where body insulation is large due to many fat deposits under the skin or several layers of thick clothing heat flow to the body surface will be less than where body insulation is small due to minimal body fat and thin clothing. General thermal comfort provides the motivation for thermoregulatory behaviour in adapting external body insulation. Other heat loss mechanisms include insensible heat loss from the lungs, and heat loss from sweating. If the atmosphere is dry sweating is very efficient, where humid sweat does not evaporate and sweating no longer has a cooling effect.

Body temperature remains constant if heat gained equals heat lost. The principal means of heat gain is from metabolic activity, and heat loss depends upon the ambient temperature and body insulation. Thermoneutrality is defined as that ambient temperature at which heat gain is balanced with heat loss, and body temperature is constant. Thermoneutrality varies according to metabolism and body insulation. Sub-zero temperatures can be thermoneutral if body insulation is sufficient to prevent heat loss, although the risk of hyperthermia occurs in an active man where body insulation reduces heat loss mechanisms despite the external cold. In warm ambient temperatures thermoneutrality occurs where heat loss mechanisms are effective with reduced body insulation.

Where man is not in an environment that is thermoneutral, mechanisms are evoked to try and make the environment thermoneutral. These mechanisms are controlled by

the hypothalamic thermostat which is affected by changes of the body temperature above or below the set point. The set point is operated by a feed back loop whereby the central control of temperature in the hypothalamus, in particular the pre–optic area, is fed information from the temperature receptors at the skin and body periphery, which alter the hypothalamic set point. As homoiothermic man maintains deep body temperature within a set range, regardless of environmental variations, the main role of thermoregulative processes is in relating heat production and subsequent heat flow, to the internal and external thermal insulations. The mechanisms for this are now well known.

When heat gain exceeds heats loss, man's behavioural thermoregulative responses involve a reduction of body insulation, with an accompanying transfer of blood to the periphery (vasodilation) for heat loss. Further mechanisms can then be evoked to continue the process of heat loss, which is achieved by sweating. Evaporative heat loss by sweating is the only means of maintaining body temperature when the ambient temperature is higher than the surface temperature. Sympathetic stimulation of in particular the eccrine sweat glands in the dermis release a primary secretion of water sodium and chloride which passes via a duct to be deposited at the skin surface through a pore opening. Sweat is mainly hypotonic, becoming less so as body temperature rises further and sweating increases. Sweating can lead to a fluid loss of up to one litre per hour in man, diminishing body water and electrolyte levels to dangerous proportions (Lovatt EC, 1957). Sweating substrates have to be supplied by local circulation which depends upon an adequate cutaneous blood supply. In cold conditions behavioural adaptation involves applying extra insulation on the body, with an accompanying reduction of blood flow to the periphery by vasoconstriction, further mechanisms will then be switched on to increase the metabolic rate by muscular contractions of shivering. The question is how well adapted is the developing newborn at making these adjustments. Thermoneutrality in the baby has been investigated for the naked newborn under laboratory conditions, using incubators. In these conditions thermoneutraiity is defined as environments in which body temperature remains normal while heat production and evaporative water loss remain at a minimum (Hey EN, 1975).

At birth the infant's thermoregulatory processes are thought to be fully developed (Brück 1961), although ill tested and of relatively limited capacity. Maintaining a constant body temperature may pose difficulties for the infant, which will be discussed with particular interest to the vulnerability of SIDS.

Hypothermia

When the environmental temperature is low, mechanisms of heat conservation and production are required. The increase in heat production, maintains a thermoregulated state. This will break down, only if heat production cannot match heat loss so that in spite of a maximal heat conservation response, body temperature falls death occurs by hypothermia.

The newborn infant loses heat very rapidly because of its large surface area to volume ratio. In a cool environment this must be compensated by increasing metabolic rate and conserving heat by adequate clothing and wrapping. The preterm infant is particularly vulnerable due to its size and an even lower metabolic rate (Hull D 1966).

Metabolic rate in the adult is increased with the aid of thermogenic metabolism of shivering. Although temperature regulation exists in the newborn there is no ability to shiver, the mechanism for this arising when the infant is approximately one year of age (Sinclair JC, Silverman 1966; Stern L, 1981). Heat production relies on the existence of brown fat sources for metabolic activity in the term baby which become replaced by white fat during the first year of life (Hull 1966; Stern L 1981). The newborn has a well developed mechanism for nonshivering thermogenesis, which is enhanced by norepinephrine and thyroid hormone acting together (Gale CC, 1973). Behavioural adaptation to the cold relies on parents to adequately insulate their infant, but the baby has the ability to change posture if not swaddled by nestling or huddling which reduces thermal conductance of peripheral tissues (Hull D, 1973).

Cold injury in cot deaths has been suggested by workers who found greater proportions of brown fat at autopsy than usual, and elevated T3 (triiodothyronine) levels (Naeye RL, 1974) although the findings support hypoxia, and febrile episodes

(Vaidés–Dapena MA, et al 1976). Any interference with the secretion of noradrenaline which induces the brown fat to produce heat could produce an abnormal reaction to cold exposure, an abnormality in the catecholamine system could inhibit the response (Cornwell AC, 1979).

The greatest concern for hypothermia is perhaps with the preterm or developmentally sensitive infant who is prone to apnoeic episodes (Collier HOJ, 1971). Hypothermia causes hypoxaemia, metabolic acidosis, and hypoglycaemia, the combination of which, if severe, could be fatal. Once cold hypoxia will reduce the metabolic response to cold (Cornwell 1979). Hypothermia could also induce apnoea (Rutter N, Hull D, 1979) as there is a decrease in urinary catecholamines found in infants with apnoea (Kattwinkle J, Mars H, Fancroft AA, Klaus MH 1976) these processes again may suggest an abnormality with the catecholamine system.

Although hypothermia has been a focus for attention there is no recent evidence to support inadequate home care of infants, in particular preterm infants, in cold homes or with inadequate clothing and wrappings, which may lead to accidental hypothermia. But what about the other extreme?

Hyperthermia

When the environmental temperature is high, mechanisms of heat loss are evoked. Metabolic heat production and any heat gain from the environment must be dissipated by the evaporation of water through the process of sweating, the reduction of body insulation as blood flow increases to the periphery, and conduction, convection and radiation from the skin. Failure to lose heat adequately by these means leads to a rising of body temperature and metabolic rate, leading to death by hyperthermia. Babies more than a month old are better at generating heat than loosing it. Indeed the baby depends upon its parents for the behavioural adaptation of removing layers of insulation when the environment is warm. The mechanism of evaporative heat loss is present at birth, and in premature and small for dates babies (Brück K, 1961). However adequate replacement of body fluid and salt again places the infant in a parent dependent state. Infant deaths due to the failure of parents to offer body fluid

replacement in a heat wave in Australia reveals the vulnerability of the baby to hyperthermia (Danks DM, Webb DW, Allen J 1962).

A rise in body temperature due to a viral illness is a situation faced by most developing infants, and poses another adaptation of the infant to engage in heat loss mechanisms. Work has identified that the kitten dies of febrile apnoea triggered by a combination of heat and infection (Lennox MA, Sibley WA, Zimmerman HM, 1954). Febrile convulsions and high temperatures in infants due to viral infection is well documented (Wegman R, 1939). Researchers suggested that a febrile convulsion may be for the young infants equivalent to apnoea as a mode of death, but no relationship has been found between rates of hospital admission for a first febrile episode and the monthly rate of SIDS (Sunderland R, Emery JL, 1981). Apnoea can be caused by upper airway obstruction by laryngeal closure. It has been found that dogs have an age related period of hypersensitivity in the laryngeal adductor neurons. Hyperthermia decreases the latency and threshold of the laryngeal adductor reflux and this is enhanced during the age related period of hyperactivity. If a similar period exists for infants then hyperpyrexia could result in fatal apnoea (Haragudis 1983). Other mechanisms suggest for a minority of cases an underlying malignant muscle–membrane disorder which predisposes the infant to hyperthermia (Denborough MA, Galloway GJ, Hopkinson KC, 1982). Work with animals has placed forward the consideration that pyrexia may facilitate endotoxin absorption (Butkow N, Mitchell D, Laburn H, Kennedy E 1984).

Hyperthermia as a causative factor in SIDS was first discussed without much evidence in 1974 (Dallas RJ, 1974). Evidence emerged with the publishing of five case histories of infants in Newcastle who had been unwell and left well wrapped. These infants had subsequently been found shocked and convulsing. In all but one case the babies died and a presumptive history of heatstroke was made (Bacon C, Scott D, Jones P 1979). A common feature of all the infants was that they were judged to be 'over wrapped', and it was felt that this, along with a mild infection, contributed to the resulting heatstroke. Postmortem findings of small gut mucosal changes were evident in this type of case, blunting of the viili, cellular debris in the crypts, lymphocytic infiltration

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and pyknotic nuclei, and suggested heatstroke (Stanton AN, Scott DJ, Downham MA, 1980). Heatstroke in children had previously been described in India, and in babies left in cars in the USA, with only one reference to this in a European winter, from France in 1945 (Bacon CJ, 1983). At a similar time a combined serial study investigating SIDS found evidence of cot death victims overdressed and sweaty to the touch when found dead. There were some cases of pathological evidence of infection and also of infants rooms being hot (Stanton AN, 1984). Studies with twins found that overheating was the outstanding common factor (Bass M 1982). It appeared that high temperature was associated with some SIDS, with a possible mode of death associated with apnoea, cerebral ischaemia, or unobserved convulsions.

Medical care of the newborn is over conscious of the risk to the baby of hypothermia. This concern may impress on parents the false assumption regarding the need to keep baby warm, which persists at home. Evidence had been found to suggest that infants were excessively wrapped, swaddled and enclosed in sleeping bags or placed to sleep with heavy forms of bedding, such as duvets, and left to sleep in warm rooms (Bacon J, Scott D, Jones P 1979). The probability of overheating from excessive clothing may be compounded by fabric and the design of infants clothes, especially the use of synthetic materials which are less permeable to sweat (Bacon CJ, 1983). Parental practice may fail to consider the thermal environment of their babies. Bringing a baby into an adult bed may prove too warm if the baby's clothing is not reduced, as may taking a well wrapped baby into warm shops without removing outer layers. Parental practice of adding extra insulation to febrile infants has been documented as maternal mismanagement of illness, especially in lower socioeducational groups (Eiser C, Town C, Tripp J 1985). Studies investigating post–neonatal death have identified parental sub–normality or low intelligence with neglect, incompetence and failure to summon medical help. Lack of understanding about health issues reduces choice and can be fatal where parents act inappropriately by failure or delay in seeking medical attention, or fail to recognise serious illness (Knowelden J, Keeling J, Nichill JP, 1985). Level of intelligence is not just about academic qualification but about the practising competence of parents, as graduate parents have been found to ignore professional advice contributing to infant deaths (Taylor EM, Emery JL 1983).

Hyperthermia is a physiological challenge faced by infants, and is associated with the winter months, a period of increased vulnerability of infants to SIDS. However, to date only anecdotal evidence has been identified. We have no idea of how many babies sleep in warm conditions and do not die, and of what physiological processes occur in babies who sleep in warm conditions. There exists a great void of knowledge concerning the normal temperature mechanisms at work in babies (of the peak incidence of SIDS at approximately 3 months of age) and the link with parental choices of infant clothing, bedding, and modern home heating methods.

Studies began to observe parents choices of home heating and infant insulation. A relationship between the amount of clothing parents placed on babies, room heating and outside weather conditions was found, where parents used more clothes and wrappings, and increased room temperatures in colder weather (Nicoll D, Davies L 1986). Younger less well educated mothers were found to use more insulation in warmer rooms, and lower social classes chose warmer rooms with more coverings at night (Bacon C, Bell SA, Clulow EE, Beatie AB 1991). However, such studies failed to make any biological associations. The normal temperature control mechanisms in babies after the early neonatal period has not been fully investigated. Continuous recordings of deep body temperature, taken in the homes of healthy babies between 3 and 4 months of age at night, identified temperature changes with sleep (Wailoo MP, Petersen SA, Whittaker H, Goodenough P 1989). Temperature fell with night sleep by 0.8°C, and rose again before waking. The thermal conditions chosen by parents for these sleeps identified a range of room temperatures from 6°C to 28°C, with a variety of clothing and bedding. These physiological findings centred on healthy infants of 3 to 4 months of age at night, pointing for a need to study further the complete thermoregulative capacity of babies throughout the day and night.

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1.4 CONCLUSIONS

The largest category of post-neonatal mortality SIDS occurs mainly in the winter months. In some way cot deaths are associated with colder weather. What exactly is the environmental factor of the cold which interacts with the infant to such fatal ends? The cold could interact through the physiological control of body temperature, especially with regard to infant susceptibility of hyperthermia. There appears to be a great deal of retrospective evidence linking hyperthermia with SIDS. It is therefore paramount that a complete understanding of the physiological responses of body temperature in infants is obtained, with reference to parental thermal care in homes today. Only then can we be certain that hyperthermia is a real risk. More recently the task required for a further reduction in cot deaths was clearly stated,

> " The most important task now is to determine the causal significance of factors for which the evidence is already reasonably strong, such as maternal age, maternal smoking, intrauterine growth retardation, bottle feeding, and thermal balance ..... *to provide* ... a greater understanding of how the well identified risk factors operate and interact".
>
> (Dwyer T, Ponsonby A-L 1992).

1.5 AIMS AND OBJECTIVES OF THIS STUDY

Aim

To examine the influence of parental choice of clothing, wrapping and room temperature on body temperature patterns, in babies aged 3 to 4 months during the day and night.

Objectives

1) To measure the deep body temperature of babies aged 3 to 4 months throughout the night.

2) To measure the deep body temperature of babies aged 3 to 4 months during the day, for the effect of sleep, feeding, and wakeful activity.

3) To measure temperature changes at the skin in association with deep body temperature, and body insulation.

4) To observe parental choices of clothing, wrapping and infant feeding in relation to thermoregulation.

5) To examine whether a change in the normal thermal care of babies will alter observed temperature patterns.

6) To formulate the optimum requirements of bedding and room temperature for babies aged 3 to 4 months of age.

CHAPTER TWO

METHOD

2.1 INTRODUCTION

The aim of the project was to investigate the effects of sleep, feeding and wakeful activity on the body temperature of 3 to 4 month old infants at home, during the day and night; and also to examine the influence of the thermal environment upon the stability of the baby's thermoregulatory mechanisms.

2.2 SUBJECTS

Selection Criteria

The study aimed to make measurements on approximately 100 normal babies, who ideally would be born with no apparent defects at term to a healthy mother, by spontaneous vaginal delivery. Term was taken to be a mature gestational age of 36 to 43 weeks at delivery, excluding extreme pre-term and post-term babies. A normal delivery, included normal spontaneous vaginal deliveries, and some abnormal deliveries by forceps, vacuum extractions, and planned lower segment caesarian sections, where no major life threatening event occurred to either the mother or unborn child. In this way mothers with serious pre-eclampsia, antepartum haemorrhage, a history of medical problems such as heart disease or diabetes, and major obstetric emergencies ie ruptured uterus, would be excluded. A healthy baby, was taken to be one who made an immediate transition to extra-uterine life without active emergency resuscitation due to hypoxia. Babies with congenital abnormality such as Downs Syndrome, or congenital heart defects or other body defects were excluded. No other selection criteria were applied.

Subjects were recruited for two monitoring periods, the first from September 1988 to May 1989, and the second from November 1989 to August 1990. The two groups were recruited by contact with parents in different health authority premises; the first from parents newly delivered at the Leicester Royal Infirmary Maternity Hospital (L.R.I.M.H.), and the second from parents visiting health authority community clinics.

Efforts were made to select a random group of subjects that would represent the

social class distribution of Leicestershire. The L.R.I.M.H receives over 6,000 women for delivery annually and as the largest maternity centre in Leicester provided a population of women from all social classes. After delivery new mothers are allocated to one of five wards, which were used to obtain subjects for the first period of monitoring. As the timing of delivery and hence presence on the wards is a matter of chance, recruitment of subjects in this way aimed to provide a random sample. Before approaching each mother the delivery record was consulted to confirm that the infant and mother fulfilled the selection criteria.

For the second period of monitoring parents were approached at a local health authority clinic two weeks post delivery. The Health Visitor identified parents who fulfilled the desired criteria. The health centres were chosen because they provided services to a mixed social class area.

All identified parents were asked to consider participating in the study, and were given a letter with information concerning the project (appendix A2). Those who chose to participate were asked to complete a portion of this letter containing their home address, phone number and signature, as informed acknowledgement of their consent. Recordings were expected to take place with subjects aged between 12 and 20 weeks, although in a few instances monitorings took place beyond the upper limit. They were asked to keep a diary for a prospective record of illness in their baby prior to monitoring (Appendix A3). The importance of an ongoing record of the babies development was emphasised to the parents. Other details were collected in a questionnaire, designed to obtain a full medical history of prenatal and postnatal details of the mother, birth factors, neonatal data, and also social details of the family (Appendix A4).

All parents were offered a home visit prior to participating to discuss practical details and for reassurance.

Summary of main information obtained on the questionnaire:

Birth data

Type of delivery, (ie. N.S.D. Forceps L.S.C.S.);

Apgar score:

Date of birth:

Gestation:

Sex:

Birth weight:

Head circumference:

Feeding:

Minor illnesses, (ie. respiratory, gastro intestinal infections etc):

Siblings current health:

Father/Mother current health:

Social factors

The following information was obtained for each family.

Parental details

Mother's name:

Date of birth:

Father's names:

Date of birth:

Mother's occupation:

Father's occupation:

Smoking – Mother/Father:

Address:

Post code:

Type of housing:

The father's occupation was used as a means of establishing social class according to the "classification of occupations" produced by the office of population censuses and surveys (OPCS). The OPCS classification of occupation is based on the classification of occupations and directory of occupational titles (CODOT) published by the Department of Employment. The groups form the basis of the OPCS classification. A definition of each group and its relationship to CODOT can be found in classification occupations coding index. The basis is to create groups with one common characteristic which relates to work done or similar occupational skill. The coding of people's occupations has become a measure of the status of a group. People of a similar level of occupational skill are brought together in classes. Each family was therefore classified into one of the following groups:-

Social Class:

1	= Professional Occupations	1
11	= Intermediate Occupations	2
IIINM	= Skilled Occupation Non-manual	3
IIIM	= Skilled Occupation manual	4
1V	= Partly Skilled	5
V	= Unskilled	6

Remaining groups

	= Armed Forces (inadequately described)	
	= Unemployed	7

2.3   GENERAL SCHEME OF STUDY

Monitoring Schedule

In order to meet the objectives of the study, babies participating were required to provide temperature data for the day and night, under different conditions, between the ages of 12 to 20 weeks. This would ideally lead to a picture of the 24 hour temperature ranges of babies at home. Normally a series of recordings were made.

1) A day recording, with parents controlling the thermal environment, to ideally include a period of sleep, feeding and wakeful activity, depending upon the individual baby and parent's daily routine. It was anticipated that a morning or afternoon alone (approximately 4 hours) would produce the required data. The timing varied considerably between subjects, with some participating for the morning or afternoon only, and others for the entire day. However, parents were encouraged to have their babies monitored for as long as possible. The day was taken to be the time of waking in the early morning from 5 am to 9 am, ending at bedtime between 5.30 pm and midnight.

2) A night recording with the parents choosing the thermal environment, began prior to the baby being placed to sleep for the night, and ended once fully awake the following morning. Again, there was variability between subjects based upon the infant's bedtime. The night sleep was taken as occurring from 5.30 pm to midnight.

3) A day recording in which the thermal environment was chosen for the parents. This involved a change in either the baby's wrappings or an increase in the ambient temperature.

4) A night recording, in which the thermal environment was chosen for the parents. This involved changes similar to the day.

It was anticipated that each baby would provide a day and night set of readings, to be known as free choice, where the parents controlled the thermal environment of the baby, and a day and night set of readings, to be known as constrained choice, in which the researcher controlled the thermal environment. Where the latter was not possible, a second set of free choice recordings was often obtained. The free choice recording asked parents to clothe and wrap their baby, and heat their home, according to their usual habits. The constrained choice recording in which the thermal environment was chosen for the parents was based on safe known limits.

The Foundation for the Study of Sudden Infant Death (F.S.I.D.) in 1988, advised a

room temperature of 19°C for babies. Previous work had shown that babies bedrooms, especially in the winter months, fell to temperatures below 19°C, and babies were covered with an average of 12 togs when sleeping (Wailoo MP, Petersen SA, Whittaker H, Goodenough P, 1989). Subjects whose rooms fell well below 19°C, were placed in a room heated by a thermostatically controlled heater to 19°C, +/- 1°C. Where parents chose to lightly clothe and wrap their baby, with less than 12 togs in total, additional wrappings were prescribed keeping the total tog level within this range. A standard set of blankets, each 2 tog units, was loaned to the parents for the monitoring period.

Each subject varied according to home conditions and parental practice. In many cases it was not possible to change the thermal environment of the baby. Babies monitored in the cold winter months were more likely to be monitored under constrained choice conditions. On the whole only one mechanism of change was feasible, either the ambient temperature or the tog values.

2.4 PROCEDURES AT EACH MONITORING

Information Gathering

At each home visit to monitor the baby information was collected, first on the current health of the baby, second the baby's thermal environment, and third physiological measurements were made. All written information was collected on a monitoring data sheet designed to contain the above categories of information (Appendix A5).

Baby's Health Data

The naked weight was recorded in kilograms on standardised portable seca scales, with the batteries changed monthly. Current feeding practice was recorded to include the type of feed (ie breast, bottle, cows milk, solid food), and frequency. Any concerns of the parents for their child's health were reported, focusing on upper respiratory infections of snuffles, colds etc. Parents were asked about prescribed medication. A vaccination history was also included, and any illness within the family.

Summary of data collection on monitoring form:

Baby's Health:
- naked weight
- current feeding
- illness
- medical intervention

Thermal Environment Data

Information was collected on how the baby was clothed and wrapped, and home heating. All clothing and wrappings were individually recorded to obtain a score of their thermal capacity, or tog value. On the monitoring sheet the tog value was recorded adjacent to the item of clothing or wrapping.

Tog Values

The human body maintains a stable core temperature at around 37°C with the aid of clothing and wrapping. Exactly what part insulation plays in controlling our core temperature is still not fully understood (Ho SP, Fan SST, 1975; Kerslake D, 1991). Mathematical formulas try to aid our understanding of the factors involved (Fan LT, Hsu FT, Hwang 1971). Parents use clothing and wrapping, as they feel appropriate, to aid their baby in maintaining a constant temperature. There is little scientific evidence for parents to base these decisions on, although measures of the thermal insulation of fabrics are available. Tog value ratings provide a standard by which to measure the amount of thermal insulation used. The warmth or insulation of fabrics is measured in tog units. The tog value of a textile is equal to 10 times the temperature difference between its two faces, when the flow of heat is equal to 1 watt per square metre, 1 tog is the thermal resistance of a fabric for a conventional mans suiting (Clulow E 1978). The greater the tog value the greater the thermal insulation provided. Tog values of adult quilts range from 7 to 14 tog units. The thermal resistance of several layers of clothing or wrapping on a baby, can be simply obtained by adding the tog values of each layer. The Shirley Institute Manchester provided a list of tog values of babies clothing that were required for this study (see Appendix A6).

Baby's Clothing	Tog Value	
nappy	2.0	
vest	0.2	
babygro	1.0	
pyjamas/nightdress	1.0	etc

Baby's Wrappings	Tog Value	
sheet	0.5	
blanket	2.0	
duvet	9.0	
shawl	2.0	etc

To complete the thermal environment, parents were asked about how they heated their home, especially rooms where the baby was nursed.

Summary of information collected on the home:

The home
Central heating – gas/oil/other;
Other methods of heating ie electric fires;

Baby's bedroom
Own/parent;
Carpet, curtains;
Position of windows, radiator door to baby's cot/crib.

Physiological Measurements
Temperature data were collected with the use of a data logger. The Grant Squirrel data logger provided a safe easily movable unit with a large data base powered by 9 Vppg batteries.

2.5 MONITORING

All equipment was organised, checked and tested for last minute difficulties before arriving at the parent's home and a file opened to contain all documentation. The timing of the recording had to be adapted to meet the needs of each family.

Attachment To The Monitor

With the help of parents the baby was placed on a flat surface, and the thermistor probes were threaded through the clothing of the partially dressed baby. The peripheral site used for the first monitoring period was the centre of the forehead, and for the second the central portion of the left shin. The site chosen to reflect the influence of clothing was the abdomen 2cm to the left of the umbilicus. The skin probes were held in place by half inch width micropore tape. The third, rectal probe, to measure deep body temperature, was inserted 5cm from the anal margin held in place by tape and the nappy (see Fig 2.5.1 and Appendix A7).

For safety the lead from the head probe was secured behind the baby's ear and threaded into the clothes at the back of the neck. All body probes were threaded under the infant's clothing to the trunk emerging at the leg or groin area. In this way they were removed as far as possible from the infant's grasp. The lead lengths which emerged from the clothing were taped to each other for safety and parental control. The head probe occasionally required fresh tape where an infant rubbed its head on the mattress. The abdominal probe was often inside the nappy where it became damp and fell away from the skin, unknown to the parents. The rectal probe was sometimes passed with a very solid stool.

The fourth, ambient probe, was placed adjacent to the baby in free air anchored to a piece of furniture. All four of the probes were attached to the Grant Squirrel Data Logger set to record at minute intervals. The data logger was placed into a small box placed inside a bag to aid movement with the baby. With the baby attached to the recording data logger, parents were given time to become confident with handling their baby and managing the thermistor leads. All practical advice was given to allow the

Figure 2.5.1

Position of thermistor probes attached to baby.

HEAD PROBE

ABDOMINAL PROBE

RECTAL PROBE

LEG PROBE
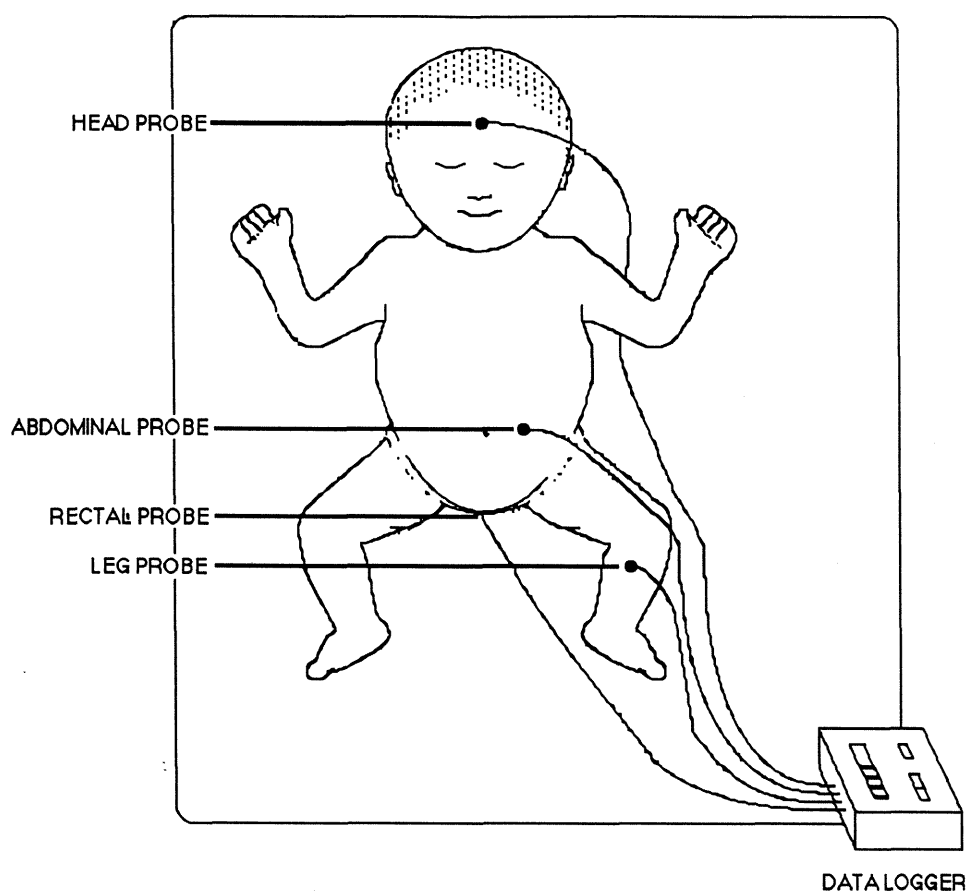
DATA LOGGER

parents to care for their baby in a normal manner.

The time the recording commenced was synchronized with the data logger and recorded on the activity sheet. Parents were asked to note the time of significant events such as feeds, sleeps, napkin change and continue to record these as they occurred on the activity sheet (appendix A8).

Arrangements were made to collect the equipment at the end of the monitoring period. On returning the data logger was stopped, and the time entered on the activity sheet. All thermistor probes were gently removed. To complete the documentation, an accurate entry of all clothing and wrappings on the baby was recorded on the monitoring sheet, with details of where the baby slept, the sleeping place and position, and details of any heating in use. The baby was weighed naked, and the parents asked about current feeding or illness.

2.6   DATA ANALYSIS SYSTEMS

Data stored in the data logger were read automatically into the micro–computer for storage and hard copy print–outs. The print–out was examined for artifact, or loss of probes from the skin sites or rectum (see probe testing for rejection criteria). Where there had been any technical failure of the equipment, or loss of probes, parents were asked to repeat the monitoring. Complete loss of data was rare, but 1 in 5 recordings would have some loss from a temperature channel. Only unblemished data, where probes had remained attached to the baby were analysed, and events that occurred during the monitoring transferred from the parents activity sheet onto the hard core printout ie. the timing of sleeps, feeds etc. Details of the clothing, wrappings and the ambient temperature were examined for the possibility of changing the thermal environment.

The 4th Dimension package was installed for storage and later analysis of all medical and social factors collected on each subject. To aid the process of constructing this

system, grids containing the required categories of data were designed. Two types of data were to be retained;

1) Base Data: a grid of constant factors such as birth details, parental age, type of housing etc, mostly found on the questionnaire form.

2) Monitoring Data: a grid of changing factors relevant to each recording session, such as date of monitoring, baby's age, weight, tog values, and temperature data etc obtained from the monitoring form.

All thermistor probes were cleaned and sterilised between use.

Statistics

Readings were tabulated for each activity. Night sleeps were recorded at averaged half hourly intervals, centred around the point at which the baby was placed to sleep. Day time sleeps were recorded at averaged fifteen minute intervals, linked to bedtime. Feeds were divided into day and nights, and data collected at 10 minute averaged intervals centred around the feeding event. Graphs were drawn to identify patterns.

Acknowledgement

Thank you letters were sent to all parents, many of whom were eager to see their baby's results and consider how warm or cold their homes were. Care was taken not to discuss any aspect of thermoregulation with the parents during the monitoring period (Appendix A9).

Ethical permission

Preparation for the study could not begin until ethical approval had been granted from the hospital medical committee. Meetings with relevant medical and nursing staff, both in the hospital and community, took place in order that all relevant professional workers involved with these families were aware of the project.

2.7 STANDARDISATION OF EQUIPMENT

Several data loggers were obtained, with thermistor probes for the measurement of skin, rectal, and ambient temperature. All equipment was sent to L.R.I.H., Department of Medical Physics for Safety Checks, following which the probes were standardised.

Calibration of Probes

The thermistor probes were calibrated in several ways.

(A) Calibration against a mercury glass thermometer of 0.1°C

The thermistor probes were attached to a Grant Squirrel Data logger set to display the channel data visually.   A small laboratory water bath, with heater control and in built magnetic stirrer, was filled with water and two clamp stands placed adjacent for attachment of a mercury thermometer and the thermistor probes. The thermometer was placed in the centre of the water bath, then secured in place by the clamp. The thermistor probes were secured together and immersed into the water bath so that their temperature sensitive ends were adjacent to the base of the thermometer.

(i) Warming Up: The water was warmed to 34°C, after which the bath heater was reduced to heat the water more slowly. At each rise in temperature of 0.1°C by the mercury glass thermometer, the reading on the visual display of the data logger, showing the temperature of the thermistor probes, was recorded. This process was continued until the temperature of the water bath was 40°C by the thermometer.

(ii) Cooling Down: With the water bath at 40°C the heater was reduced to allow the water temperature to fall slowly. As the temperature fell, spot readings of the thermistor probes attached to the data logger were taken and recorded as before at each 0.1°C by the mercury glass thermometer.

The combined results of warming and cooling the thermistor probes in this manner against a mercury glass thermometer was used to produce graphs on each probe for each process, ambient (Fig 2.7.1 and 2.7.4) rectal (Fig 2.7.2 and 2.7.5) and skin (Fig

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2.7.3 and 2.7.6).

(B) Stress testing of the thermistor probes

With the thermistor probes still in situ in the water bath their range of sensitivity was tested by adding ice into the warmed water bath to quickly reduce the temperature levels. The water was heated and stabilised at 40°C and then ice added. Spot readings of the probes and mercury glass thermometer were taken at 40°C and immediately after the ice was added. The probes fell to read ambient 21.05°C, rectal 21.1°C and skin 21.2°C with the thermometer at 22°C. This was a difficult experiment relying on human reactions, so the process was repeated with the data logger set to continuously log the probe changes at 00.01 seconds. The probes were then transferred from the warm water bath held at 40°C into a bath of cold tap water reading 21°C by the mercury thermometer. In this way the speed of adaptation to changing temperatures could be clearly seen (Fig 2.7.7).

(C) Practical use of the data logger

The reliability of the rectal probe to identify deep body temperature was tested. A data logger set to log at second intervals recorded the rectal temperature of an awake baby aged 6 months clothed. The rectal probe was rapidly withdrawn into the nappy at a given time, the response can be seen in Fig 2.7.8. Identification of different temperature sites were made by monitoring the infant with a rectal probe in correct position, a skin probe placed on the outer buttock within the nappy, and a skin probe on the peripheral leg site. The recordings again identified clear differences of temperature (Fig 2.7.9) pointing to evidence to support clear identification of any loss of the rectal probe during monitoring. The ability of the probes to detect rapid change in temperature, and the clear differences in temperature especially of the rectal probe when out of the rectum, allowed clear acceptance criteria to be set. A rectal probe with readings below 35.95°C would be rejected, and one where a rapid fall occurred within a 5 minute period. Only temperature data before the point of rejection would be accepted.
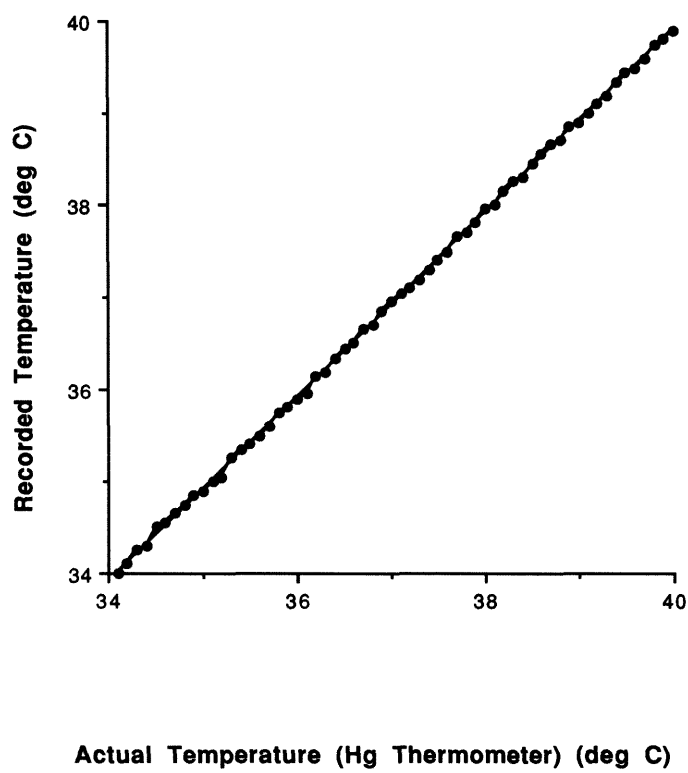
Figure 2.7.1 The relationship between temperature recorded by a calibrated mercury thermometer and the ambient probe during a temperature rise.
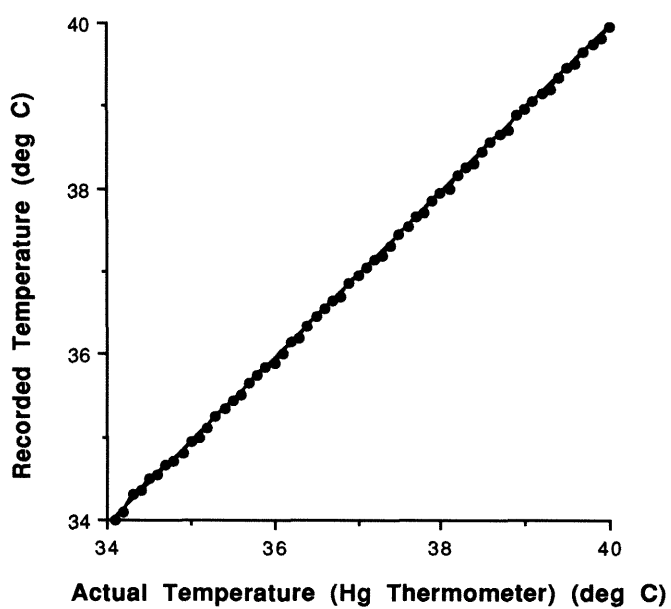
Figure 2.7.2 The relationship between temperature recorded by a calibrated
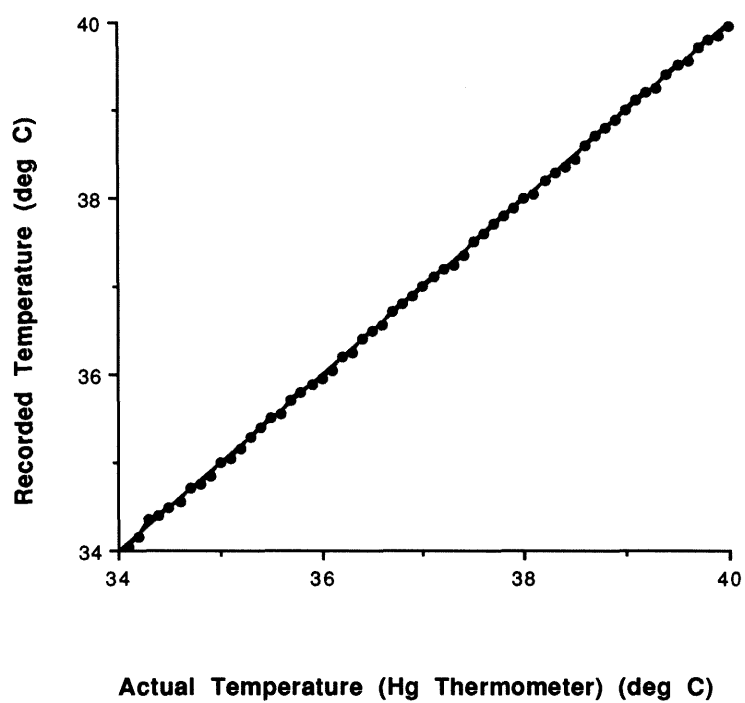mercury thermometer and the rectal probe during a temperature rise.

Figure 2.7.3 The relationship between temperature recorded by a calibrated
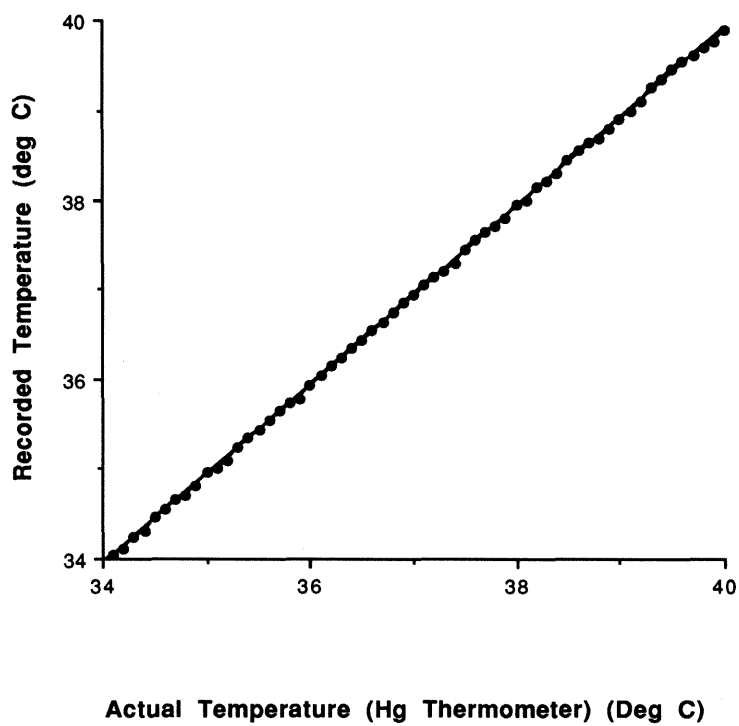mercury thermometer and the skin probe during a temperature rise

Figure 2.7.4 The relationship between temperature recorded by a calibrated
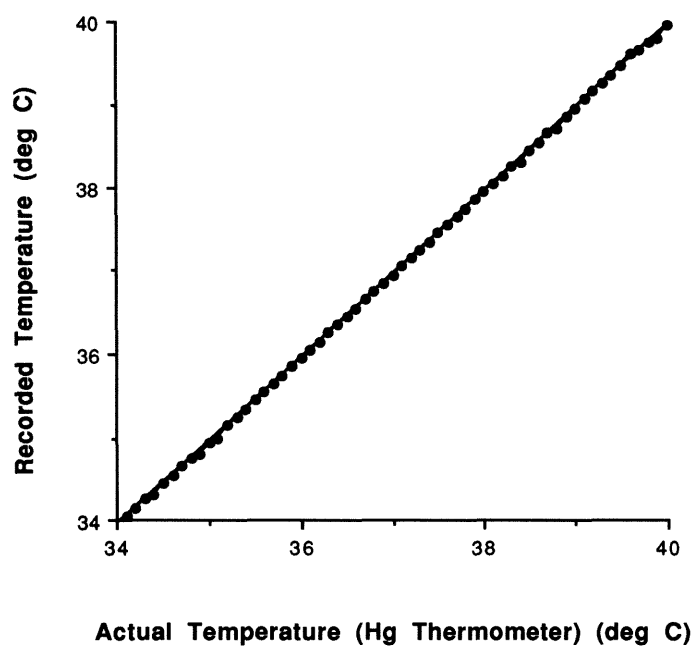mercury thermometer and the ambient probe during a temperature fall.

Figure 2.7.5 The relationship between temperature recorded by a calibrated
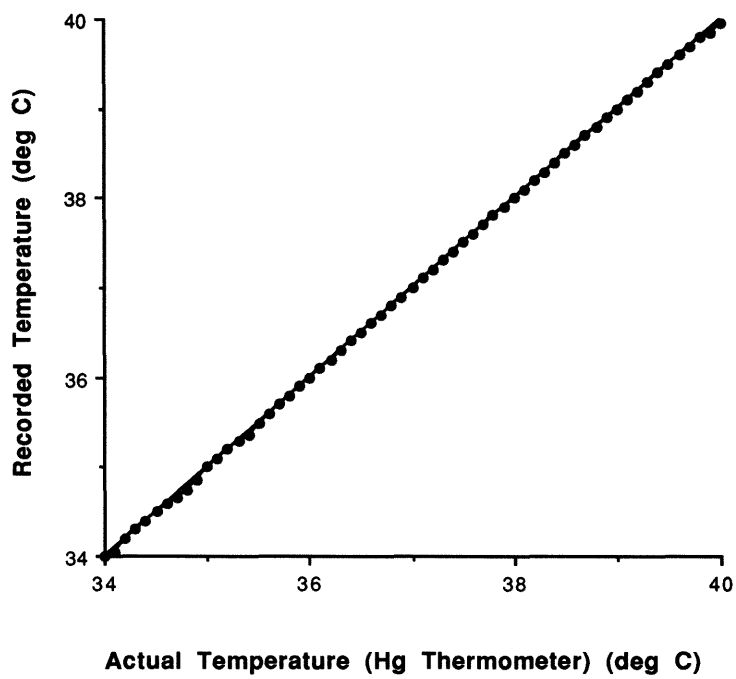mercury thermometer and the rectal probe during a temperature fall.

Figure 2.7.6 The relationship between temperature recorded by a calibrated mercury thermometer and the skin probe during a temperature fall.
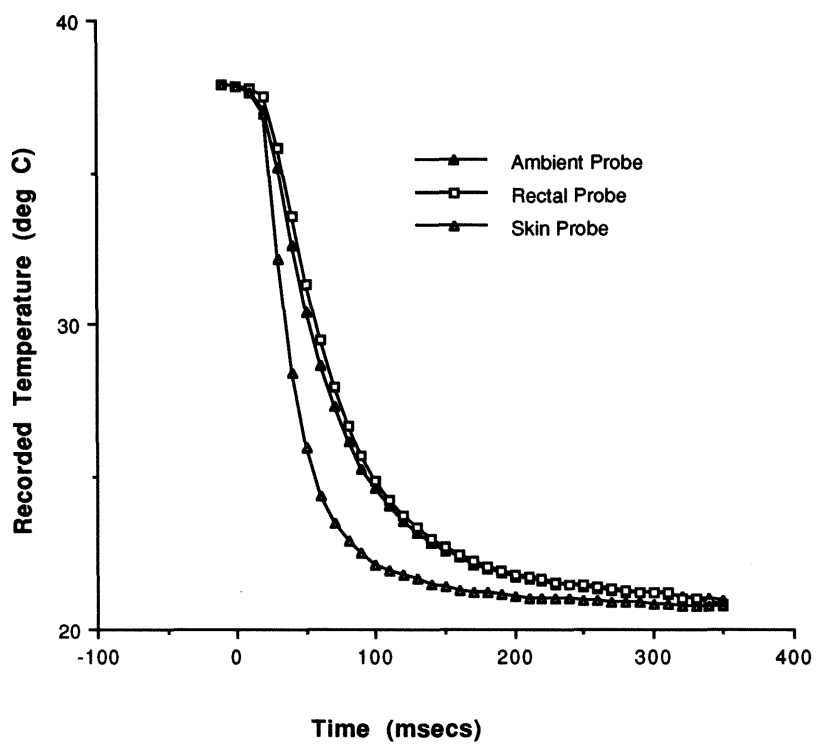
Figure 2.7.7 The response of the ambient, rectal and skin probes when immersed in warm water to which ice was added.
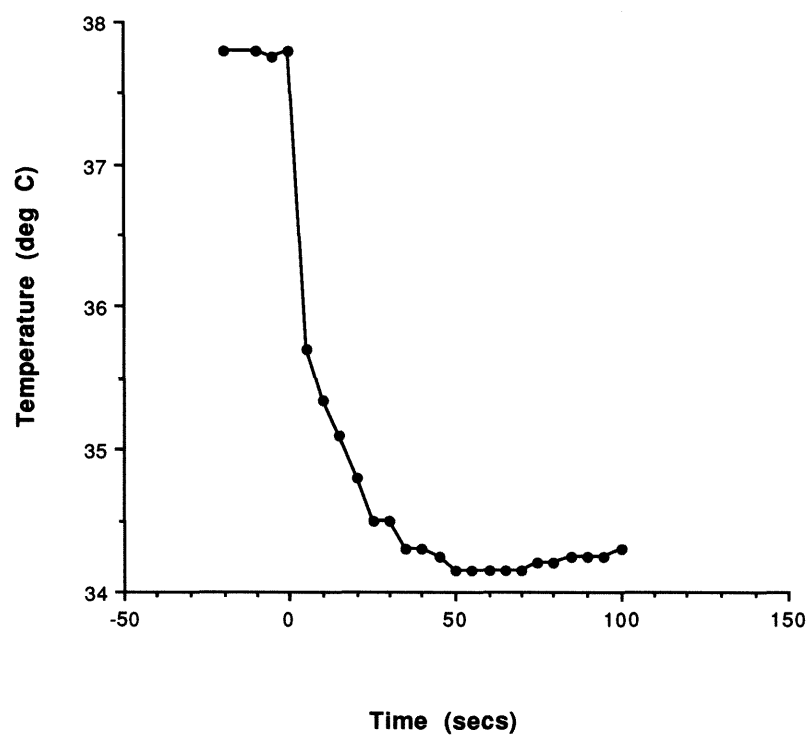
Figure 2.7.8 The response of the rectal probe when rapidly withdrawn
from the rectum.

Pilot Study Of Data Logger

Time was spent becoming familiar with the data logger, and the practical implications of attaching thermistor probes to babies aged 3 to 4 months. Four parents, whose babies were on the paediatric wards of L.R.I.H. aged between 12 and 18 weeks, gave permission for their babies to be monitored on the wards. Following discharge, two of these babies were monitored in their homes.

This time revealed numerous difficulties which were overcome by trial and error. It became obvious that the data logger could be moved easily with the baby, when placed inside a small cardboard box in-turn placed into a bag that could be carried on the parent's arm, leaving both hands free for care of the baby. Also revealed was that all thermistor probes required to be attached to the baby should, where clothing permitted, leave the baby's body below the waist, to avoid being accidentally caught in the baby's grip. Toddlers in the home proved to be a constant concern if the leads and bag were not placed out of sight.

Testing Of Portable Heater

A portable electric heater, model 971 (BEAB approved) and socket thermostat were obtained for changing the ambient temperature. After safety checks from the Department of Medical Physics, time was spent testing its ability to maintain a stable temperature of 19°C in bedrooms.

The heater was tested in several homes, some old and reported to be cold, others modern with cool and warm rooms. In each bedroom, doors and windows closed, the heater was left over night, on different thermostat settings from mark 2 to mark 4. The room temperature was logged at minute intervals with an ambient probe attached to a data logger. The aim at each logging was to achieve an ambient temperature of approximately 19°C throughout the night. The results show how variable the temperature patterns were, possibly due to several factors including changing outside weather, differences in room insulation, and the relationship of the probe to the heater. All the variables were considered as small variations could affect the outcome, therefore restricting the effectiveness of the heater. In Figure 2.7.10 the heater was

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set to mark '2' in an old cool home and a warm modern home. In Figure 2.7.11 the heater was used in the same house and room on three consecutive nights which experienced differing outside weather conditions. The heater produced differences again on mark 3 when used in a warm. well insulated room compared to a cold, poorly insulated room (Fig 2.7.12). Again variability was found on mark 4 between a cool and warm home, but this proved to be too high a setting always producing temperatures above 19°C (Fig 2.7.13). The pilot study indicated that in general mark 2 and 3 would increase the ambient temperature to within the range of 19°C, but its effectiveness would vary between homes and with variable weather.
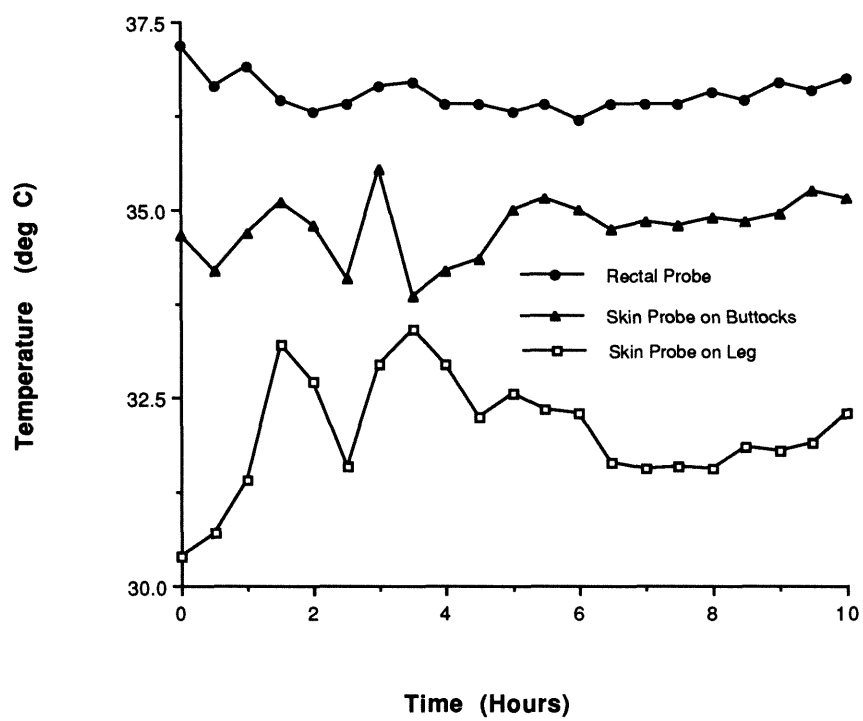
Figure 2.7.9   The difference between deep body temperature and skin temperature at two sites.
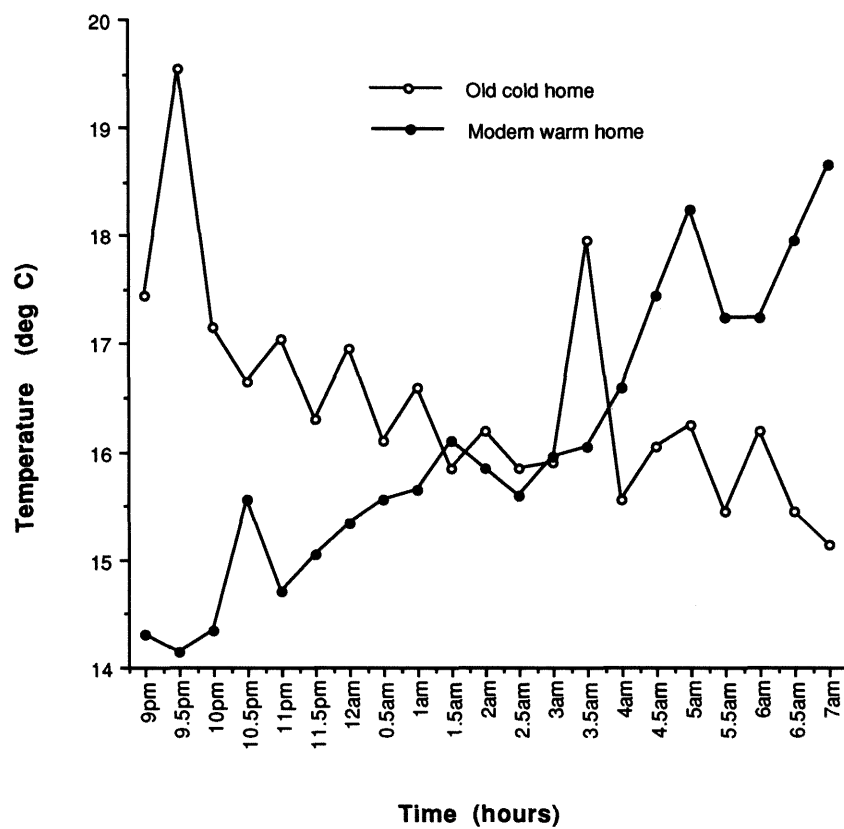
Figure 2.7.10 The overnight ambient temperatures of two homes in which the heater was set to mark "2".
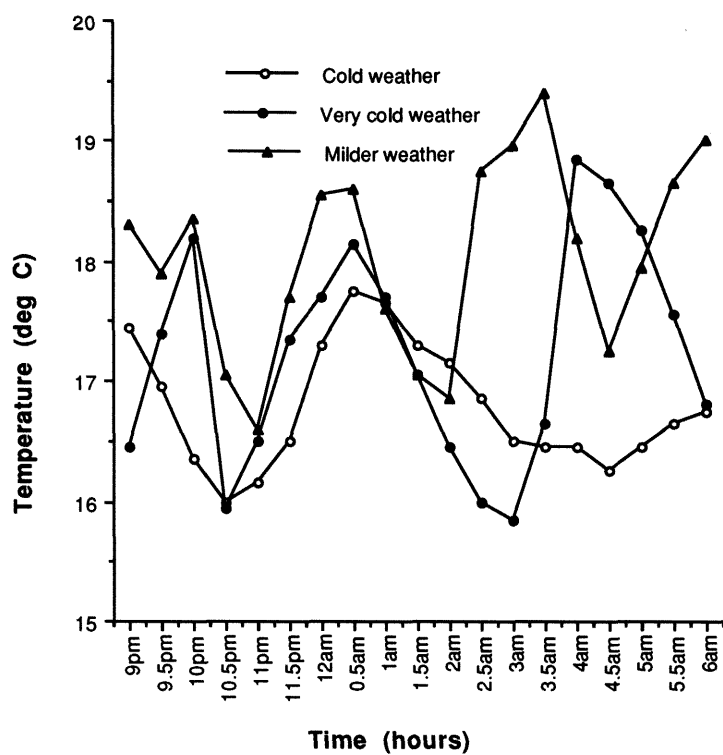
Figure 2.7.11 The overnight ambient temperatures taken on three consecutive nights in one home with the heater set to mark "2".
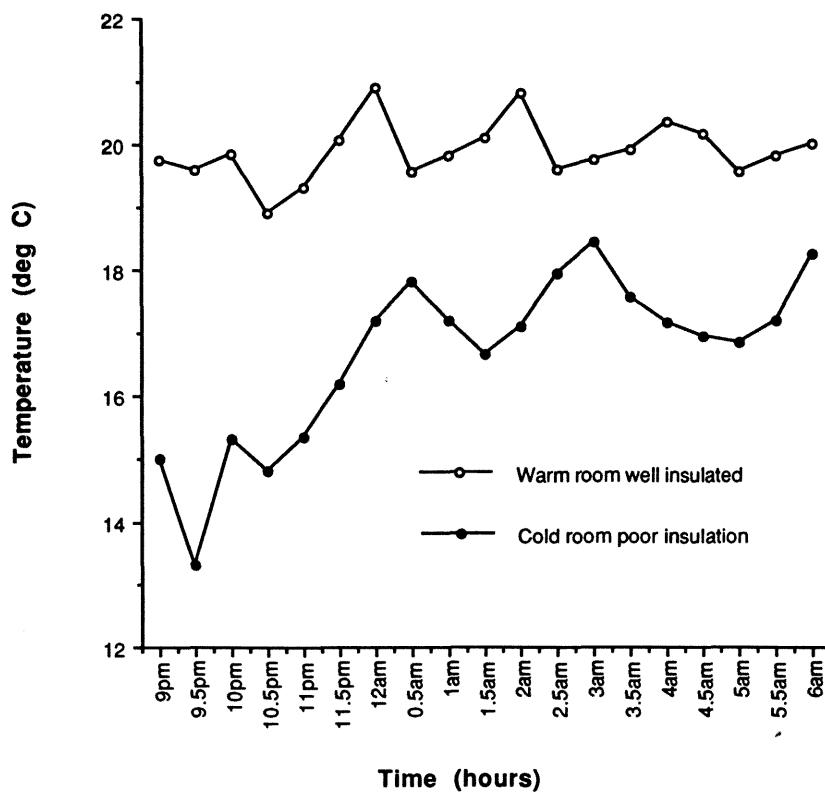
Figure 2.7.12 The overnight ambient temperatures in two different homes with the heater on mark "3".
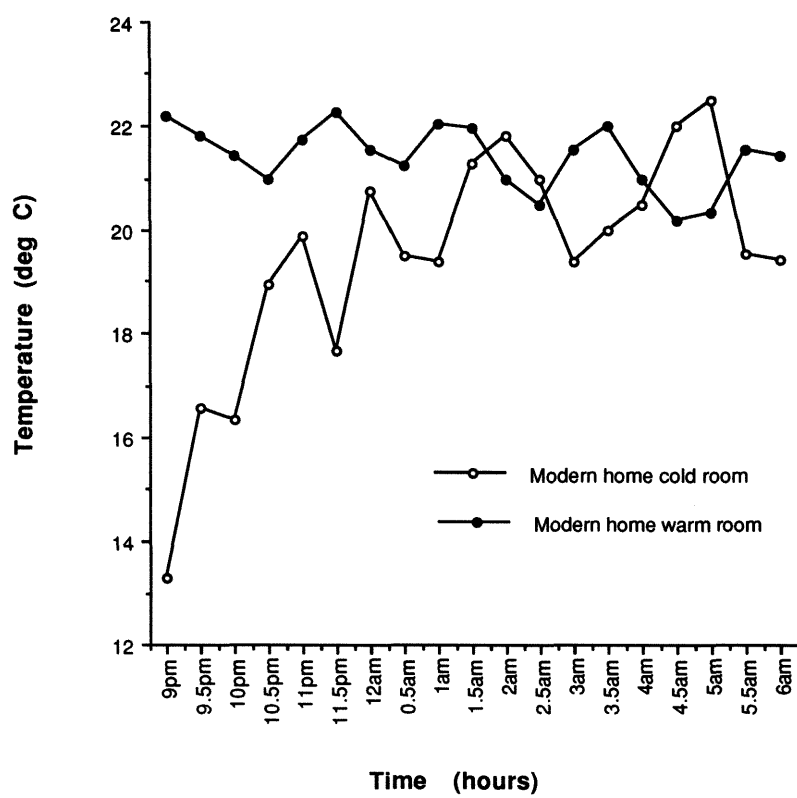
Figure 2.7.13 The overnight ambient temperatures in two different homes with the heater on mark"4".

CHAPTER THREE

DESCRIPTION OF SAMPLE

3.1 SAMPLE SIZE

A final total of 70 subjects produced useable data, the parents agreeing to have their baby's temperature monitored on at least one occasion. A list of all parents contacted revealed that for every one willing participant, four had to be contacted. This included parents who withdrew consent at the second point of contact. A total of 75 subjects were included but parental non-compliance (removal of thermistor probes), and technical difficulties with equipment, caused the loss of data from 5 babies.

3.2 SAMPLE CHARACTERISTICS

Sex: Of the 70 babies, 38 (54%) were male, and 32 (46%) were female.

Birth Details

Gestation: Gestational age ranged from 36 to 43 weeks, with a mean (SEM) of 40 weeks (0.14). The distribution is not significantly different to a normal (Fig 3.2.1).

Delivery: 51 (73%) of the babies were born by normal delivery, 14 (20%) by forceps, 3 (4%) by caesarean section, and 2 (3%) were breech deliveries.

Birth Weight: The mean (SEM) birth weight was 3485g (58g), the mean weight of male babies was 3544.2g (80g), and the mean weight of female babies was 3416g (83g).

Apgar Score: These were collected from community records on as many subjects as possible, as a means of assessing the baby's condition during its first minutes of extra-uterine life. Fifty-three apgar scores were obtained at 1 minute of the ranges 8 to 10, (see Fig 3.2.2). The remaining scores were not recorded on community records, and were unobtainable. These 16 subjects were reported by parents to have breathed spontaneously after birth requiring no medical intervention, remaining with their parents post-delivery. It can be concluded that their apgar scores would have
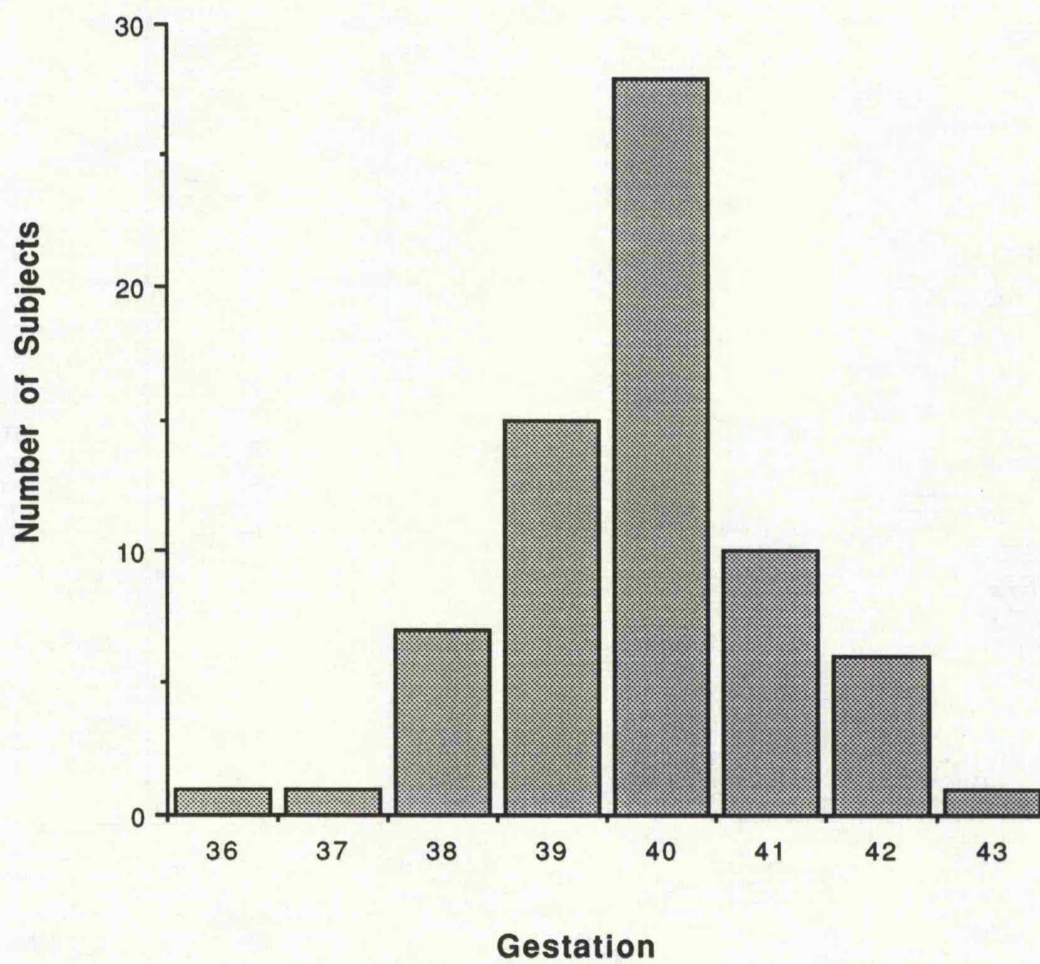
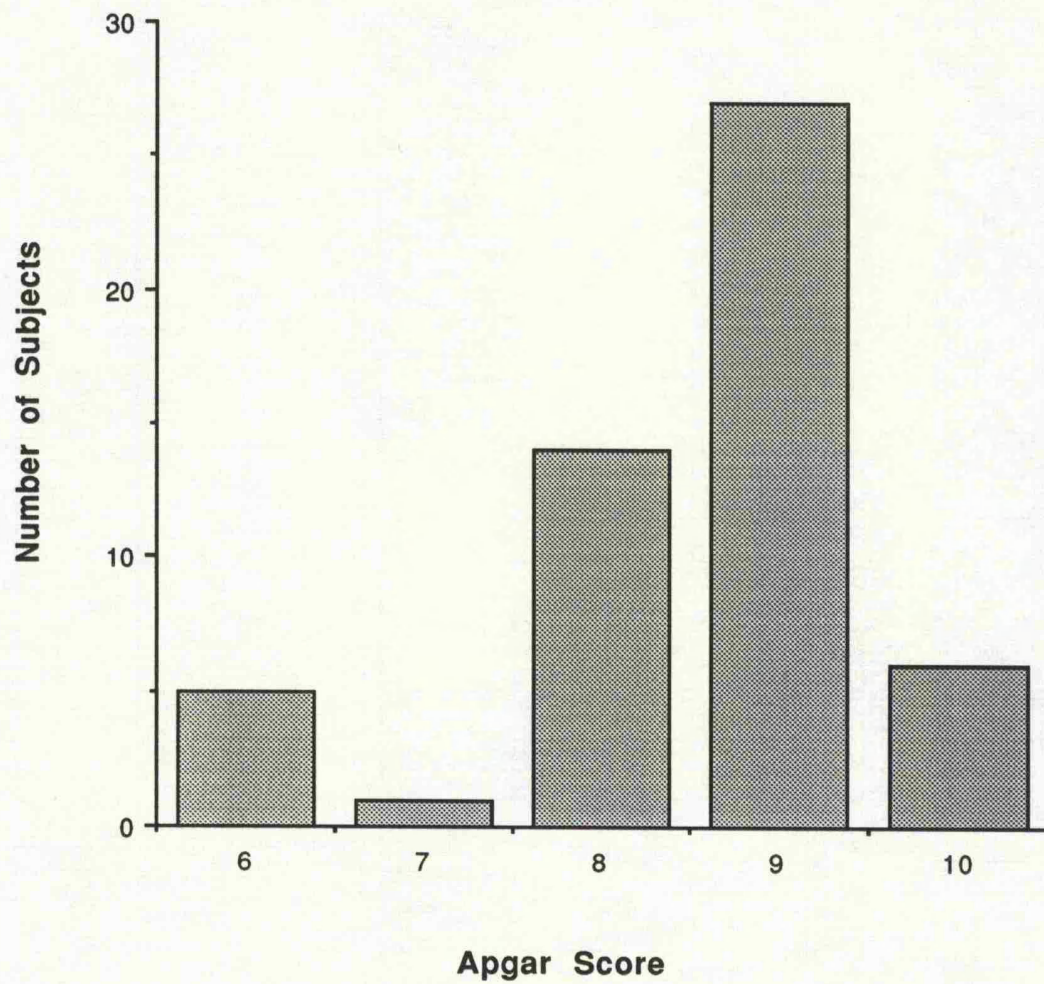Figure 3.2.1   The distribution of the babies gestational ages, at birth.

Figure 3.2.2   The distribution of babies apgar scores taken at one minute after birth.

been likely to fall in the higher range of 6 to 10.

Perinatal Data: Birth trauma was only identified in one baby (apgar= 6); however, several of the babies required special observations in the 48 hour period after birth. These consisted of 4 babies, whose apgar scores were above 6 and who were observed for a short time in Special Care Baby Units for low body temperature, mild respiratory distress syndrome (baby of 36 week gestation), and other respiratory difficulties (ie. intercostal recession). Many babies had minor illness during their first week of life, including snuffles (3), sticky eyes (3), jaundice (13), phototherapy for 24 hours (1), and vomiting (1).

Feeding: At birth 17 (24%) were bottle fed, 51 (73%) were breast fed, and 2 (3%) were both breast and bottle fed. Of the breast fed babies, 27 (51%) were male and 26 (49%) were female; whereas of the bottle fed babies, males were more dominant 13 (68%) males to 6 (32%) females. The mixed feeders were both male.

3.3 CHARACTERISTICS OF PARENTS

Age: Parental age on both mother and father was obtained for all 70 subjects, see table 3.3.A. The majority of parents were over 25 years of age.

Social Class: The Registrar General's social class distributions were referred to in this study population as numbers from 1 to 7. Using the code of occupations each family was classified as follows:

GROUP 1   Professional ie. Lawyer
GROUP 2   Professional ie. Teacher, Nurse
GROUP 3   Skilled Non-Manual ie. Clerk
GROUP 4   Skilled Manual ie. Electrician
GROUP 5   Semi-Skilled ie. Machine operator
GROUP 6   Unskilled ie. Labourer
GROUP 7   Unemployed

TABLE 3.3.A– PARENTAL AGES

AGE	MATERNAL	PATERNAL
15–20	2	1
21–25	11	10
26–30	35	31
31–35	14	20
36+	8	8

TABLE 3.3.B– SOCIAL CLASS COMPARISON

SOCIAL CLASS	STUDY POPULATION *	CITY OF LEICESTER **
1	1%	2.6%
2	34%	12.7%
3	14%	8.6%
4	33%	29.7%
5	10%	16.4%
6	4%	4.5%
7	3%	22.1%

* No armed force   ** Armed forces=3.5%

The study population contained a lower proportion of manual classes 4 to 5, and a higher proportion of non–manual classes 1 to 3 than the population of Leicester as a whole (see Table 3.3.B). There was a significant difference when comparing the manual and non–manual groups between the two populations (Chi^2=4.32   DF=1 P<0.05).

Marital Status: There were 69 couples of traditional marriage, with one couple co-habiting.

Ethnicity: One study family was Asian (1.4% of the study population), although the proportion in Leicester is almost 28%.

Housing: The majority of families lived in owner occupied housing (86%) ranging from large detached to small terrace town houses. The remaining families lived in council rented (14%) or private rented property (see Table 3.3.C)

TABLE 3.3.C– PARENTAL HOUSING

STYLE OF PROPERTY	OWNER– OCCUPIED	COUNCIL RENTED	PRIVATE RENTED
Bungalow	3		
Detached	15		
Semi– detached	32	7	
Terrace	10		1
Flat		2	

Children: The majority of babies were first or second children. Parents with more children mostly refused (see Table 3.3.D).

TABLE 3.3.D– NUMBER OF CHILDREN PER FAMILY

ONLY CHILD	ONE SIBLING	TWO SIBLINGS	THREE SIBLINGS
39 (55.7%)	22 (31.4%)	7 (10%)	2 (2.85%)

Current Health Status: All the parents were in good health, with no relevant family histories of illness, or disability.

Smoking: All parents were asked if they smoked cigarettes. Of the mothers 12 (17%) and of the fathers 16 (23%) smoked.

3.4 SUMMARY: CHAPTER 3

DESCRIPTION OF SAMPLE

1. 70 subjects produced useful data for final analysis.

2. The subjects fulfilled the set criteria, being full term normal, healthy infants, from a spread of social classes.

3. The study population differed slightly from the general population of Leicester both in the proportion of social classes, and the number of ethnic families.

CHAPTER FOUR

DEEP BODY TEMPERATURE–NIGHT.
Free choice conditions.

4.1   INTRODUCTION

Of the 70 subjects who produced useable data, 67 babies participated in a night recording, several participating on more than one occasion, giving a total of 90 data sets. The three subjects who failed to participate did so for reasons of practical difficulty as the babies slept with the parents for all or the majority of the night. The data sets were scrutinized for evidence of disturbance of the rectal probe before analysis, and only complete recordings used (see methods). At this recording the subjects ranged in age from 12 to 22 weeks (standardised to a 40-week gestation), with a mean (SEM) age of 15.7 (0.33) weeks. The time span of attachment to the data logger was similar for all subjects, in that the monitoring began in the early evening and ended early the following morning. However, for each individual subject the timing of bedtime, night activity, and waking varied enormously. Bedtime ranged from 6.30 pm to 12.30 am with the most popular bedtime being around 8 pm, see Figure 4.1.1. There were 38 (56%) babies who disturbed their parents, 16 (42%) of whom did so within 5 hours of being put down to sleep but many babies slept throughout the night for up to 11 hours. Babies spent from 8 to 11½ hours total time in their cot or crib, mean (SEM) 9.58 (0.18). Waking time ranged from 5.15 am to 9 am, the most popular time being around 7 am see Figure 4.1.2.

Results

For each of the 67 subjects one recording was analysed with data for every minute of the night obtained to the nearest 0.05°C. For the purpose of analysis, spot averaged readings were taken at 30 minute intervals (temperature readings for 5 minutes either side of the time were averaged), relating to the baby's bedtime. In this way each subject's results could be tabulated and synchronised to bedtime. This process identified a common pattern with a standard curve whose time axis was expressed relative to bedtime. This pattern has been reported on a similar subject population (Wailoo MP, Petersen SA, Whittaker H, Goodenough P, 1989). On further analysis the night was divided into the first 8 hours of sleep after bedtime (Fig 4.1.3), and the last 4 hours of sleep prior to waking (Fig 4.1.4). In this way the variability of sleep length for each subject would not distort the pattern, as like circumstances would be observed.
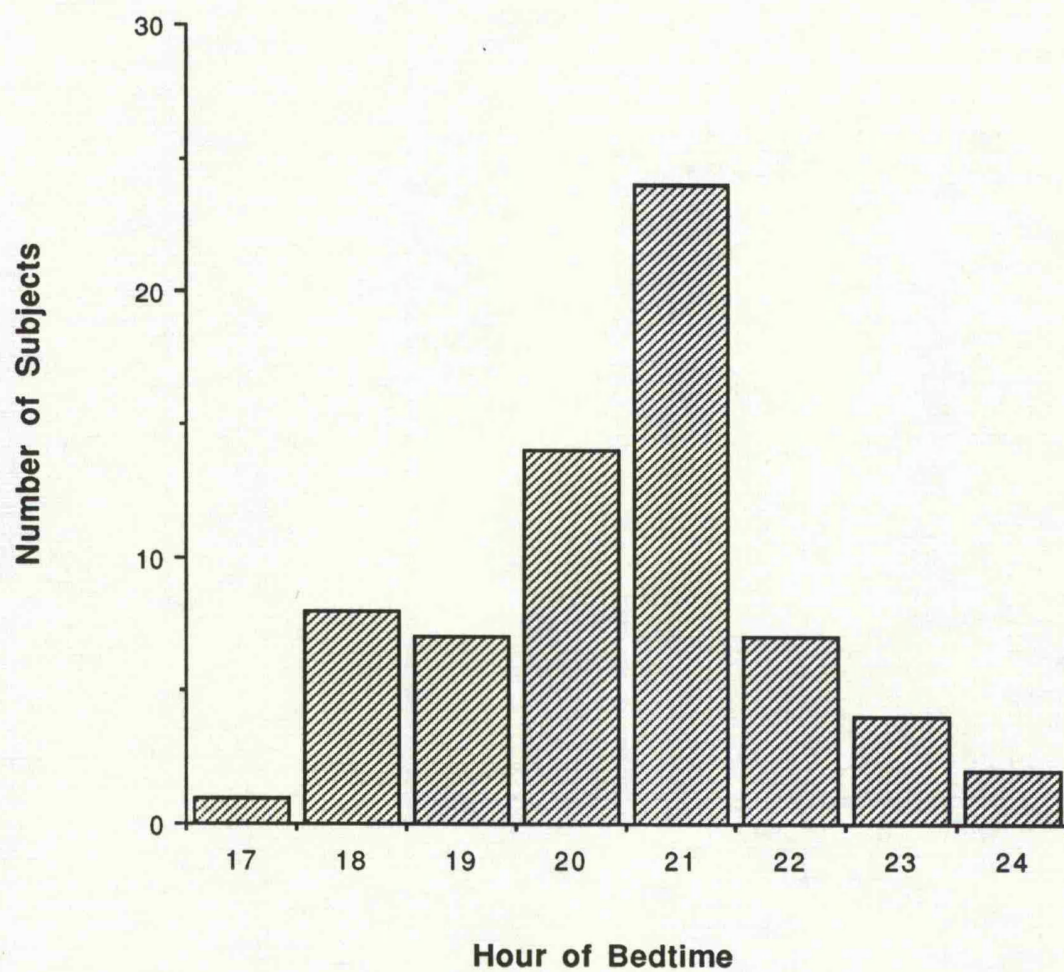
70

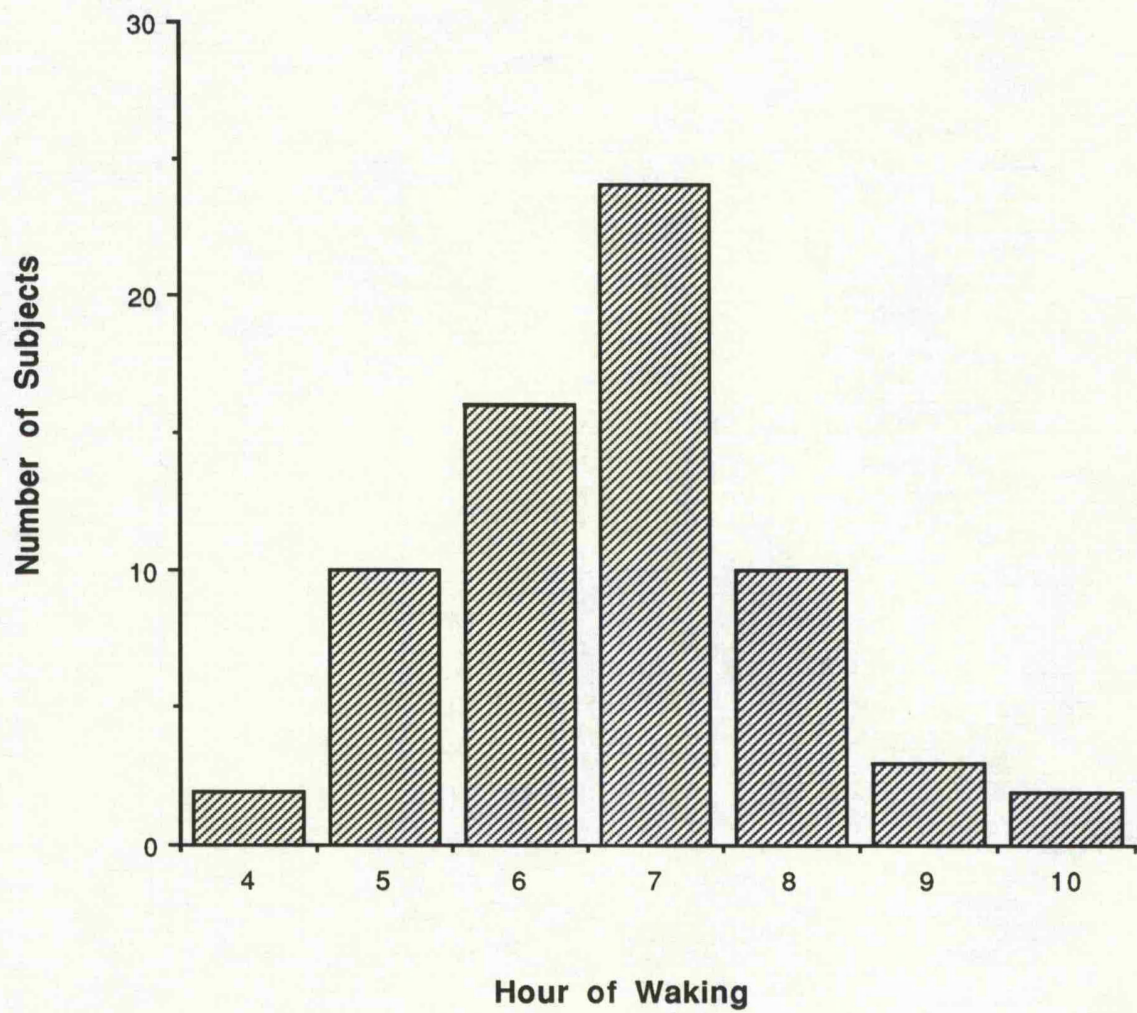Figure 4.1.1   The distribution of bedtime hours in which babies were placed to sleep for the night.

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Figure 4.1.2 The distribution of the hour in which babies were got up in the morning, following a nights sleep.
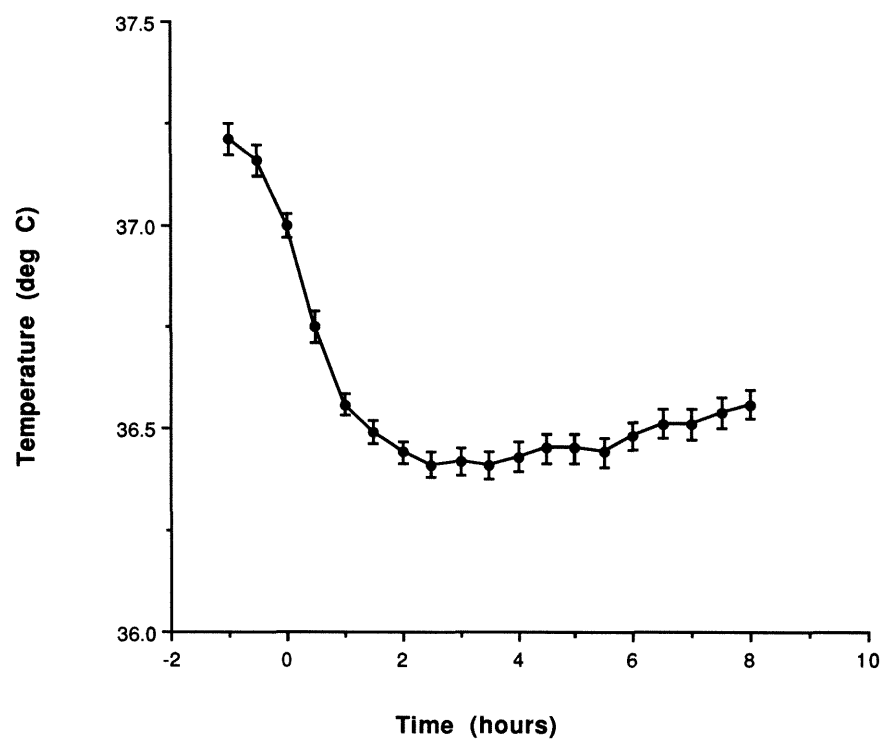
Figure 4.1.3   The mean (±SEM) rectal temperature readings from bedtime
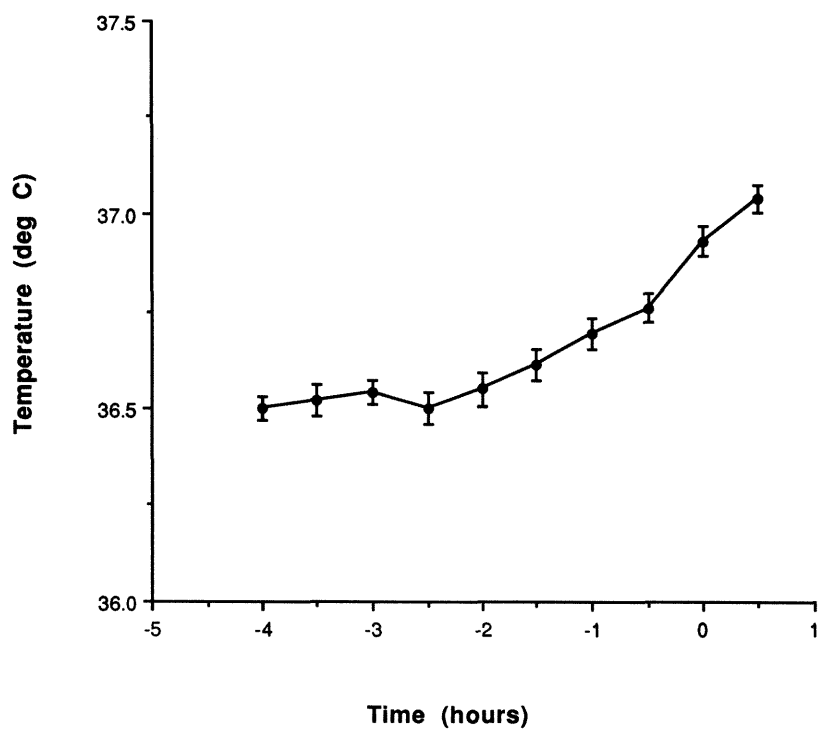to 8 hours into night time sleep.

Figure 4.1.4 The mean (±SEM) rectal temperature readings from 4 hours prior to waking, to waking in the morning.

4.2   THE FIRST 8 HOURS OF NIGHT TIME SLEEP

The pattern revealed that at or immediately prior to bedtime the deep body temperature was above 37°C. When placed to sleep the deep body temperature fell rapidly so that after an hour the average baby's rectal temperature was stable at around 36.3°C, some 0.7°C lower, where it remained for approximately 2 to 3 hours.

The distribution of rectal temperature at bedtime (Fig 4.2.1) fits a normal, with the majority of readings within the range 36.9–37°C. There were 12 readings below 37°C. Examination of the complete night's data revealed that these babies went to sleep an hour earlier than the bedtime reported by the parents and were therefore entering the fall period of deep body temperature associated with an hour after bedtime. The distribution of rectal temperature 3 hours into the night (Fig 4.2.2) again resembles a normal pattern with a high proportion of data at the lower ranges of 36–36.5°C, with very few recordings at or above 37°C. As this was an arbitrary time when it was felt the majority of babies were in the lowest point of the sleep curve it does include some data of babies whose temperature pattern had temporarily risen at this point. The fall in rectal temperature from bedtime to 3 hours into the night was statistically significant at $p<0.001$ (Students paired t–test, $t=13.64$ DF= 66 $p<0.001$). The mean (SEM) minimum temperature for all the 67 recordings was 36.28°C (0.03), the distribution of which (Fig 4.2.3) shows the extent of readings around the trough of the curve. However, several babies did not reach such a minimum. There were 6 babies whose minimum rectal temperatures were above 36.5°C (36.6°C= 2 subjects; 36.7°C= 2 subjects; 36.9°C =2 subjects). Two of these were reported to be ill, their temperatures being 39.9°C, the remaining four can now be attributed to lack of maturity (Lodemore MR, Petersen SA, Wailoo MP, 1991) a phenomenon outlined in the discussion. In Figure 4.2.4 a comparison of the rectal temperature of night time sleep in three subjects indicates a normal mature curve (subject 55), an immature pattern (subject 32 at 13 weeks of age) and a subject with an infection (subject 42).

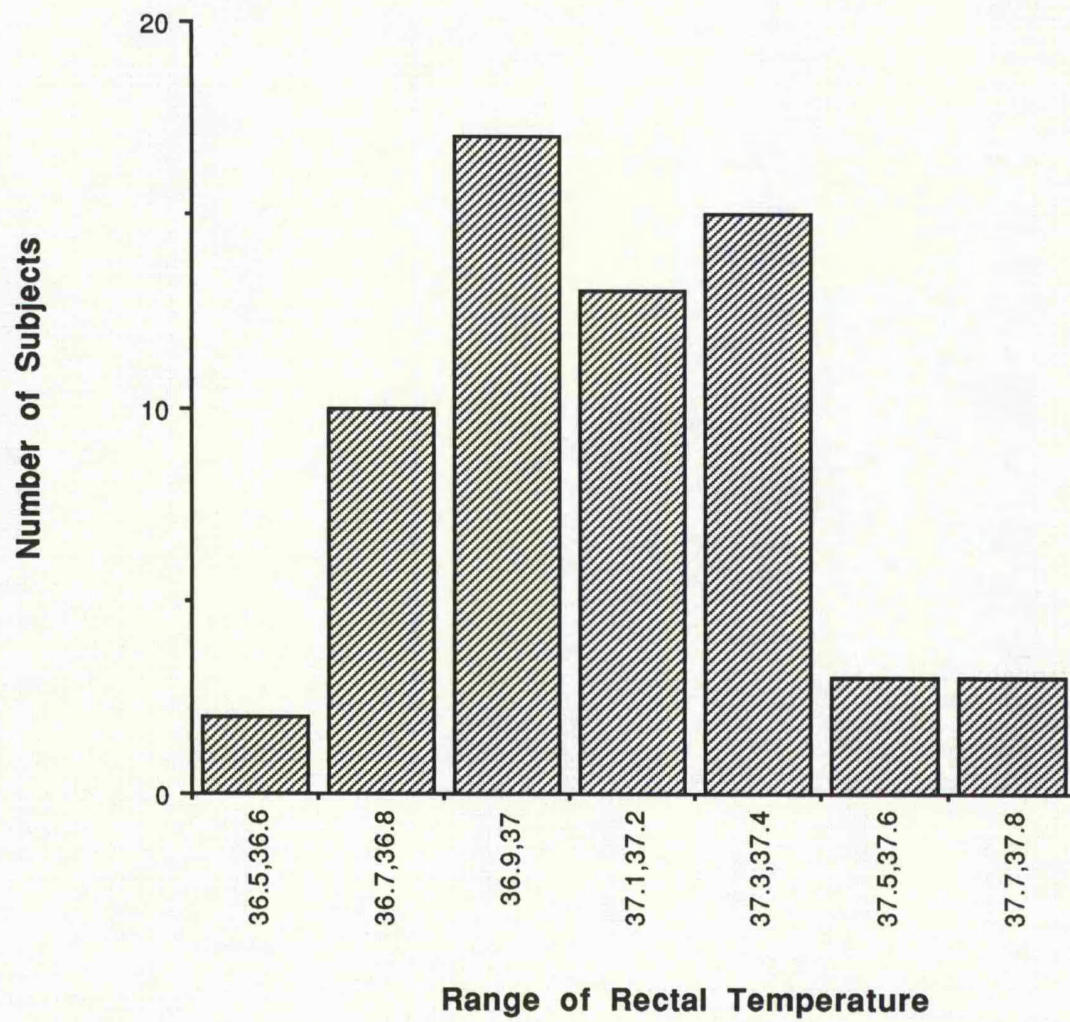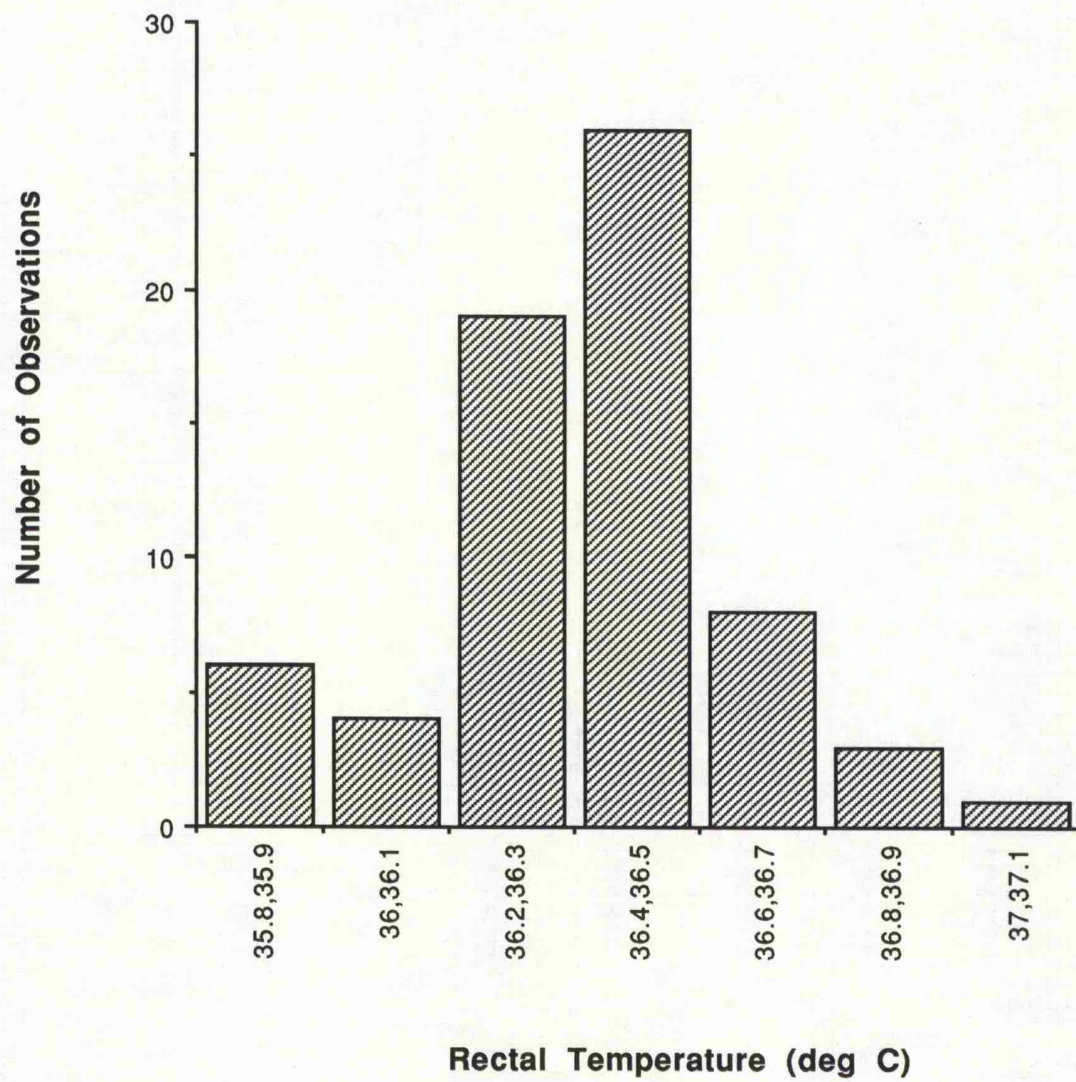Figure 4.2.1   The distribution of rectal temperature at bedtime.

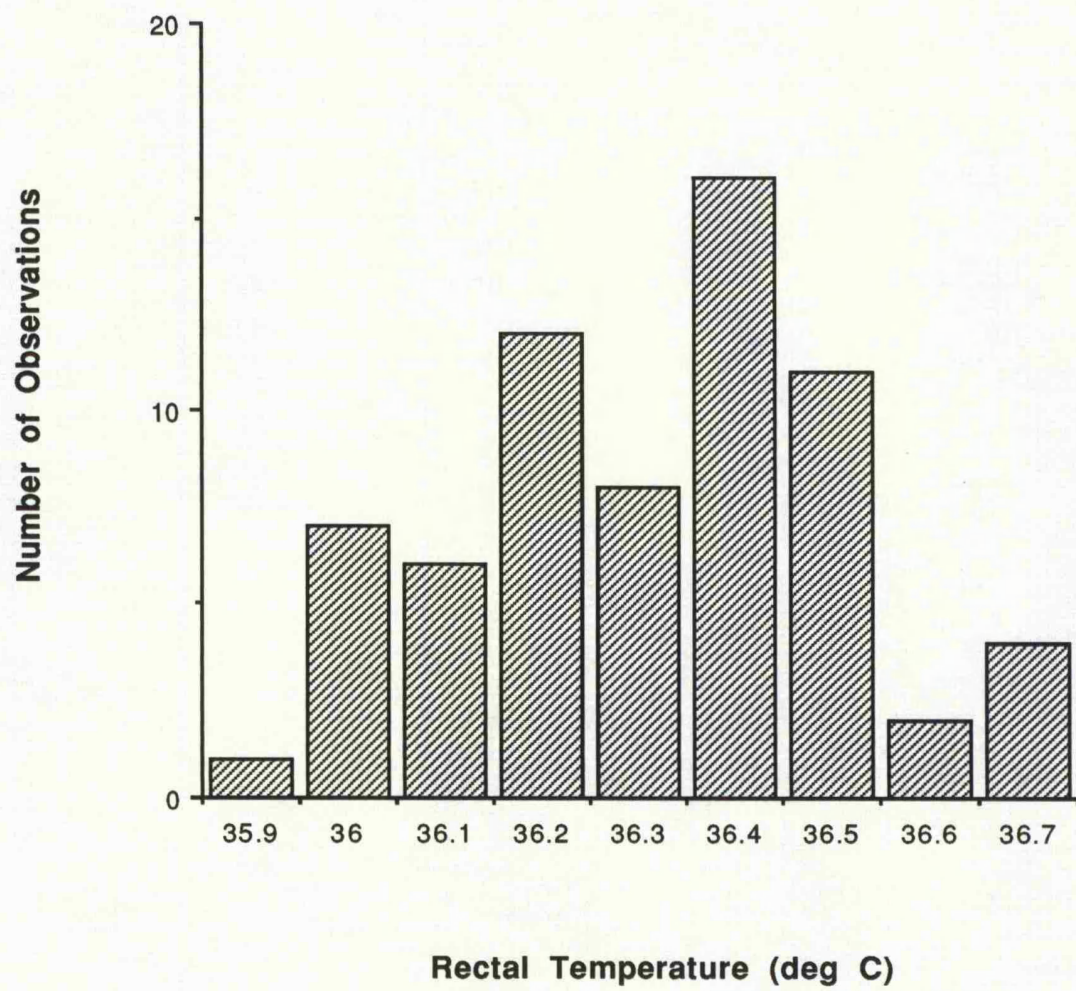Figure 4.2.2 The distribution of rectal temperature 3 hours into the night.

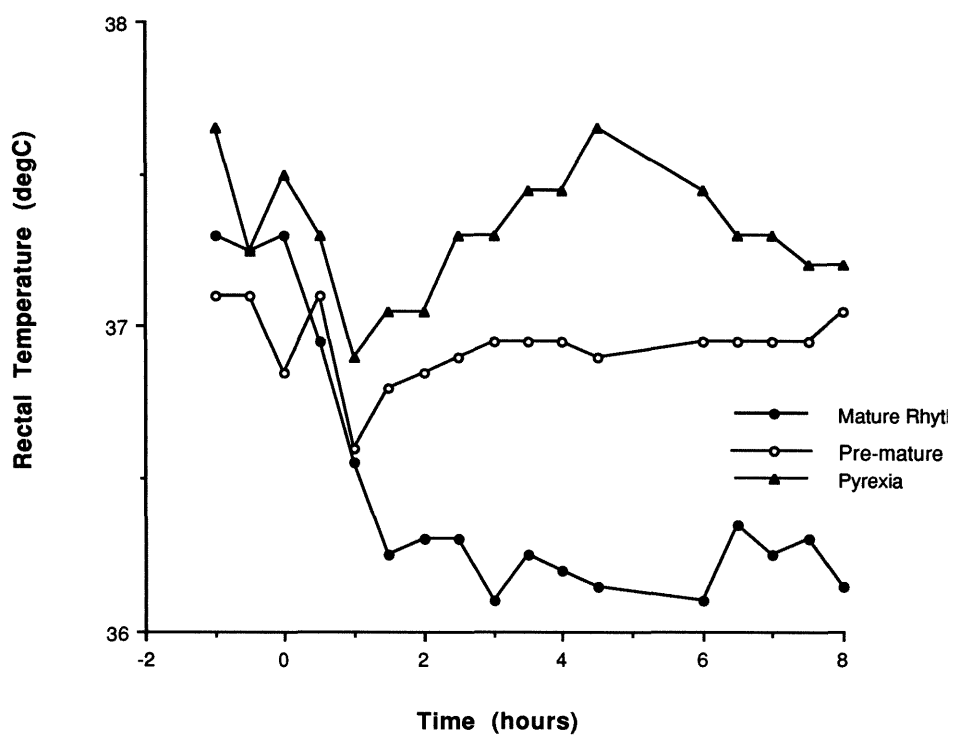Figure 4.2.3 The distribution of minimum night time rectal temperatures.

Figure 4.2.4 Comparison of the rectal temperature during the first 8 hours
of night sleep between a baby who was reported to be ill, a baby prior to
developing a mature rhythm and a baby with a mature rhythm.

4.3 THE LAST 4 HOURS OF NIGHT TIME SLEEP

Data were synchronised to waking time, and calculated at point averages at 30 minute intervals (Fig 4.1.4). The rectal temperature having stabilised for the central part of the night now rises again to return to 37°C, revealing a normal distribution of data ranging from 36.7°C to 37.4°C (Fig 4.3.1). Rectal temperature one hour before waking resembles a normal distribution at a lower range of 36.7°C to 36.8°C (Fig 4.3.2).

The process of warming is more gradual than cooling at the beginning of the night, appearing to be in two steps or stages and taking approximately 4 hours to achieve. By examining the data backwards from waking ensures that the true picture of slow warming, prior to waking, is not distorted by individual differences in sleep length.

4.4 DISTURBANCES TO NIGHT TIME SLEEP

Of the 38 babies who woke during the night many resettled with comfort. The remainder required feeding. A total of 29 subjects woke for feeds, 15 were breast fed and 14 bottle fed. Rectal temperatures were recorded at 10 minute averages associated with the onset of feeding including 60 minutes prior to the feed and 90 minutes after. The rectal temperature rises slightly with the feed but quickly returns to pre-feed levels. This rise in temperature is so small that it does not distort the temperature pattern of the night as described (Fig 4.4.1) .

4.5 THE THERMAL ENVIRONMENT

Season

Forty seven (70.1%) babies were monitored during the colder months of October to March and 20 (29.9%) in the warmer months of April to September. Of the winter monitorings 33 (49.2%) were in the coldest months of November to February, and in the summer 5 (7.5%) were in the warm period of June to August.
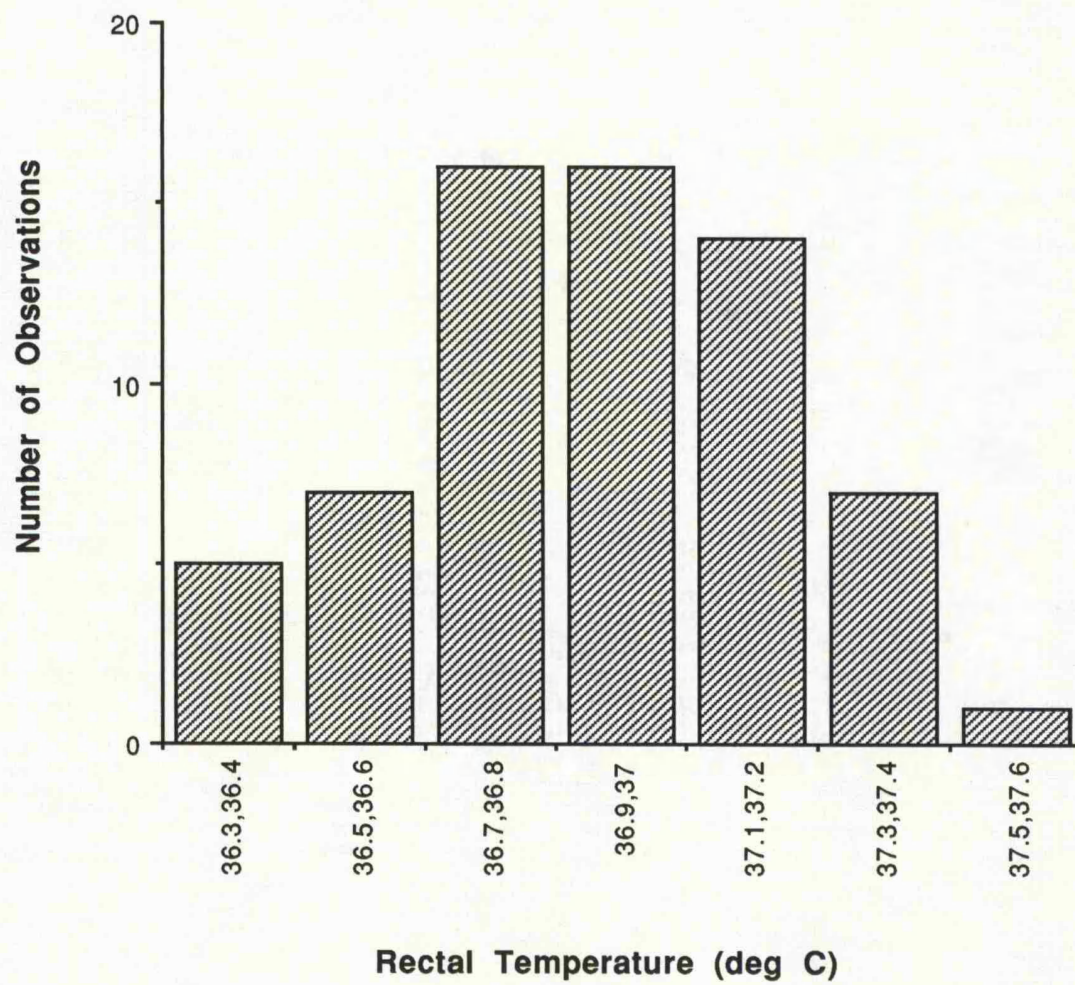
Figure 4.3.1 The distribution of rectal temperatures at waking.
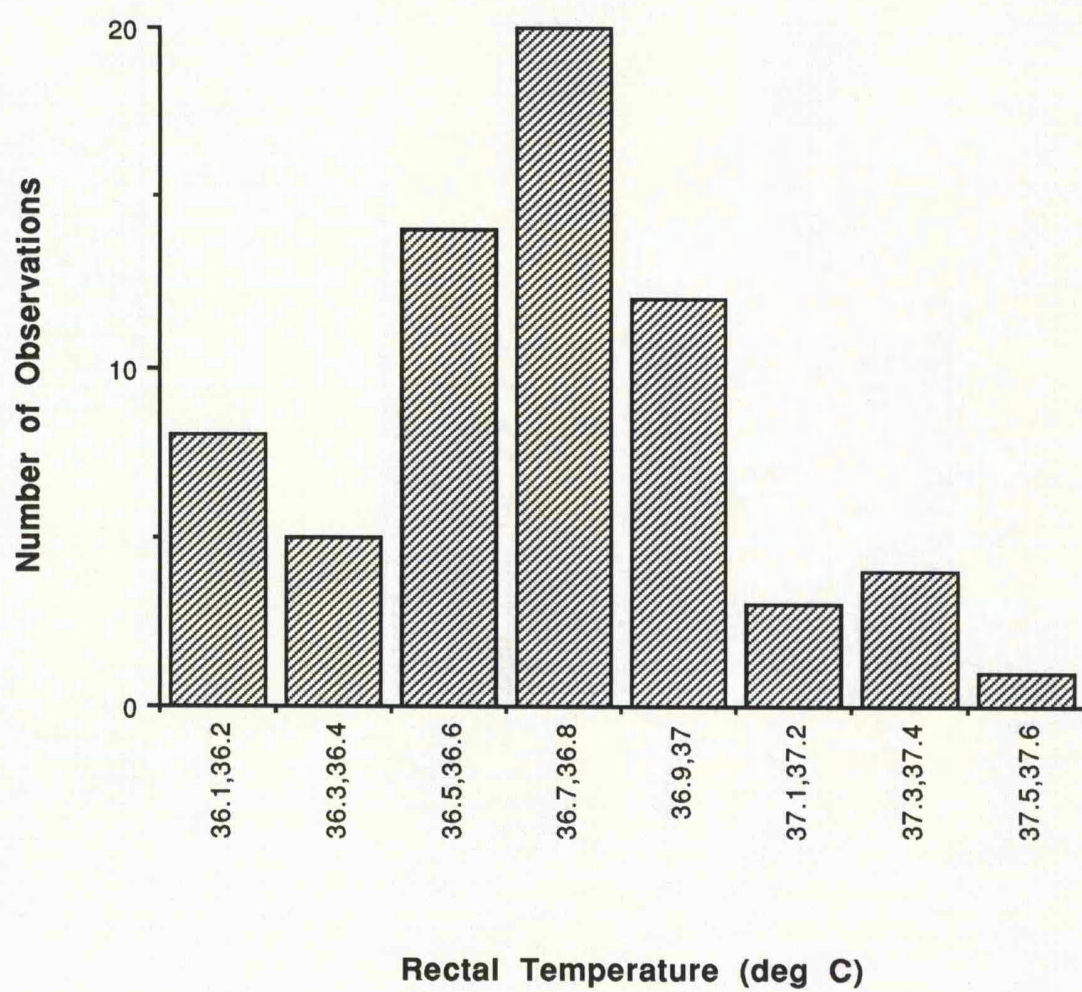
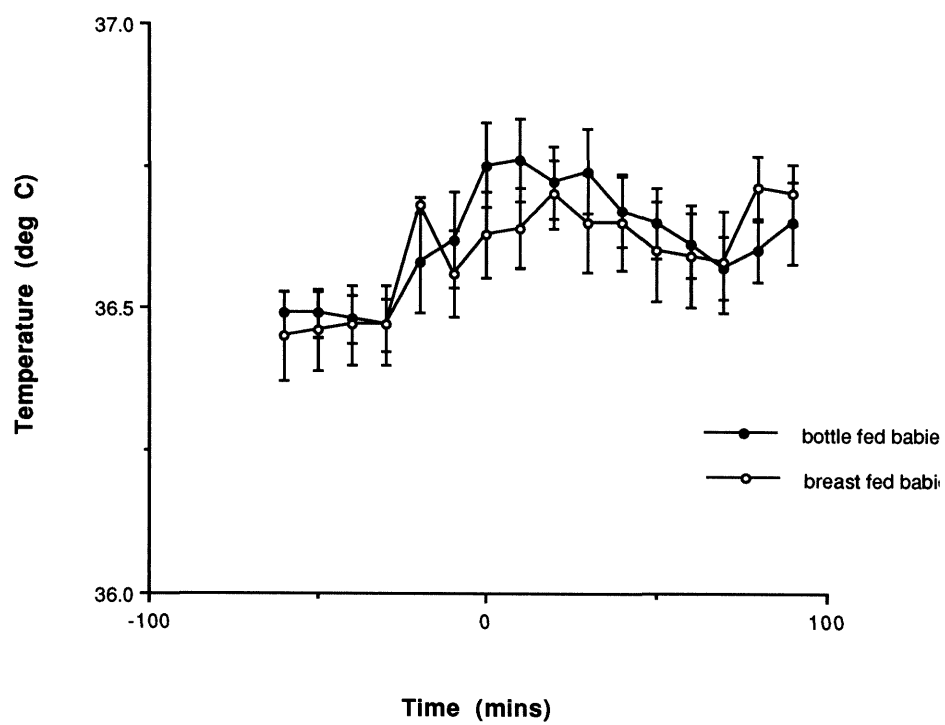Figure 4.3.2 The distribution of rectal temperatures one hour prior to waking.

Figure 4.4.1 The effect of breast and bottle feeds during the night upon the rectal temperature of babies.

Parental Choice of Heating

Of the 67 subjects, 56 (83.5%) were in homes that had central heating, 54 had homes with gas central heating and 2 used solid fuel. Of the eleven homes without central heating, 2 (2.9%) used electric heaters in the baby's room and elsewhere, and 9 (13.4%) had no form of local heat in the bedrooms, but had local heat in other rooms.

Use of central heating varied enormously between parents. Of the 56 homes with this source of heating, only 53 were in use, 3 being switched off for the summer. The central heating systems were either in continuous use (11 families) or partial use on a timed basis (42 families), usually on in the early evening and again first thing in the morning. The range of heating time for the early evening varied from 4 pm to 12 midnight, and in the early morning from 5 am to 12 noon. Of these families 27 could accurately state the number of hours the heating was in use, with a mean of 3.8 hours in the evening, and 2.9 hours in the morning. The timed use of central heating influenced changes in the ambient temperature, at bedtime when the central heating stopped, reflected by a drop in homes with temperatures above 19°C (Fig 4.5.1), and in the morning associated with waking, when heating systems were set to re-start, revealing an increase in ambient temperatures in the higher range of above 17°C (Fig 4.5.5). Subjects in the lower ranges represent homes with no heating, and those in the higher ranges reflect rooms with constant heat or a summer monitoring (Table 4.5.A).

Room Temperatures

To examine the range of ambient temperatures several spot temperature recordings were taken. These included maximum and minimum temperatures for each subject, bedtime temperatures and the pattern of changes up to five hours into the night.

At bedtime the mean (SEM) ambient temperature for all 67 subjects was 19.46°C (0.3), with some bedrooms experiencing temperatures of 22°C (Fig 4.5.1), and a few as low as 10°C to 12°C. Half an hour later the mean (SEM) ambient temperature was 18.7°C (0.3) and the distribution (Fig 4.5.2) again that of a norm, reveals a drop in the

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number of babies experiencing temperatures up to 22°C, with more temperatures at the lower range of 12°C to 15°C. An hour after bedtime the mean (SEM) ambient

TABLE 4.5.A– COMPARISON OF THE EFFECT OF HEATING SYSTEMS ON THE MEAN (SEM) AMBIENT TEMPERATURE OF 67 SUBJECTS.

SUBJECT CATEGORY	NO HEAT	TIMED USE – central heating	CONTINUOUS – central heating
Maximum Room Temperature	19.96°C (1.1)	19.73°C (0.4)	20.83°C (0.5)
Minimum Room Temperature	17.03°C (1.3)	16.96°C (0.5)	17.06°C (0.7)

temperature was 18.65°C (0.3) the distribution (Fig 4.5.3) reveals room temperatures below 19°C, the minimum temperature remaining at 12°C. The pattern five hours after bedtime changes further: the mean (SEM) temperature being 17.74°C (0.4) with the distribution (Fig 4.5.4) shows the vast majority of bedrooms below 18°C, with more babies experiencing temperatures at 12°C. The bedtime temperature resembles the mean (SEM) maximum ambient temperature of all 67 subjects, 19.6°C (0.4), and the temperature five hours after bedtime resembles the mean (SEM) minimum room temperature of all 67 subjects, 17.20°C (0.5).

At waking the mean (SEM) ambient temperature was 17.92°C (0.4) with subjects in cooler conditions than at bedtime (Fig 4.5.5). One hour before waking the mean (SEM) room temperature was 17.47°C (0.4) with a distribution of temperatures slightly lower than those at waking. The patten 2 hours before waking reflects that of 1 hour prior to waking with a mean (SEM) temperature of 17.45°C (0.4) (Fig 4.5.6).

Figure 4.5.1 The distribution of ambient temperature at bedtime.

Figure 4.5.2 The distribution of ambient temperature half an hour after bedtime.
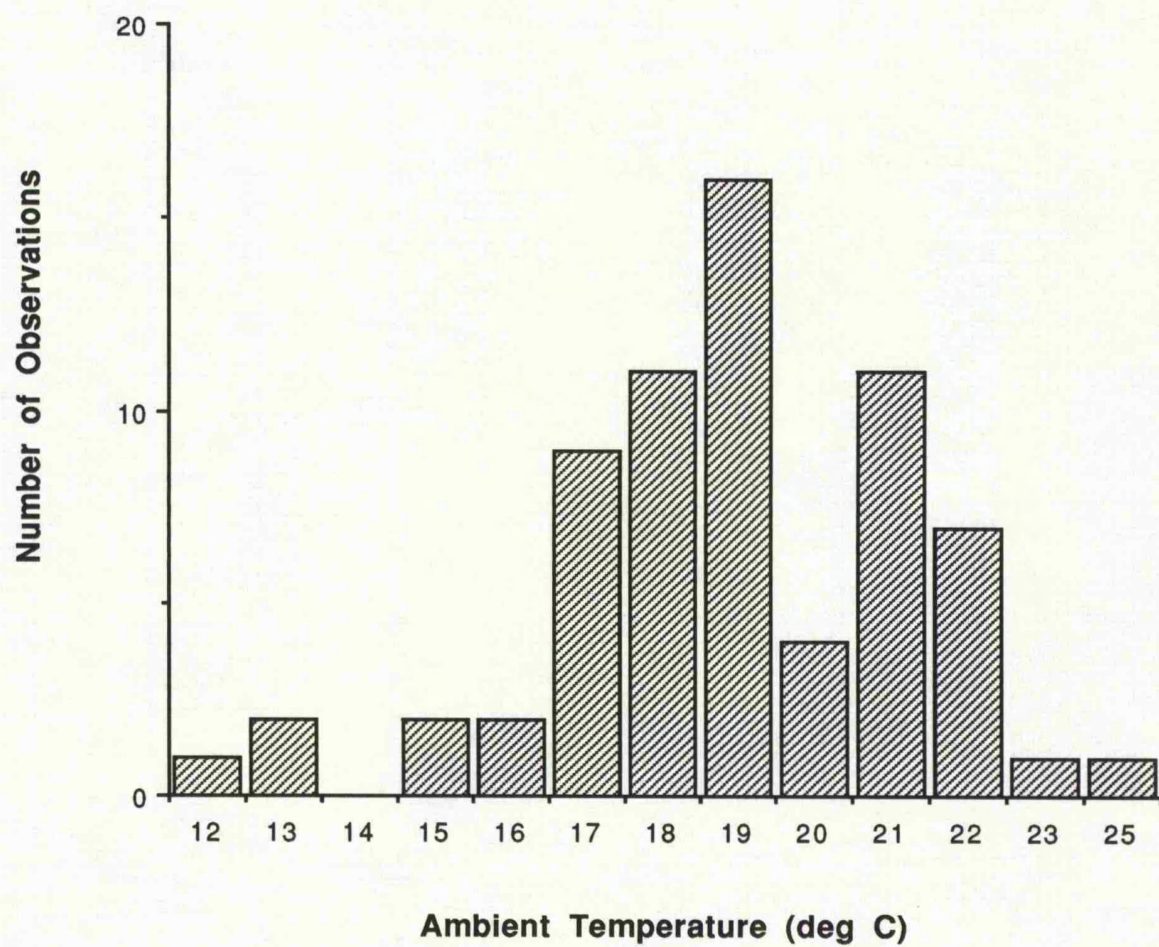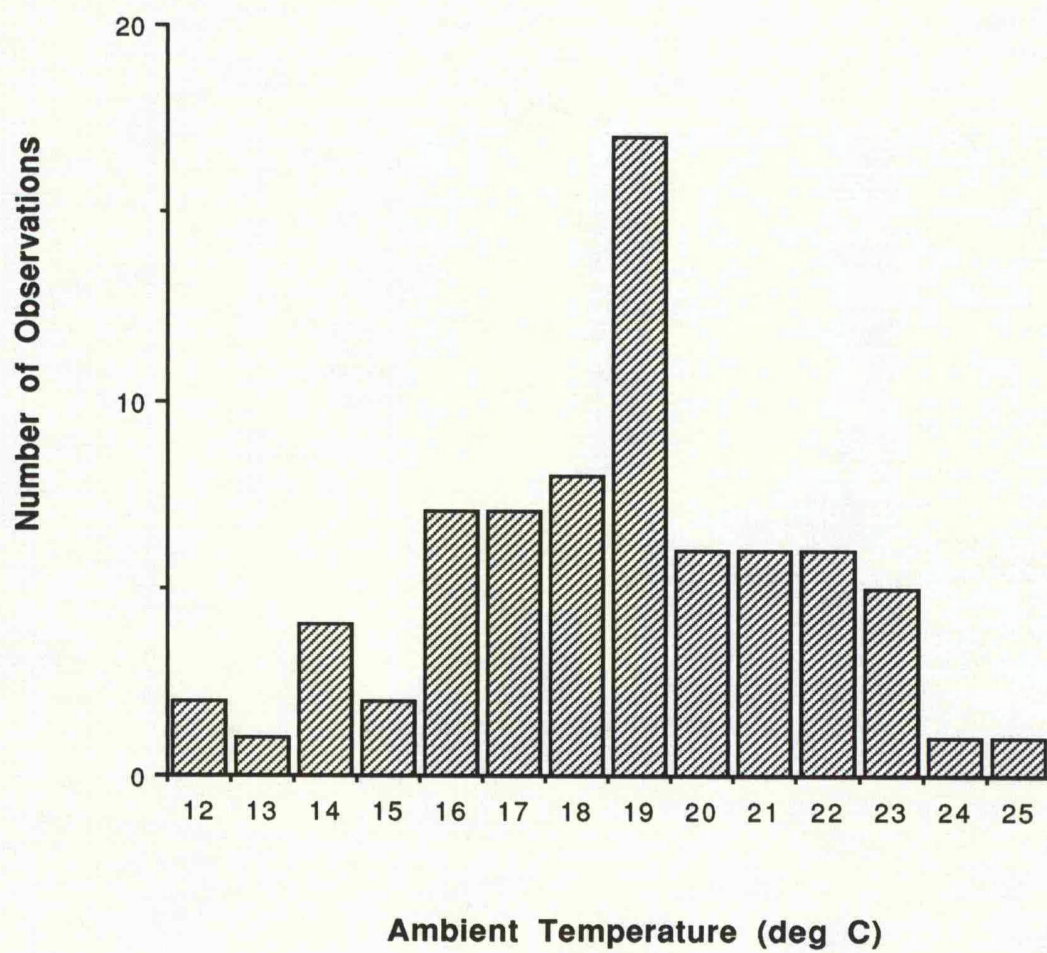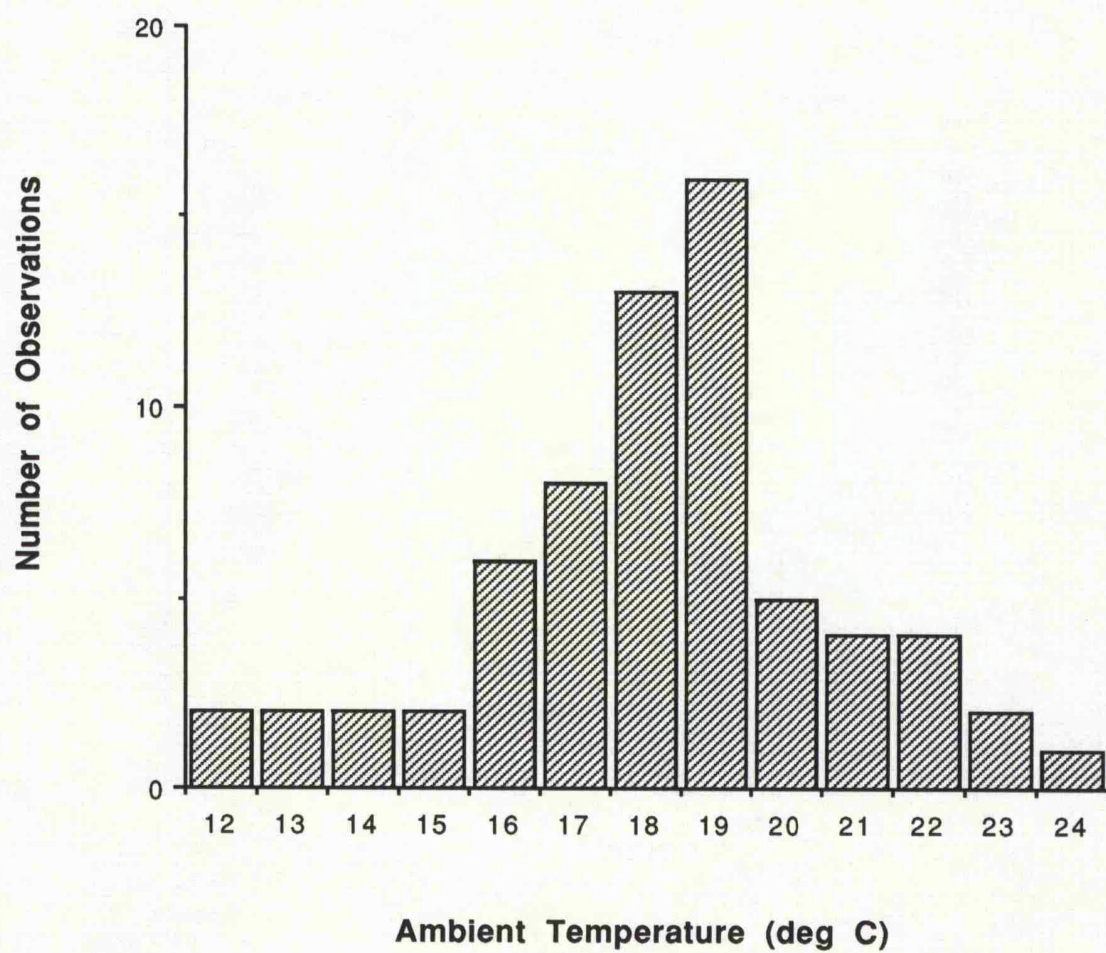
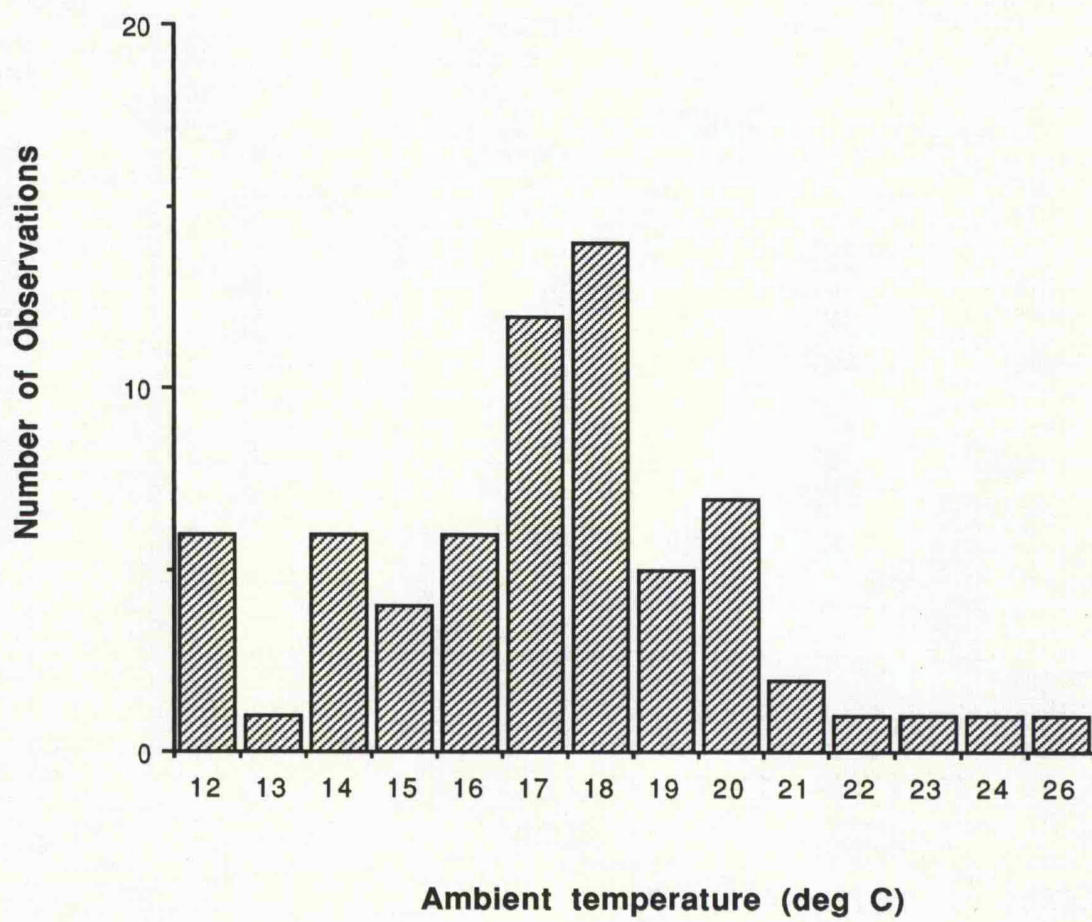Figure 4.5.3 The distribution of ambient temperature one hour after bedtime.

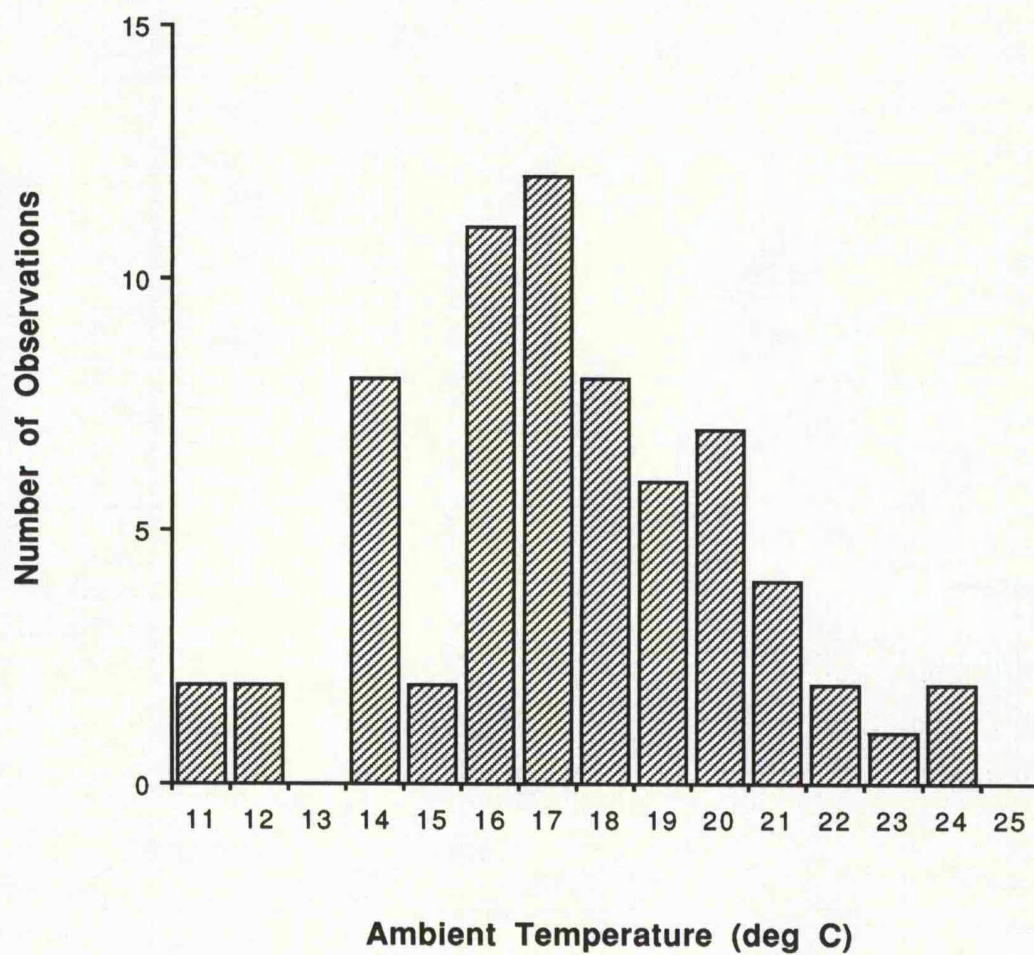Figure 4.5.4 The distribution of ambient temperature five hours after bedtime.

Figure 4.5.5 The distribution of ambient temperature at waking.
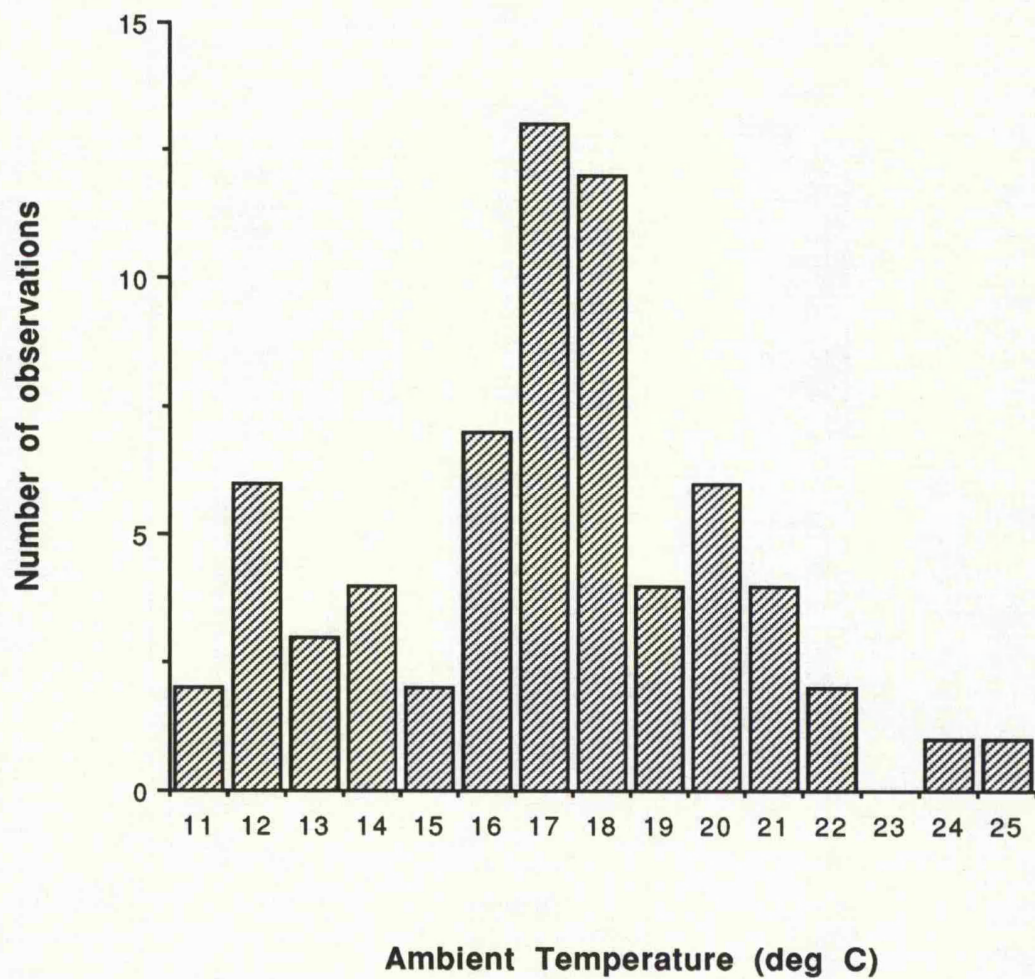
Figure 4.5.6 The distribution of ambient temperature one hour before waking.

Parental Choice of Clothing and Wrapping

The tog values of all items of clothing were added to give a total for each subject. The mean (SEM) tog value for clothing was 4.13 (0.2), with a range of 2 to 7.5 togs. This comprised three main decision groups of parents, first the choice of a nappy, vest and babygro 3.2 tog units 40 subjects (59.7%), second, the choice of nappy, vest, babygro and cardigan 5.2 tog units 12 subjects (17.9%), and third, a combination of a sleepsuit over the standard vest nappy and babygro giving a tog value over 5.2 togs, 11 subjects (16.4%) (Fig 4.5.7). There remained 3 (4.4%) babies with tog values of less than 3.2 tog units.

Similarly all the tog values for the layers of bedding were totalled to give a value for each subject. The mean (SEM) tog value of bedding was 9.37 (0.3) with a range of 3 to 18 togs. Adding together the total tog value on each baby gave a range from 3 to 25.2 togs, with a mean (SEM) total tog value of 13.5 (0.4). To assess the most popular choice of bedding the subjects were divided into tog bands of <6.0, 6–12, >12, and items of bedding listed in these bands.

There were 11 (16.4%) parents who choose <6.0 tog units of bedding. Five of these used a thin duvet, of which two also added a sheet. The remaining 6 (17.9%) parents used a combination of blankets with or without a sheet or a wool shawl.

The majority of parents 52 (77.6%) chose a combination of bedding of a tog value of 6 to 12 units. To examine this range further the category was divided again, 6 to 8.9 togs (14 subjects) and 9 to 12 togs (38 subjects). In the lower band the parents used a combination of layers of blankets with a sheet (total 7 subjects) and sometimes a thin duvet (7 subjects in total). In the higher range all but one baby was covered by a duvet. The majority (33 parents) choose a thick duvet of 9–12 togs only (9 babies), or with a sheet (17 babies), and also a blanket (7 babies) Figure 4.5.8.

Finally 4 parents had their babies covered with a tog value >12 tog units. In three of these cases the parents used a standard thick duvet with several blankets and a sheet. In one case the baby was covered with an adult eiderdown of man–made fibre
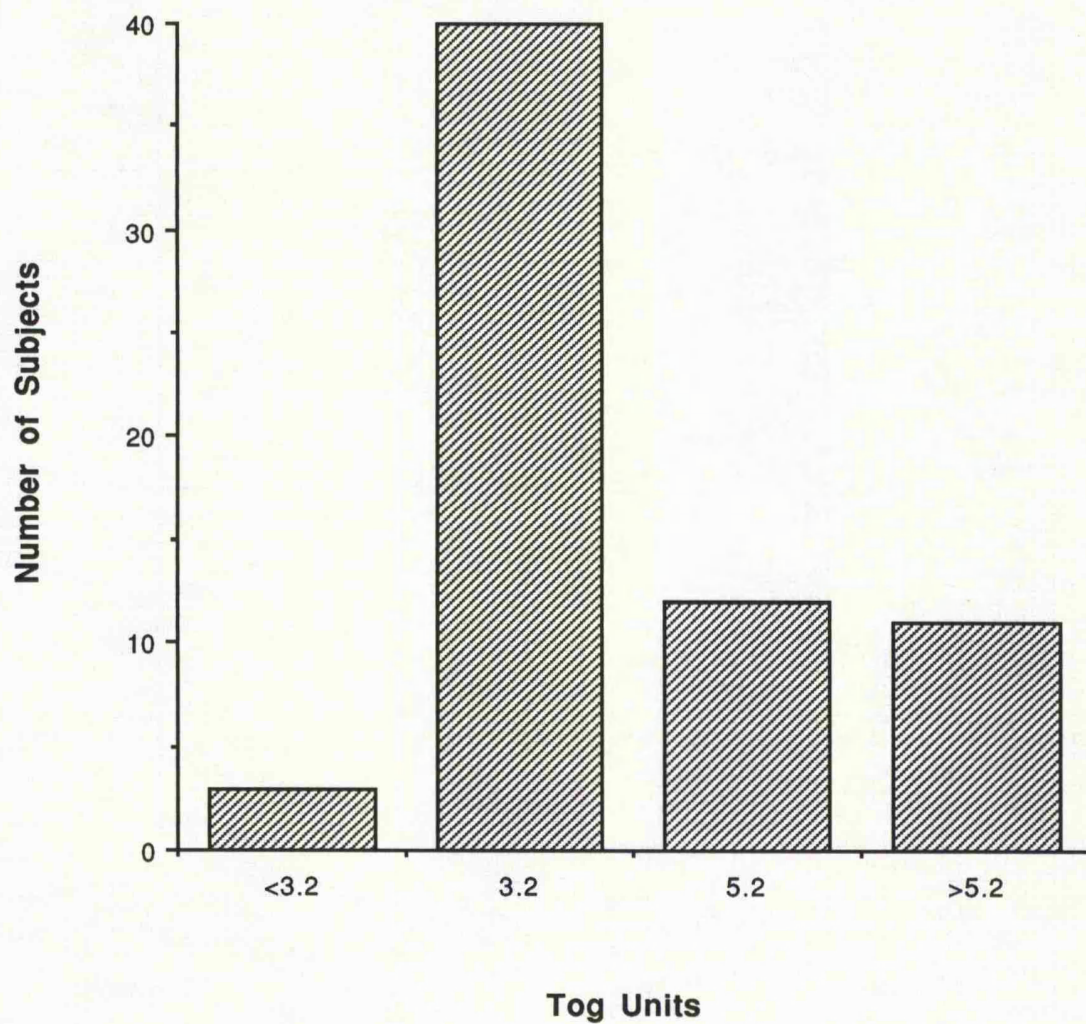
Figure 4.5.7   The distribution of tog units of clothing worn for the night time sleep.
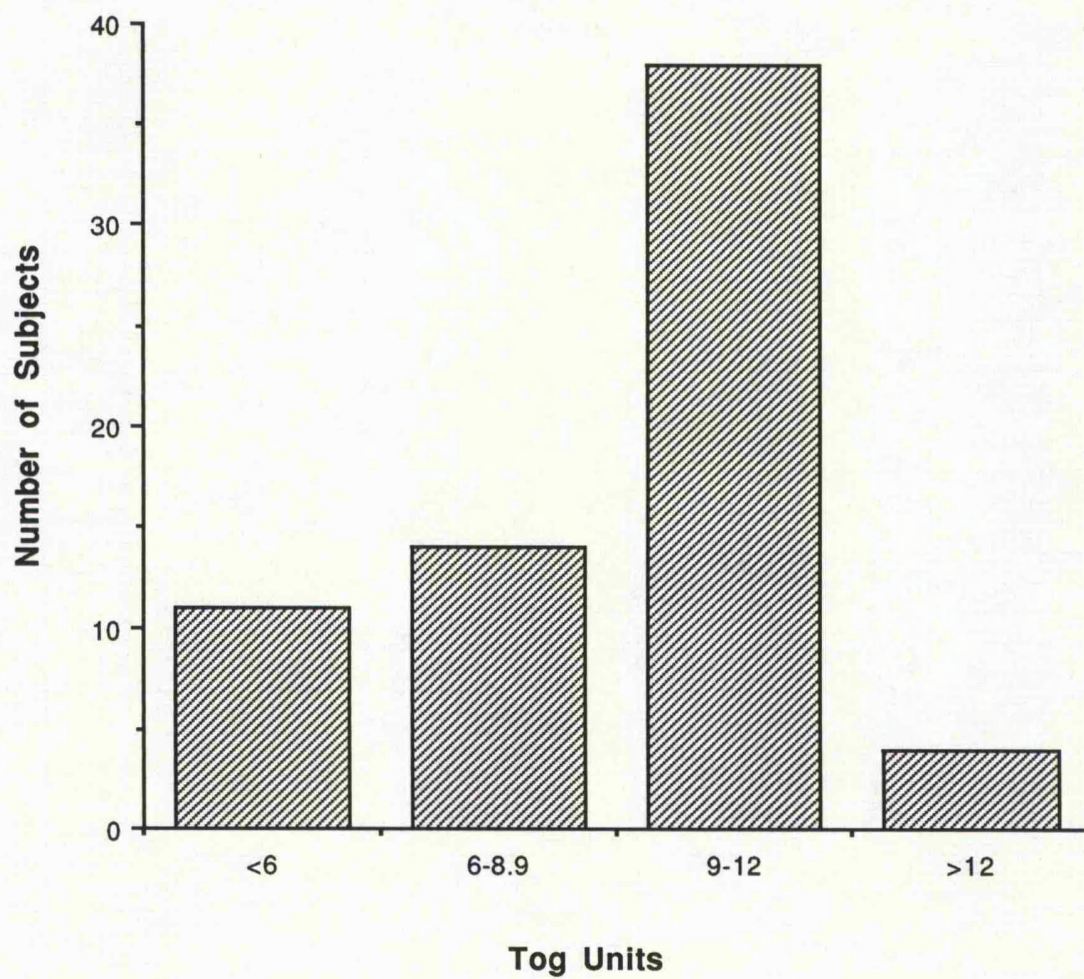
Figure 4.5.8   The distribution of tog units of bedding applied for night time sleep.

folded twice with a sheet and blanket.

4.6   PARENTAL CHOICE OF INFANT CLOTHING AND WRAPPING.

Parental choices were also examined by comparing the four groups of babies with different types of bedding for the following variables: month of monitoring, social class, sex, birth weight, maximum and minimum room temperature, choice of clothing and use of heating.

Babies with light bedding, <6 togs, were lightly clothed, their rooms revealing even temperatures throughout the night, achieving the highest minimum temperature of all four groups. These monitorings were spread evenly between the seasons.

TABLE 4.6.A– COMPARISON OF THERMAL CONDITIONS

Tog bedding	Season	Heating y/n	Maximum Room Temp	Minimum Room Temp	Tog Clothes
<6 0	w=6 s=5	y=9 n=2	20.63°C	18.28°C	3.71 (0.39)
6–8.9	w=11 s=3	y=10 n=4	20.33°C	16.54°C	4.10 (0.41)
9–12	w=35 s=3	y=35 n=3	19.71°C	15.93°C	4.14 (0.18)
>12	w=4 s=0	y=2 n=2	18.21°C	15.16°C	5.45 (0.85)

As a group they were dominated by the higher social classes, confirming other reports stating a tendency for higher social classes to wrap their infants with moderate wrappings (Bacon C, 1991). These babies had the highest birth weights, with slightly more female infants.

The second group of moderate bedding, 6 to 8.9 togs, were dressed with slightly more togs on average, and were predominantly monitored during the cold months. Their

homes used heating but achieved a lower minimum temperature. It would appear that parents used slightly more togs in total as their homes were slightly cooler although still warm. There were no differences in terms of sex, birth weight or social class.

TABLE 4.6.B– COMPARISON OF TOG VALUES WITH SUBJECT VARIABLES

Togs	Social Class manual/non manual		Birth Weight	Sex m f	
<6.0	nm=9	m=2	3544g	m=4	f=7
6–8.9	nm=6	m=8	3432g	m=6	f=8
9–12	nm=19	m=19	3489g	m=25	f=13
>12	nm=1	m=3	3515g	m=1	f=3

The higher group of firstly 9 to 12 tog units, appear to have cooler homes despite their use of heating, being predominantly monitored in the coolest months (average minimum room temperature 15.93°C). They were evenly divided between the social classes, with no difference in birth weight, but were predominantly male infants.

The highest score group, >12 togs, were few in number, but more heavily clothed. These homes were the coolest (minimum ambient temperature 15.16°C), though they were monitored in the coldest months. Half were without heat, they had more female infants of a good weight, and were mostly the manual social classes.

There were no strong correlations between the tog of bedding and room minimum temperature ($r= 0.128$ $p< 0.1$) for all 67 subjects despite a difference in the averages between the groups found on Table 4.6.A (Fig. 4.6.1). There was also no correlation between tog total of bedding and wrapping and room minimum temperature ($r=0.114$ $p<0.1$) (Fig. 4.6.2), and an insignificant correlation between total tog and room maximum temperature ($r=0.143$ $p<0.1$) (Fig. 4.6.3).
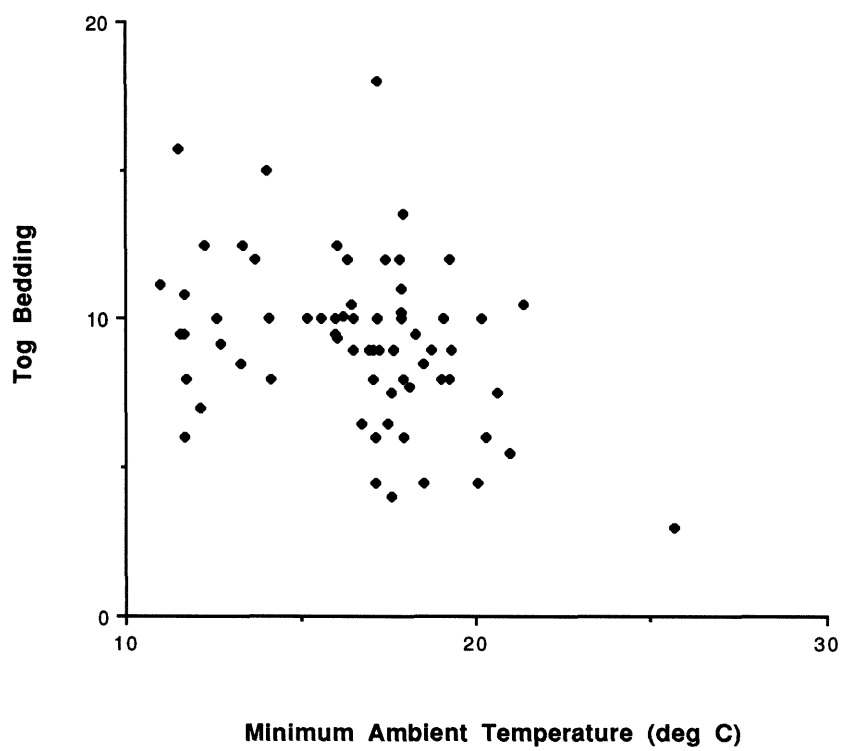
Figure 4.6.1 Correlation between tog bedding and room minimum temperature during night time sleep (r= 0.128 ns).
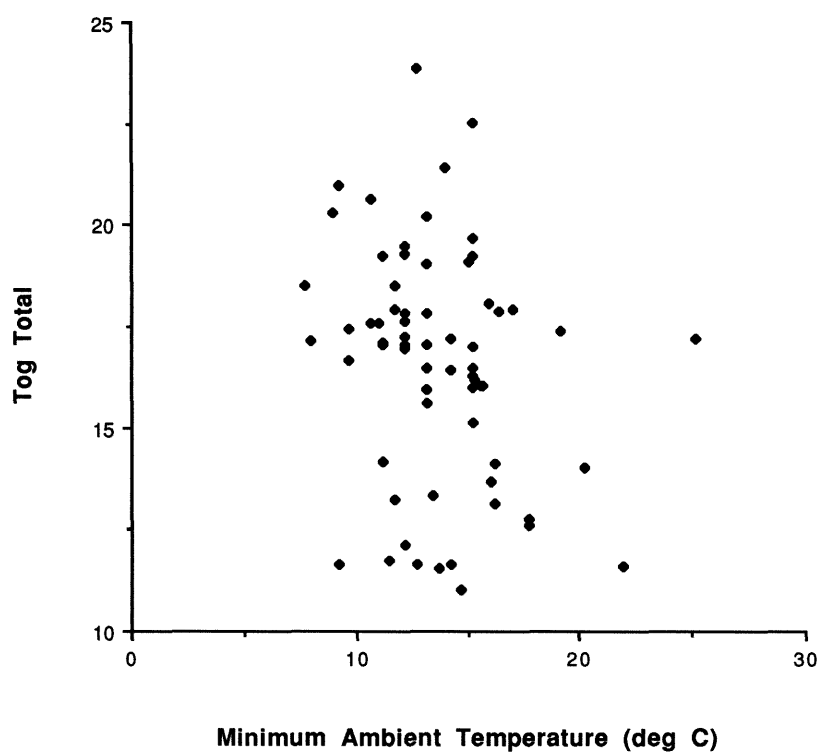
Figure 4.6.2 Correlation between the total tog and room minimum
temperature during night time sleep (r=0.114 ns).
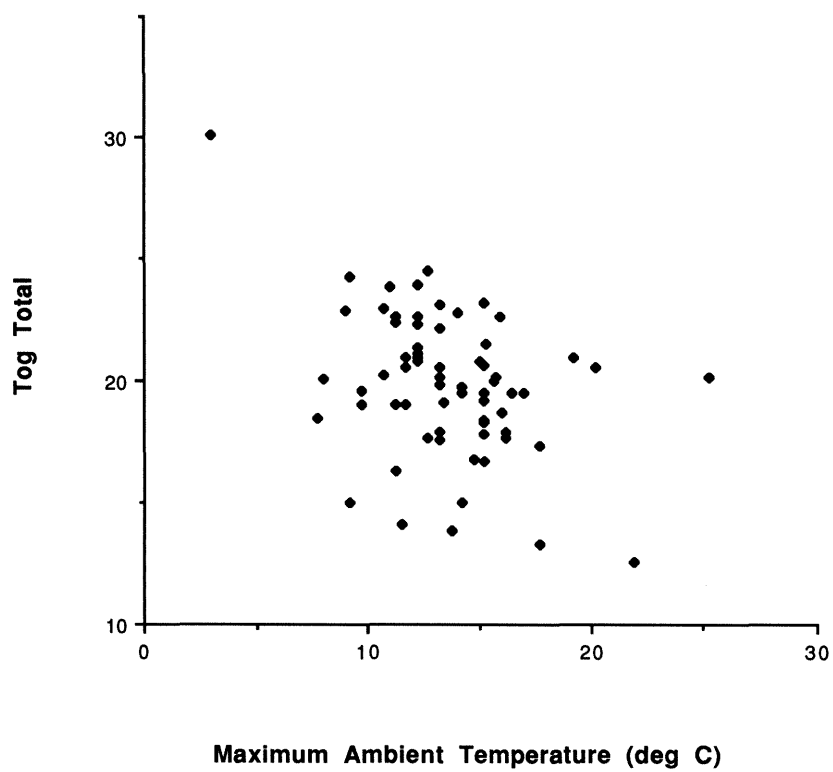
Figure 4.6.3 Correlation between tog total and maximum
room temperature during night time sleep (r=0.143 ns).

Comparison of the combination of parental choice of clothing, wrapping and ambient temperature.

As the choice of thermal environment consists of two elements, first clothing and wrapping, and second heating, a score to measure thermal environment for each subject was made by adding tog total to the minimum room temperature. By doing this a large proportion of differences were cancelled out as the vast majority of scores fell within a central point at 30 (see Table 4.6.C below).

For the majority of subjects this combined score was within the range 27 to 32. Two groups of subjects had scores above or below this range, indicating parental choices of cool rooms with light clothing and wrapping, and warm rooms with infants more heavily wrapped. Analysis of the two extreme groups with thermal scores over 32, a warm group, and those less than 27, a cool group, were made for social factors (see Table 4.6.D).

TABLE 4.6.C– THERMAL SCORES

Thermal Score (tog tot+ room min temp)	Number of Subjects
< 27	14
27–32	40
>32	13

These consisted of social class, method of feeding, a history of any upper respiratory tract infection, and a general assessment of the standard of care observed by the experimenter as factors Health Visitors would assess during a home visit including, parental ability to cope with the demands of parenthood, responsiveness of parent to child, and measure of family stress which may affect or interfere with care including the number of children especially under five, financial insecurity etc.

There were no social class distinctions for the warm group, but the cool group were

more likely to be from the higher social classes (Chi^2 =4.69 df=1 p<0.05). There were no differences in illness, but more mothers in the cool group were breast feeding, and

TABLE 4.6.D– COMPARISON BETWEEN WARM AND HOT BABIES

Category	Social Class non-manual, manual	Illness	Breast Fed, Bottle Fed	HV Score	Children
warm	7, 6	3	2, 11	Good= 6 Poor = 7	1 = 7 2+= 6
cold	11, 3	2	8, 6	Good=14	1 = 10 2+= 4

more mothers in the warm group were bottle feeding. There were no homes assessed as poor with regard to the standard of care witnessed in the cool group, but half were assessed as less able in the warm group. The cool group were predominantly first babies, there were no sex differences between the groups.

To confirm the findings of social class a larger sample was required. In July 1992 data from the data base of infants taking part in the thermoregulation study in Leicester totalled over 500. Using this information, thermal scores of infants aged between 12 and 22 weeks were extracted for examination of social factors. The distribution of thermal scores for a final total of 534 subjects revealed a small group with scores greater than 32 (total 63), thermal scores between 27 and 32 (total 132), leaving the greater proportion in cooler conditions less than 27 (total 201), see Figure 4.6.4. Analysis of the social class distributions in the middle range of averaged thermal conditions was compared to those in the warmer thermal conditions. The results confirmed a greater proportion of lower social classes 5 to 7 in the warm group (see Fig. 4.6.5), Chi^2=6.35 df=1 p<0.025. There were no differences in maternal ages between the groups (see Table 4.6.E), with feeding choice revealing significant differences, with bottle fed babies more likely to be in warm conditions, and breast fed babies more likely to be in cooler conditions (Chi^2=3.9 df=1 p<0.05).
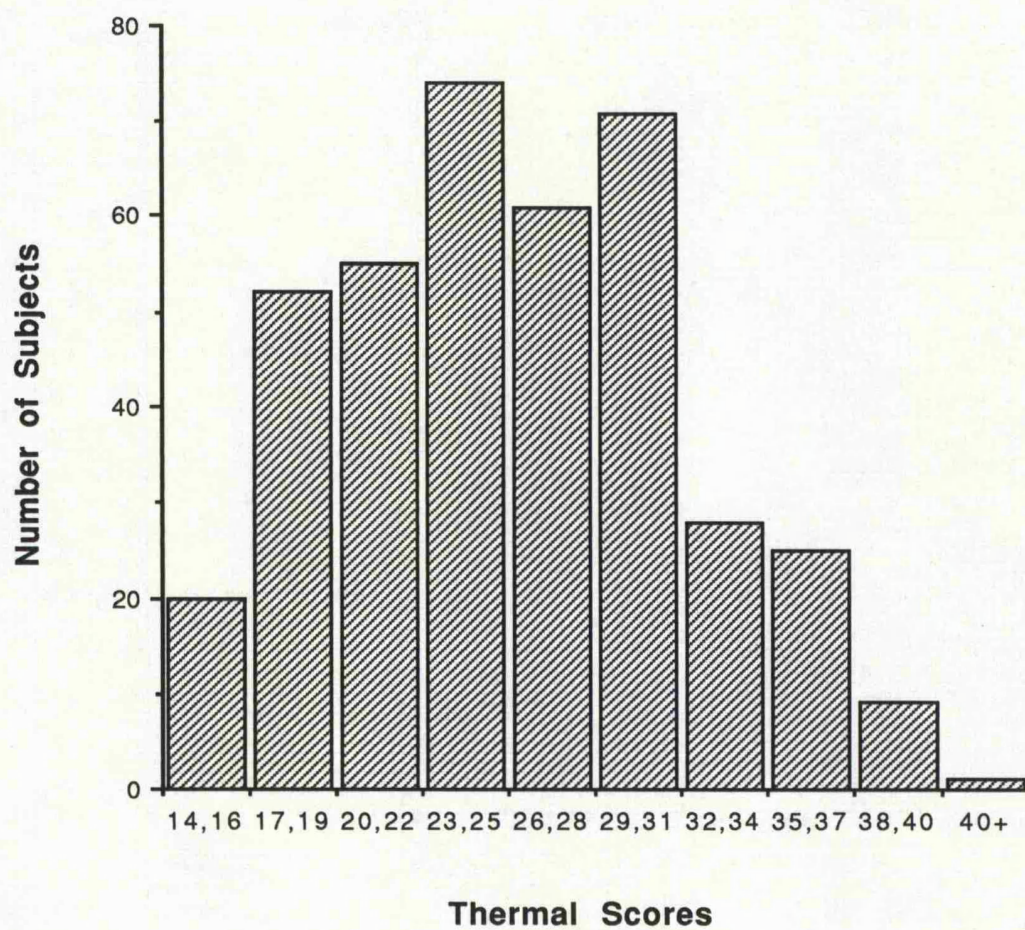
Fig 4.6.4 The distribution of thermal scores of 534 subjects aged 12 to 22 weeks,

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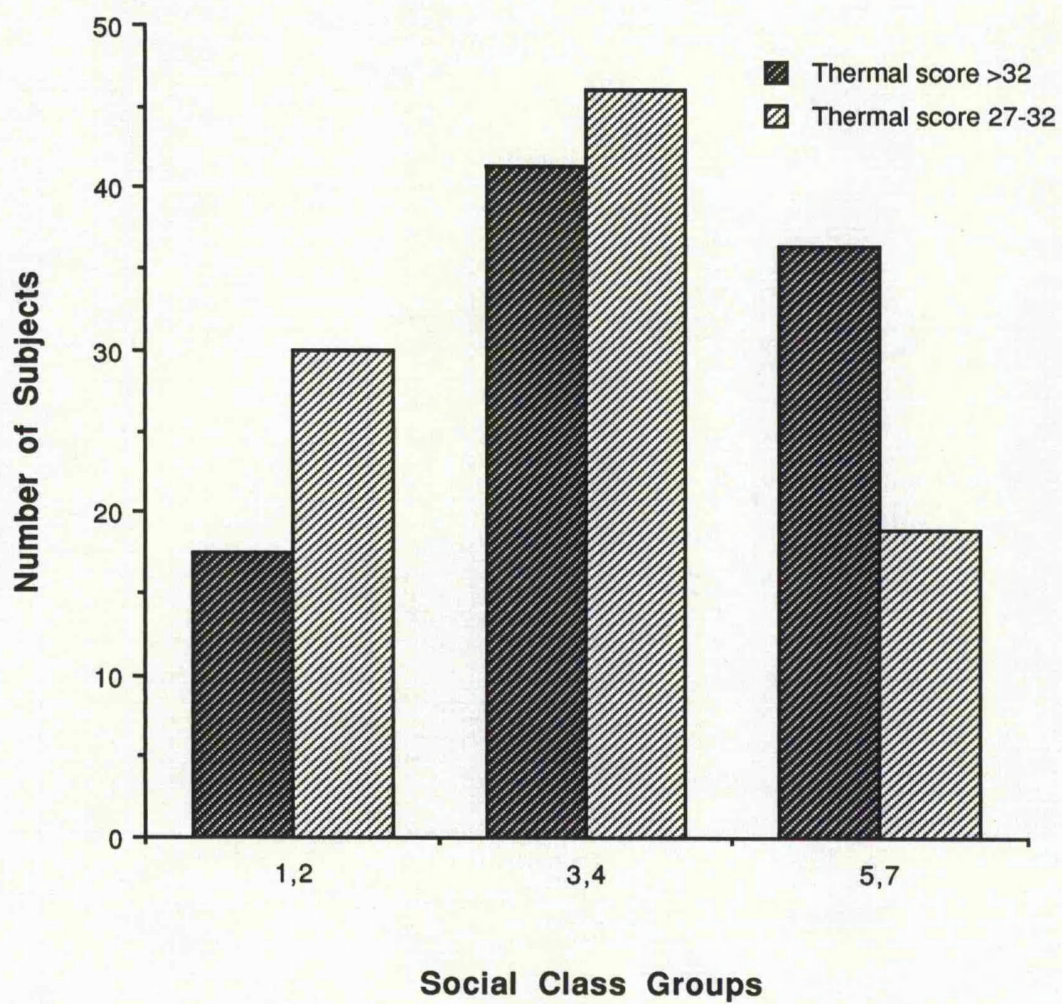
Fig 4.6.5 The percentage distribution of parents chosing average or
warm conditions for their babies, by social class.

TABLE 4.6.E– CHOICE OF THERMAL CONDITIONS AND MATERNAL AGE.

Maternal Ages	Percentage		
	WARM	**AVERAGE**	**COOL**
<19	0%	0%	3.7%
20–24	28.57%	21.2%	27.12%
25–30	44.4%	43.18%	51.06%
31–35	20.6%	26.5%	16.48%
36+	6.3%	6.8%	7.9%

The Effect of Thermal Environment

How important are the parent's choices of thermal environment on their baby's ability to enter into the normal response of rectal temperature to night sleep seen earlier in Figures 4.1.3 and 4.1.4.?

The rectal temperature of night time sleep was compared between subjects with a low thermal scores, and those with a high thermal score. Subjects produced deep body temperature patterns as previously identified (Figs 4.6.6 and 4.6.7). There were no significant differences 3 hours into the nights sleep, or at 6 hours, and also 4 hours and at 1½ hours before waking.

4.7   OTHER PARENTAL DECISIONS

Choice of Sleeping Place

Choice of room varied but was not always a factor of choice for the parents, due to family size and number of bedrooms. Many babies were in their own rooms 36 (53.7%) where they were placed to sleep in cots (five of these shared this room with a sibling). The remaining 31 (46.2%) were in their parents' room sleeping in Moses baskets or a crib of a similar style.
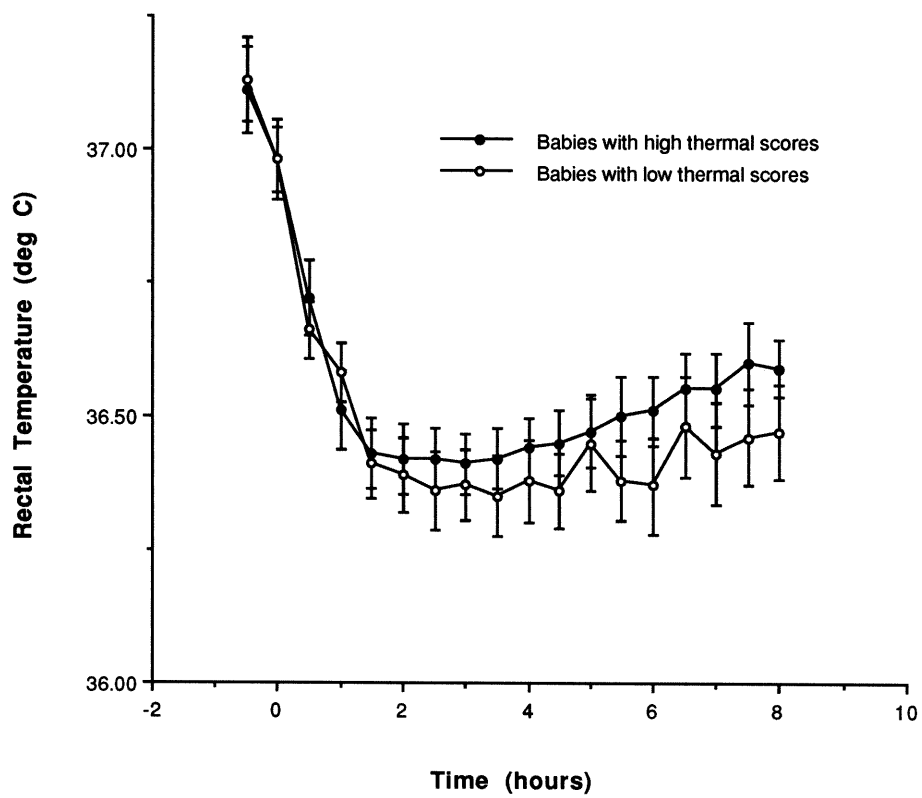
Figure 4.6.6 The rectal temperature pattern during the first eight hours of night sleep, of babies in differing thermal environments.
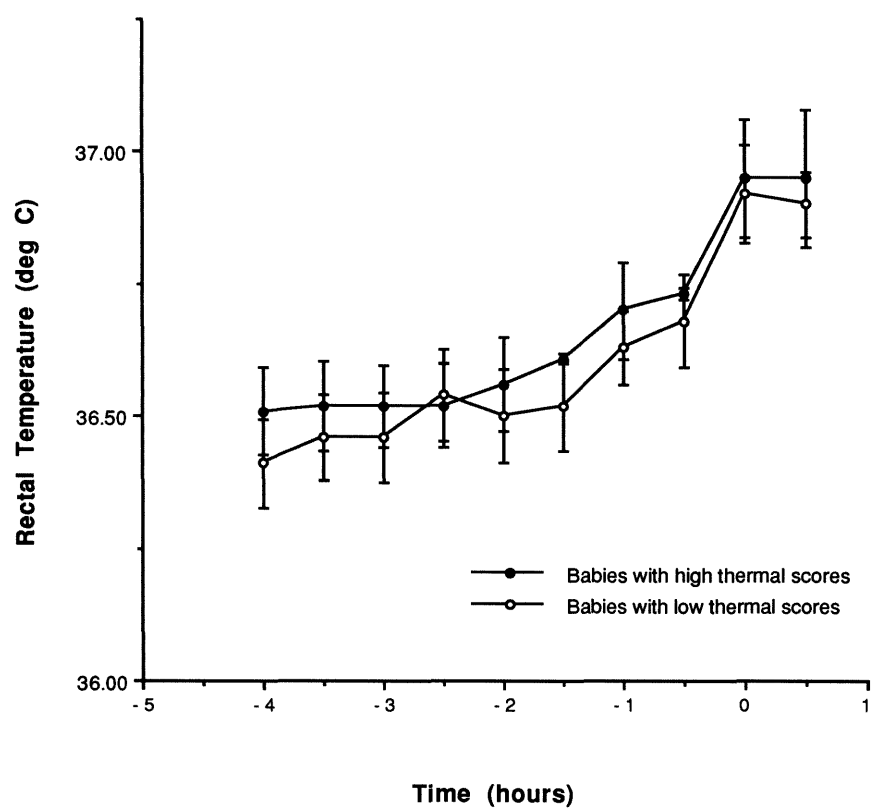
Figure 4.6.7 The rectal temperature pattern prior to waking of babies
in differing thermal environments.

Choice of Sleeping Position

Parents were asked how they placed their babies down to sleep in terms of on their stomachs (prone position), on their sides (lateral position), or on their backs (supine position). Forty-eight babies were placed in the prone position (71.6%), 5 babies in the supine position (7.5%), 7 babies were placed laterally (10.4%). There remained 7 babies who were reported by the parents to have been placed on their sides but shortly afterwards moved onto their backs (10.4%). Three babies who produced no data for the night time, were sleeping in their parents beds.

4.8 SUMMARY: RESULTS CHAPTER 4:

OBSERVATIONS OF PARENTAL BEHAVIOUR AND PHYSIOLOGICAL MEASUREMENTS OF RECTAL TEMPERATURE OF BABIES AGED 3 to 4 MONTHS AT NIGHT.

1. In all subjects deep body temperature was found to follow a distinctive pattern, whereby shortly after bedtime rectal temperature fell by 0.7°C where it stabilised until a gradual warming took place prior to waking. The rhythm was not distorted by night time feeds.

2. There were wide variations in parents choices of clothing, bedding and room heating at night.

3. When considering all the parental choices of thermal environment together the majority of parents behaved similarly and placed babies to sleep within a narrow range of conditions.

4. Despite differing home environments the pattern of rectal temperature at night was remarkably reproducible between subjects.

5. There was no difference in body temperature pattern between babies sleeping in the warmest, or coolest environments.

* There was no evidence that differing thermal environments affect deep body temperature during night time sleeps.

CHAPTER FIVE

DEEP BODY TEMPERATURE–DAY.
Free choice conditions

5.1   INTRODUCTION

All 70 subjects were monitored on at least one occasion during the day. Some subjects produced data for a short part of the day (4 to 7 hours) which could not take account of the complete cycle of daytime activity but included a variety of daytime events, while others were willing to be monitored for the entire day (9 to 16 hours).

In order to obtain a range of events, subjects were encouraged to produce a complete 24-hour recording. A total of 45 subjects were prepared to repeat the day recording in this way to give a broader range of daytime hours for analysis. Of these subjects, 21 were monitored for a full 24 hours, and 24 for 18 to 23 hours. Of these subjects who were fully monitored over a day their monitored hours ranged from 9 to 16 hours (mean 10.1), those who were monitored for almost a complete day had a daytime attachment range of 6 to 13 hours (mean 9.86), leaving 25 who were only monitored for a part of the day ranging from 4 to 7 hours (mean 5.4).

TABLE 5.1.A– DURATION OF DAYTIME MONITORING

HOURS	FULL 24 HRS	18–23 HRS	DAY ONLY	TOTAL
4–5	0	0	15	15
6–7	0	5	10	15
8–9	1	7	0	8
10–11	3	6	0	9
12–13	11	4	0	15
14–15	6	0	0	6
16	0	2	0	2

The parental diary sheet contained a prospective account of the day's events of all 70 subjects, during their monitoring period. A 24-hour timed grid was designed into which the pattern of all daily activities was plotted for all subjects, blocking out those times when the subject was not monitored. In general the day's events for all subjects included sleeps, feeds, nappy changes and periods of activity such as play or outings. The timing and duration of these events varied enormously between subjects.

Daytime Sleeps

All 70 subjects were reported to have slept for a period during a day's monitoring. Parents were asked to check their infants every 15 minutes because of the possibility of the sleep being short, therefore ensuring an accurate estimate of sleep duration.

Data from babies (total 40) monitored for at least 8 daytime hours were analysed to assess the amount of sleep. Sleeps were divided into morning (from waking to 12 mid-day), and afternoon (from 12 mid-day to bedtime). Of this group thirteen subjects did not sleep during the morning, 19 had one sleep averaging 75 minutes (range 30 to 180 minutes), and 8 subjects had two sleeps averaging 58.4 minutes (range 30 to 120 minutes).

The majority of subjects had more than one sleep, with some having four or five. Afternoon sleeps were more numerous, observed in all but one subject. Where subjects had numerous afternoon sleeps they tended to be shorter in length. By chance all the remaining 30 subjects with less than 8 hours of daytime data were monitored predominantly in the afternoon where the greater proportion of sleeps occurred.

Looking at individual total daytime sleep patterns across the 40 subjects again revealed variations in sleep. Some babies had only one sleep during the day, while others had as many as six or seven (Fig 5.1.1). The most frequent sleep duration was 2 hours (15 subjects=37.5%) and 3 hours (10 subjects=25%).

The duration of sleeps taken during the day, shows that those who slept less had longer sleeps than those who slept more. The average sleep length of those with one daytime sleep was 150 minutes, compared to 40.7 minutes for babies sleeping 7 times in the day (see Table 5.1.B). Although the number of sleeps varied as did their length, there were no subjects monitored for these longer periods who did not have one daytime sleep of 60 minutes, where the range was from 15 to 250 minutes. Subjects with numerous daytime sleeps were generally found to have one sleep of a minimum of 60 minutes although the remainder may have been shorter.

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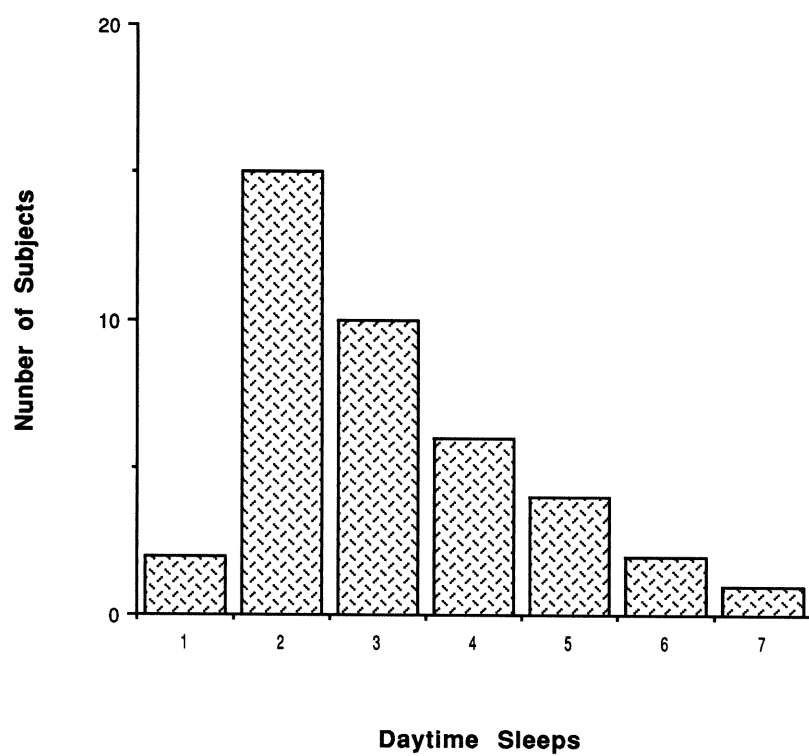
Figure 5.1.1 The distribution of the total number of daytime sleeps taken by 40 subjects.

TABLE 5.1.B– INDIVIDUAL SLEEP DIFFERENCES.

SLEEPS TAKEN	NUMBER OF SUBJECTS	RANGE (mins)	MEAN (mins)	TOTAL MEAN SLEEP (mins)
1	2	130–180	150	150
2	15	30–250	88	176
3	10	30–180	97.6	291
4	6	30–120	62.17	248.7
5	4	15–120	54.25	271.25
6	2	15–120	86.25	517.5
7	1	15–60	40.7	284.9

Sleep Variation

The daytime total sleep pattern of 40 subjects was analysed. The night sleep diaries of these subjects were compared to identify the complete daily pattern of sleep taken in 24 hours between subjects.

The mean daytime sleep requirement of these 40 subjects was 3.6 hours, with a mean night's sleep of 10 hours. Variations between daytime and night time sleeps across these subjects reveals day time sleeps ranging from 1 to 6 hours (Fig 5.1.2) and at night from 7 to 13 hours (Fig 5.1.3). Adding together each subject's day and night sleeps reveals the variability of sleep taken in 24 hours between subjects. This range (5.1.4) from 11 to 17 hours represents wide differences in sleep need between subjects. Comparing subjects at these two extremes reveals that those who had 11 hours sleep (total 7 subjects) had a mean daytime sleep of 2.35 hours and a mean of 9.07 hours at night. Those who had the most sleep (total 3 subjects) 16 to 17 hours in 24 hours, slept for a mean 4.6 hours in the day and a mean of 12.3 hours at night.
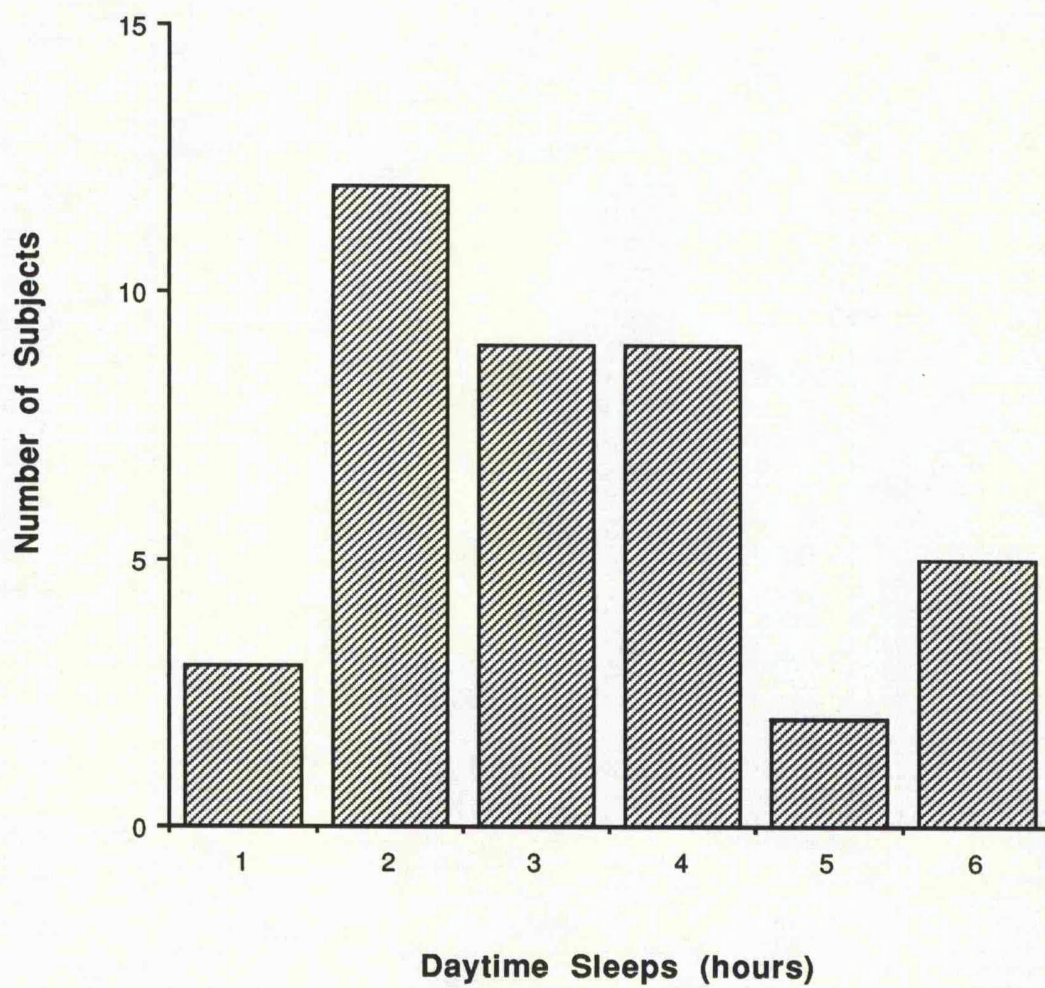
Figure 5.1.2 The distribution to show the length of daytime sleep, in hours.
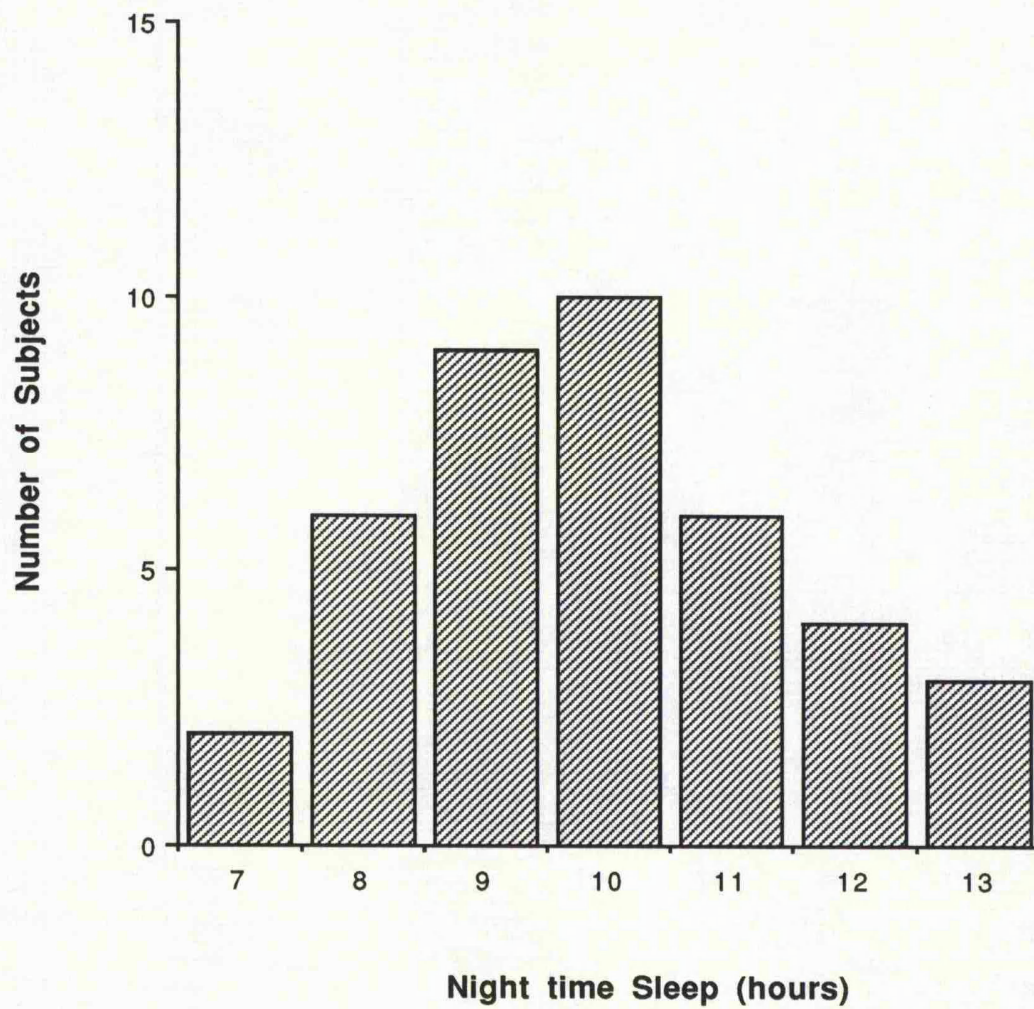
Figure 5.1.3 The distribution of the longest night time sleep in hours.

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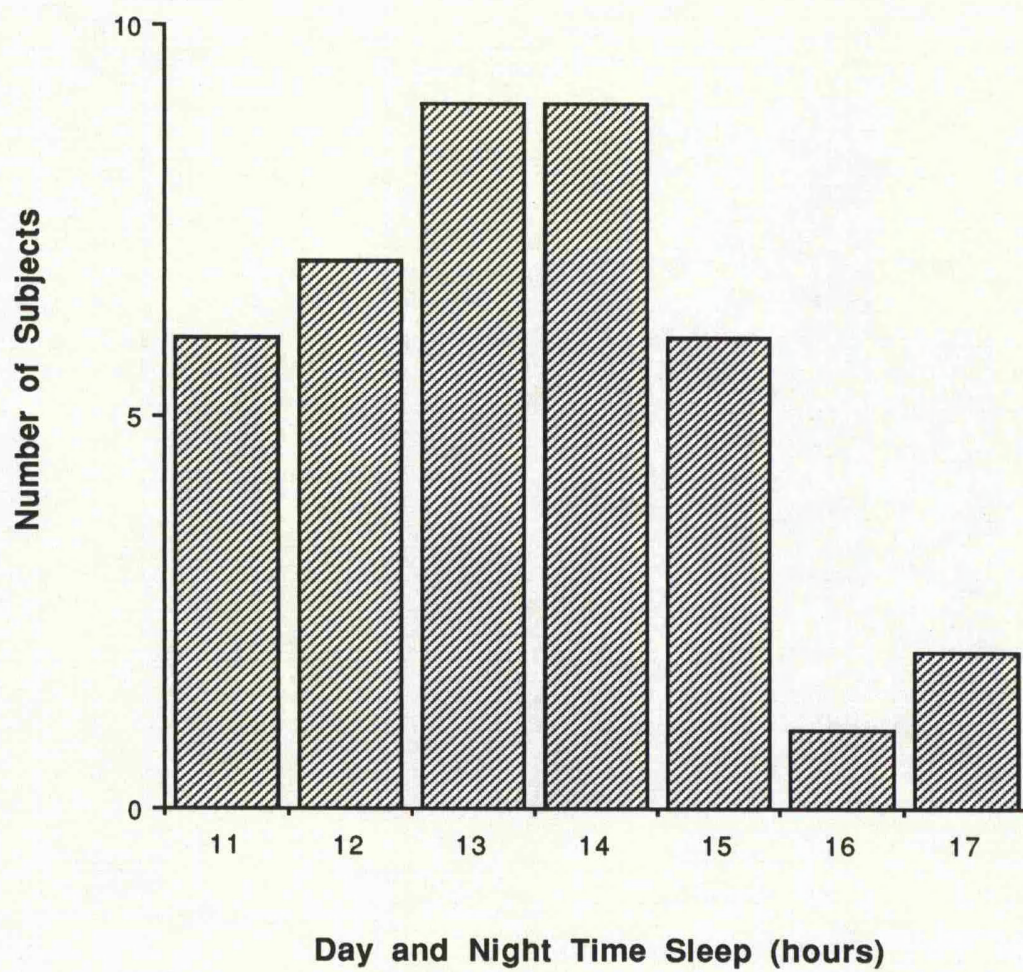
Figure 5.1.4   The distribution of total sleep taken in 24 hours.

5.2 TEMPERATURE DATA

The data was again scrutinised for evidence of disturbance of the rectal probe (see methods). Periods of sleep were edited on the print–outs and raw data tabulated according to the time indicated by parents for placing the baby into the pram, cot etc, until the time parents indicated the baby waking. As daytime sleeps are shorter than the night, the data were averaged at 15 minute intervals normalised to the onset of sleep.

Taking one sleep from each of the 70 subjects equal to and greater than 60 minutes in total duration reveals the effects of daytime sleep on deep body temperature (Fig. 5.2.1). At the point of being placed down to sleep the rectal temperature of the subjects was above $37^{\circ}C$ (mean $37.13^{\circ}C$ SEM 0.03), falling significantly after 45 minutes to around $36.8^{\circ}C$ (mean $36.82^{\circ}C$ SEM 0.03) ($p<0.001$ paired students t test $t=10.39$, $df=69$).

As sleep length ranged from the very short sleeps of 15 to 30 minutes to longer sleeps of 3 or more hours, two groups of sleeps were then tabulated, short sleeps less than 60 minutes (total 41 subjects) and longer sleeps greater than 90 minutes (total 52 subjects). Daily activity associated with the sleep also varied in that some sleeps were preceded by a period of play or activity, while others followed a feed. To examine like circumstances between subjects temperature data was then matched, by sleep length and activity in the hour prior to sleep. For both the short and long sleeps, there were two groups of subjects, those who slept after a period of activity, and those who slept after a feed.

5.3 DAYTIME SLEEPS >90 MINUTES

Although each baby slept for a period of the daytime monitoring not all babies produced a 90 minute sleep both preceded by a feed and a period of activity. In total taking one from each subject 39 data sets were obtained of babies fed before sleeping for 90 minutes, and 40 babies who were not fed prior to a 90 minute sleep.

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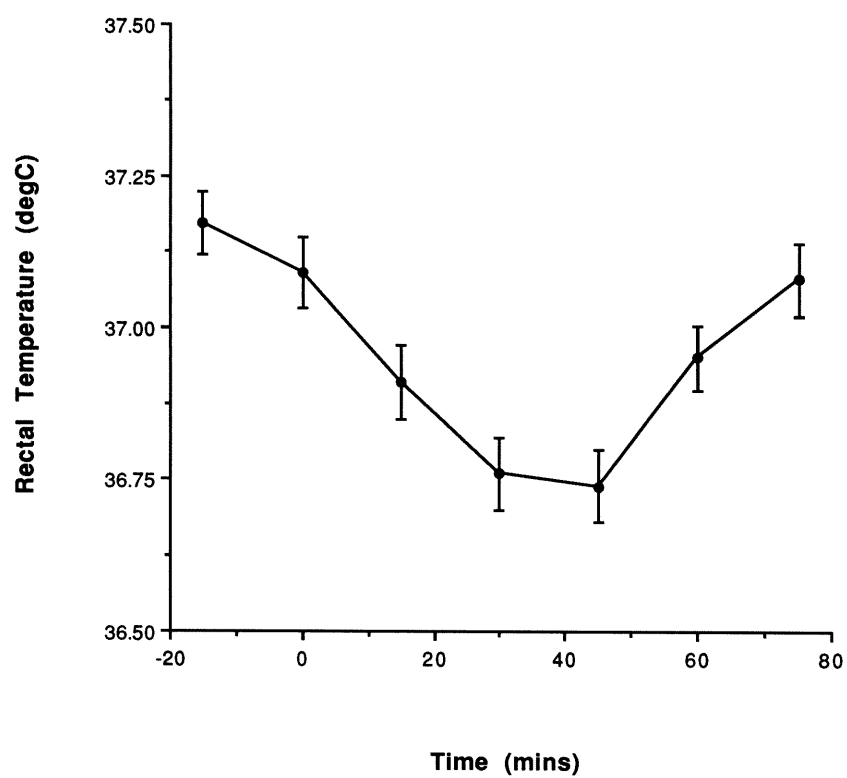
Figure 5.2.1 The mean (±SEM) rectal temperature during daytime sleeps.

Figure 5.3.1, shows the comparison of rectal temperatures of daytime sleeps >90 minutes in babies who were fed and those who were not fed. For both fed and non-fed babies during the day, rectal temperature fell after sleep from a level above 37°C to around 36.8°C 45 minutes later. The temperature of babies who were not fed had a faster rate of fall than babies who were fed prior to sleep. For both fed and non-fed babies, rectal temperature 45 minutes after bedtime was significantly lower than at bedtime, (p<0.001 paired students t test, t= 6.79 df=38; p<0.001 paired students t test t= 6.76 df=39): fed babies mean (SEM) at bedtime 37.18°C (0.03°C) and 45 minutes later 36.83°C (0.04°C), non-fed babies mean (SEM) at bedtime 37.10°C (0.04°C and 45 minutes later 36.84°C (0.03°C).

There appeared to be a slight difference between fed and non-fed babies in ability to cool at the onset of sleep. At 15 minutes and 30 minutes after bedtime, rectal temperature was lower in non-fed than fed babies: at 15 minutes in fed babies, mean (SEM) 37.06°C (0.04°C) and in non-fed mean (SEM) 36.97°C (0.03°C) although this was insignificant, at 30 minutes in fed babies the mean (SEM) rectal temperature was 36.92°C (0.04°C) and in non-fed babies 36.83°C (0.03°C), also insignificant. The differences between fed and non-fed can be identified by comparing the distribution of data at 30 minutes of the daytime sleeps. Fed babies have a greater proportion of readings above 37°C than non-fed babies (Figs 5.3.2).

After reaching the lowest point some 45 minutes into the sleep, for both fed and non-fed babies, temperature begins to rise to around 37°C at 90 minutes or waking time with a mean (SEM) 36.96°C (0.04°C) in fed babies and 36.91°C (0.04°C) in non-fed babies. At 60 minutes the fed babies appear to be warming faster, although there were no significant differences, the mean (SEM) of fed infants 36.87°C (0.04°C) and not fed 36.85°C (0.04°C) (Fig 5.3.3).
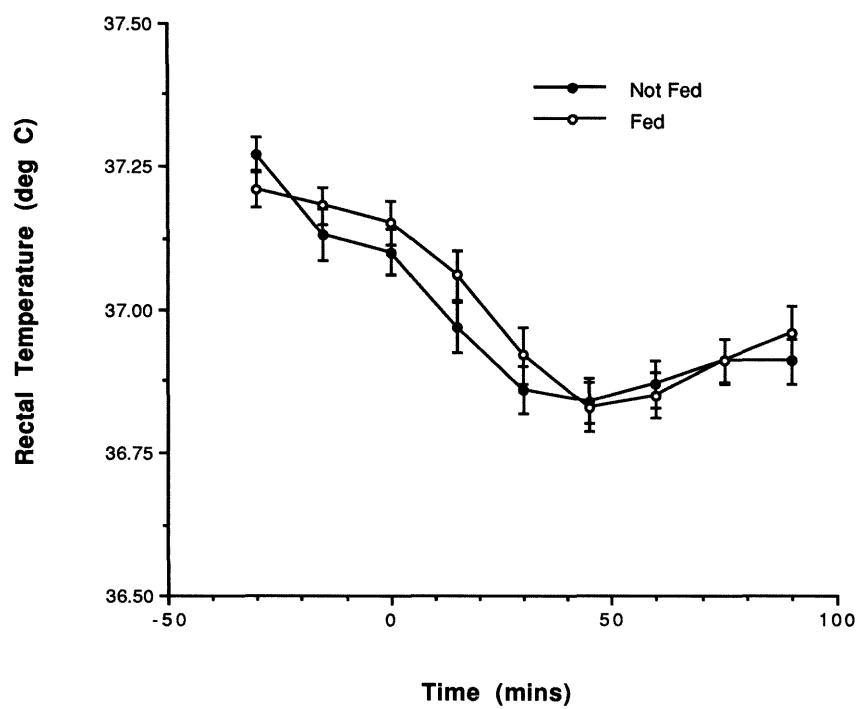
Figure 5.3.1 Comparison of the mean (±SEM) rectal temperature pattern
between babies who were fed prior to a daytime sleep, and babies
who were not fed.

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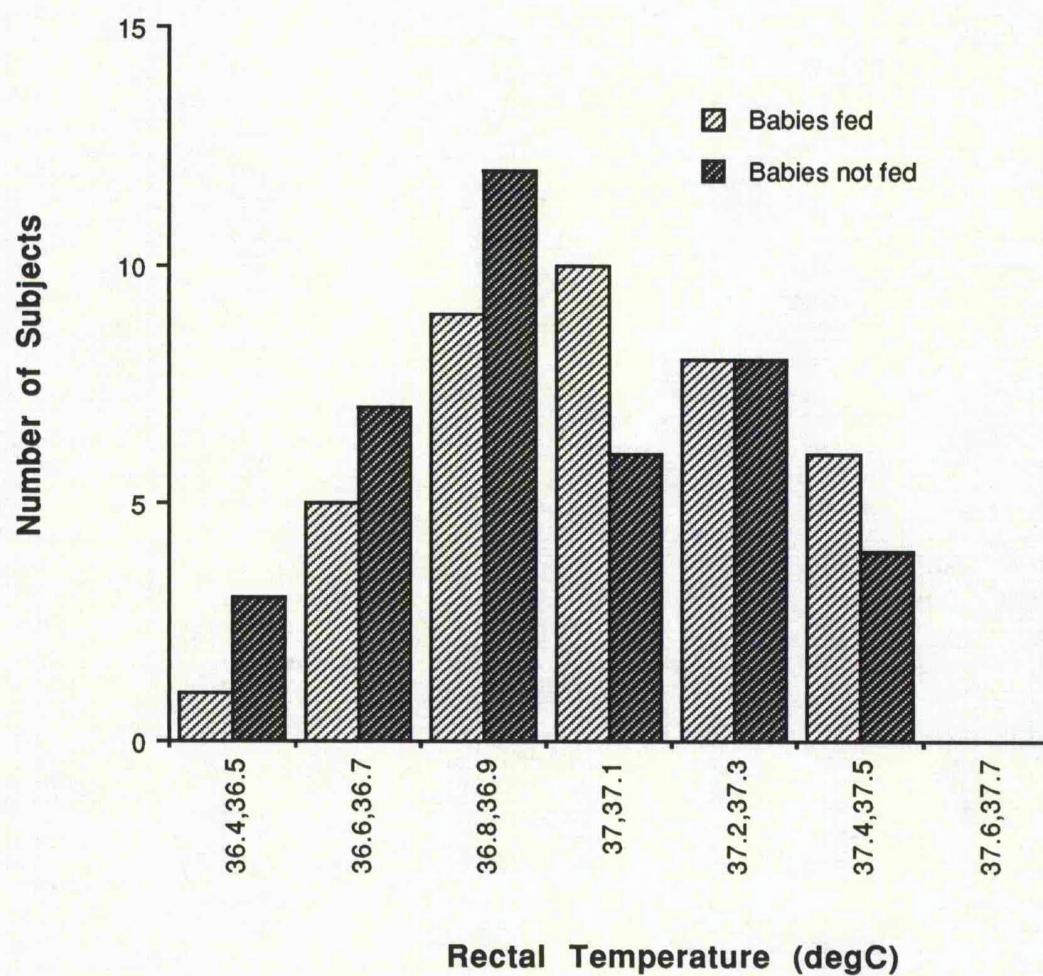
Fig 5.3.2 Comparison of the distribution of rectal temperature 15 minutes, into daytime sleep between babies who were previously fed and not fed.
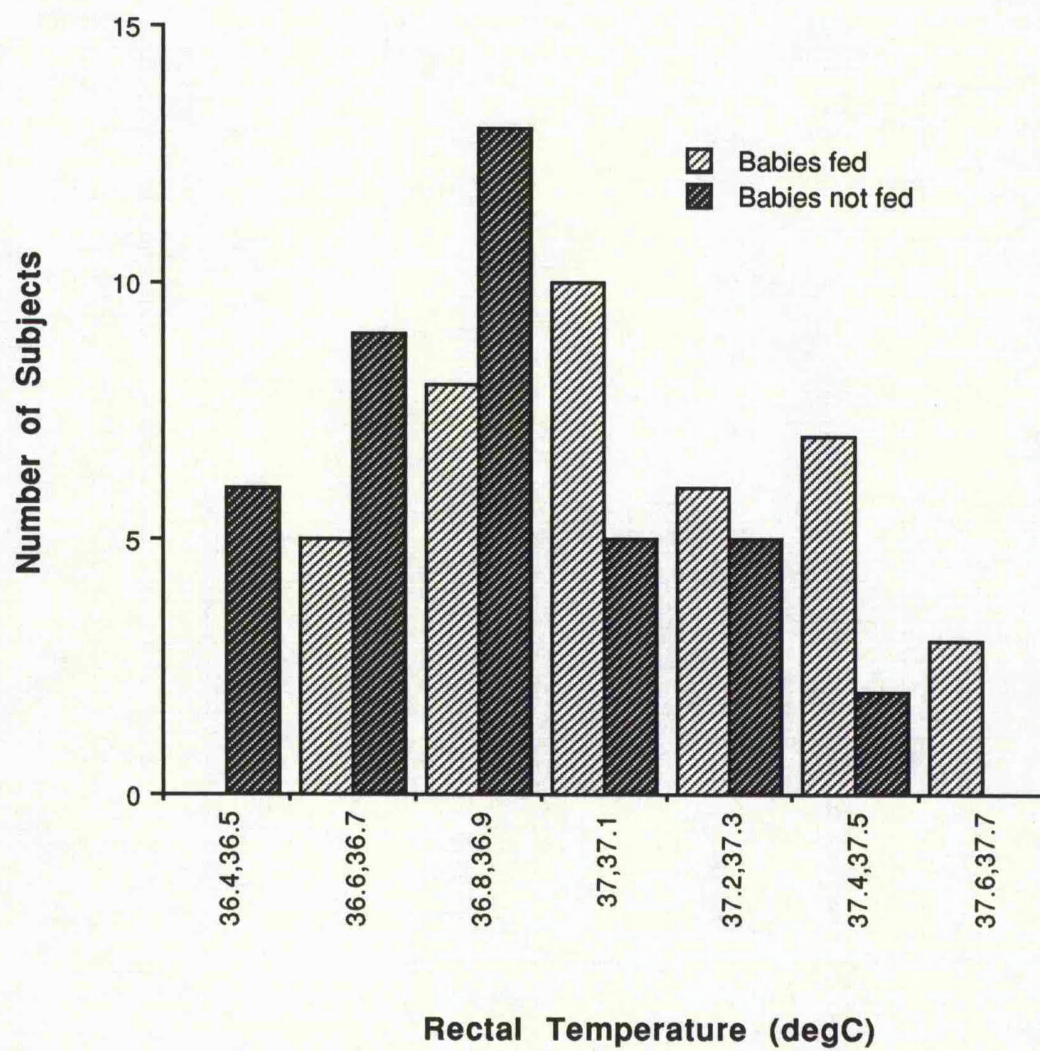
Fig 5.3.3 Comparison of the distribution of rectal temperatue 30 minutes into daytime sleep, between babies who were previously fed or not fed.

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5.4 DAYTIME SLEEPS <90 MINUTES

There remained 41 short sleeps of a minimum of 60 minute duration, maximum 80 minutes. The overall pattern for all 41 sleeps resembles that of the longer sleeps (Fig. 5.4.1). At bed time the rectal temperature was above 37°C (mean 37.09°C SEM 0.058°C) falling after 45 minutes to a level some 3°C lower (mean 36.74°C SEM 0.059°C). Separating each sleep according to prior events, gave 19 sleeps in which the baby was previously fed, and 21 sleeps in which the baby had not been fed. The differences between these two states appear to be more evident than in the longer sleeps, as fed babies have a sleep curve higher than the non–fed babies throughout the sleep duration (Fig. 5.4.2). At bedtime the mean (SEM) of fed babies was 37.16 (0.07) and non–fed babies 37.01 (0.08)(t test not significant), and at 30 minutes into the sleep the mean (SEM) of fed babies was 36.87 (0.084) and non–fed 36.64 (0.082), unpaired t test t=1.99 df=38 p<0.05.

5.5 THE THERMAL ENVIRONMENT

Room Temperatures

The maximum and minimum ambient temperatures were recorded for sleeps of 60 minutes and more. Taking one sleep from each subject the mean (SEM) maximum ambient temperature was 19.99°C (0.4) with a range of 15°C to 28°C. The mean (SEM) minimum temperature was 17.49°C (0.29) with a range of 12.85 to 26.05°C. The ambient temperatures of the subjects who slept >90 minutes (total 52) produced a more varied pattern than for subjects who slept 60 minutes (total 42).

The mean (SEM) maximum temperature during long sleeps was 21.35°C (0.4) with a minimum mean (SEM) temperature of 17.1°C (0.3), where the range was from 28°C to 16.1°C, these normal distributions can be seen in Figures 5.5.1 and 5.5.2. Whereas for shorter sleeps the mean (SEM) maximum ambient temperature was 18.64°C (0.3), the mean (SEM) minimum ambient temperature was 17.81°C (0.5), with a range of 12.85°C to 21.85°C, the normal distributions in Figures 5.5.3 and 5.5.4. The wider ranges found in longer sleeps indicates more time for cooling to take place.
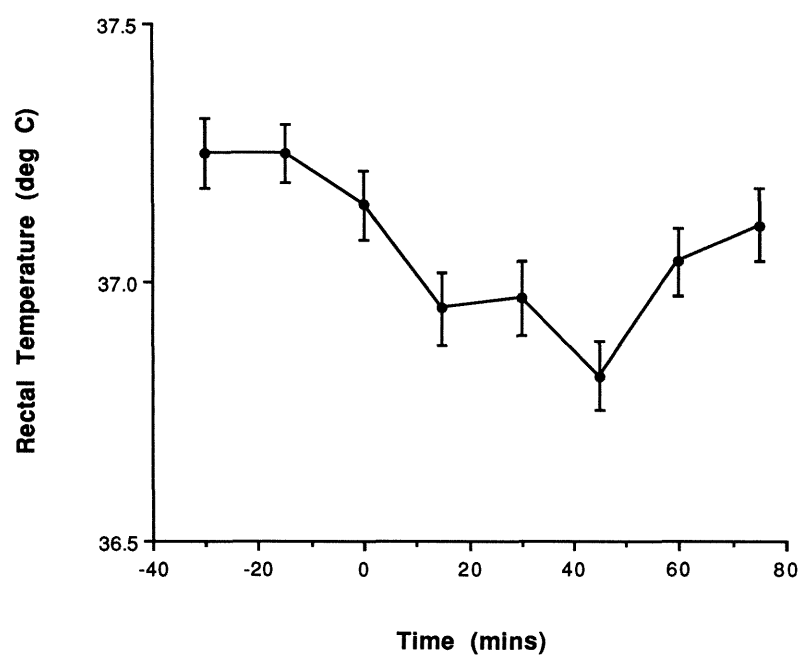
Figure 5.4.1 The mean (±SEM) rectal temperature pattern of babies during a short daytime sleep.
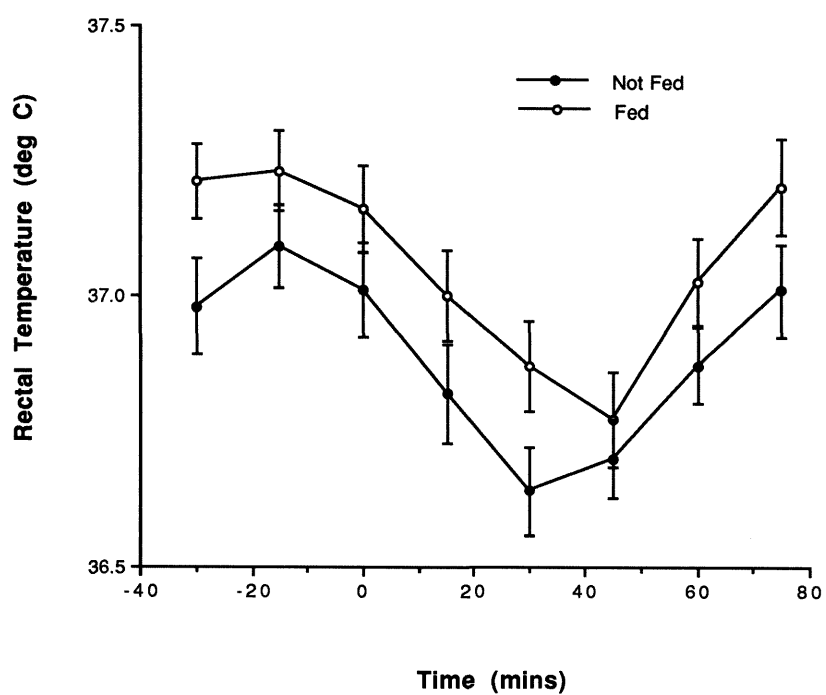
Figure 5.4.2 Comparison of the rectal temperature pattern between babies
who were fed and not fed prior to a short daytime sleep.
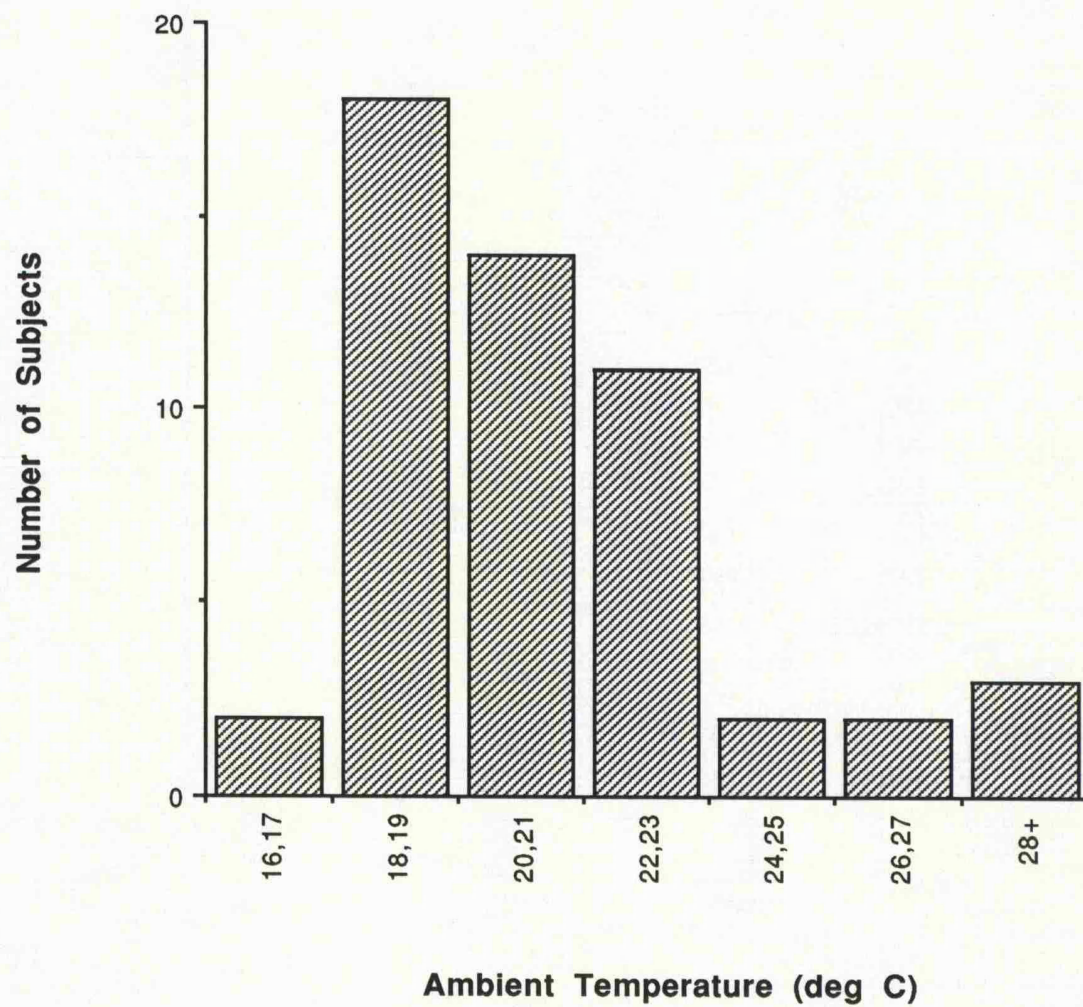
Figure 5.5.1 The distribution of maximum ambient temperature during 90 minute sleeps.
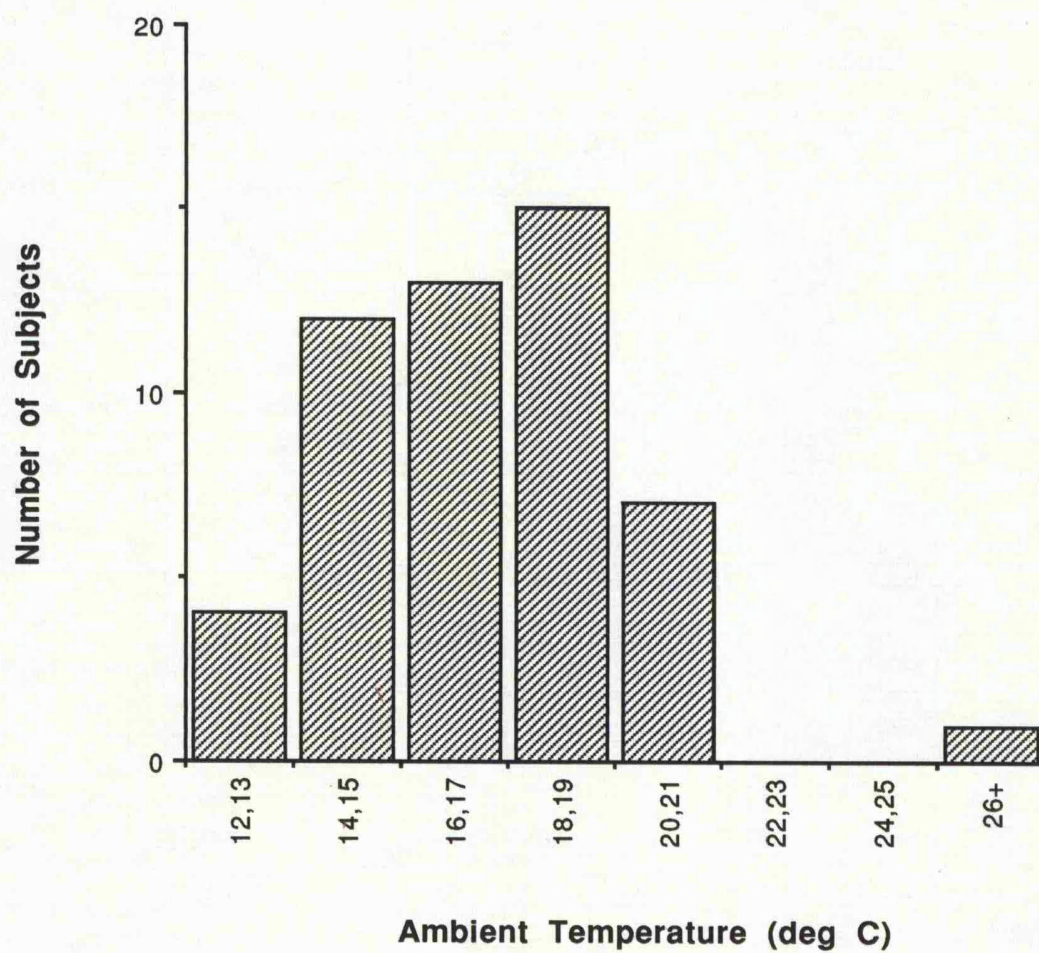
Figure 5.5.2 The distribution of minimum ambient temperature during 90 minute sleeps.
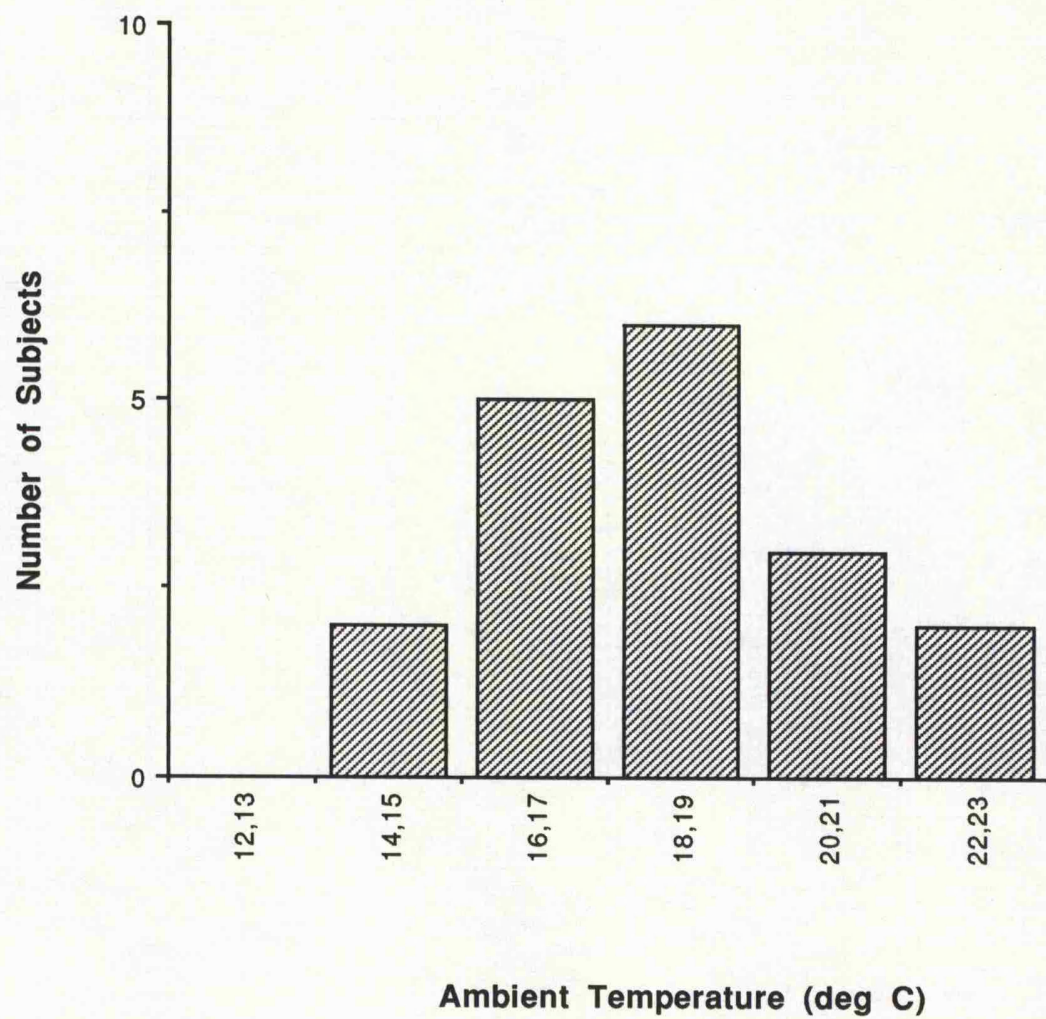
Figure 5.5.3   The distribution of maximum ambient temperature during sleeps of less than 90 minutes.
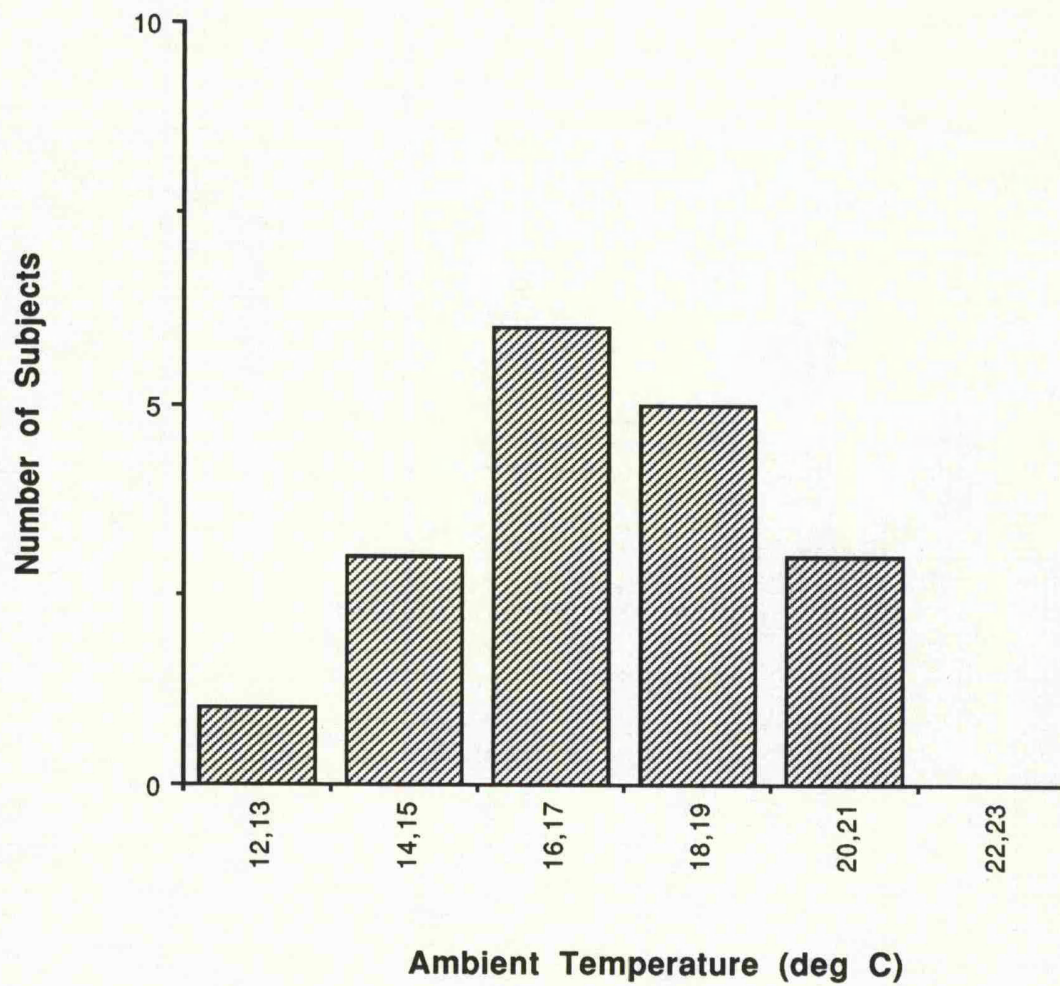
Figure 5.5.4   The distribution of minimum ambient temperature during
sleeps of less than 90 minutes

The Effect of heating and season on ambient temperature

Of the 70 subjects, 46 (65.7%) slept with a form of local heat, 24 (34.3%) with no local heat. Of the 56 homes with central heating, only 5 were in use during the day. The choice of heating was predominantly a local source of heat used in the place where the baby slept such as a lounge gas fire or electric heater.

Of the parents with no heat, 5 were monitored in summer. The ambient temperatures of the summer babies reflect the warmer conditions beyond parental control, average maximum temperature of 21.4°C average minimum temperature of 20.35°C. The extent of the summer daytime heat can clearly be seen for long sleeps in the normal distributions of maximum temperature where some subjects were in conditions of 28°C (Fig. 5.5.1). Excluding the summer monitorings, subjects who slept with local heat experienced an average maximum temperature of 20.45°C and minimum of 18.28°C.

The average maximum ambient temperature of the sleeping environment of babies with no form of heating was 19.06°C, the minimum 16.42°C. Those homes with central heating on a timed basis in the early morning and evening with no form of heat during the day had a maximum ambient temperature of 19.96°C, and minimum 16.89°C. The homes with no central heating and no local heat in use during the daytime sleep reveal a maximum ambient temperature of 18.15°C, and minimum 15.7°C.

5.6   PARENTAL CHOICE OF CLOTHING AND WRAPPING

The tog values for clothing and wrapping were listed for each subject's longest sleep. The mean (SEM) tog for clothes was 5.15 (0.18) where the range was from 2 to 8.2 tog units. The lower end of the tog range, 2 to 3.9 tog units, was the most popular daytime clothing when asleep (total 27=38.6%) see Table 5.6.A. The middle ranges, 4 to 4.9 tog units, were also popular with 21 subjects (30%) falling within this range, and 19 subjects had a tog value of 6 to 7.9 togs (27.1%). Only 3 subjects had a tog value between 8 to 10 units (4.3%).

The most popular form of clothing in the lower ranges was 3.2 togs representing a vest, nappy and standard babygro. The tog range 4 to 5.9 included babies wearing this combination of clothes with a cardigan or jumper. It also included a combination of different sex clothing in the form of dresses and cardigans for girls and tracksuits, trousers, shirts and jumpers for boys.

TABLE 5.6.A– TOG UNITS OF DAYTIME CLOTHING

TOG RANGES	NUMBER OF SUBJECTS
2 to 3.9	27 (38.6%)
4 to 5.9	21 (30%)
6 to 7.9	19 (27.1%)
8 to 10	3 (4.3%)

The higher range of 6 to 7.9 tog units represented a range of choices of knitted suits, wool dresses with cardigans, tracksuits with a jumper and similar combinations, all including thicker fabrics or wools. The 3 subjects in the highest ranges wore the normal under layers of nappy and vest with thick trousers, a jumper and a cardigan, the highest tog value being 8.5 units.

The mean (SEM) tog unit for daytime bedding was 7.07 tog units (0.43), with a range of 0 to 15.7 togs. As with night sleeps the layers of wrappings were analysed in 4 tog ranges, <6.0 togs, 6 to 8.9 togs, 9 to 12 togs, and 12+ togs, (see Table 5.6.B).

The most popular type of bedding in the lower range of <6.0 togs was one blanket (blanket= 2.0 togs). There were several babies monitored in the summer months who slept with no bedding. The next category of bedding 8.9 tog units consisted of a combination of a sheet with various layers of blankets. This can be clearly seen in Figure 5.6.1 showing the distribution of togs within the range 0 to 8.9 tog units, the dominance of 2, 4, 6, 8 tog units reflecting the use of increasing layers of blankets.
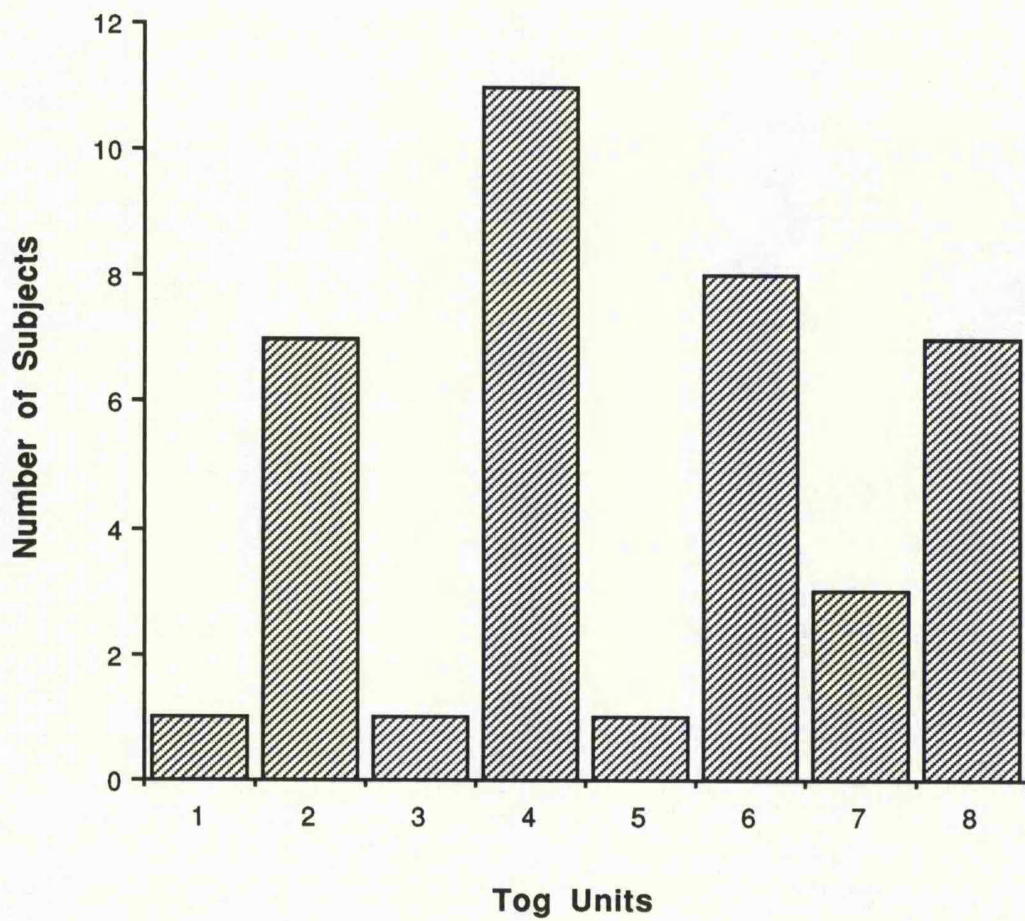
Figure 5.6.1 The distribution of the amount of bedding in tog units, used on babies during daytime sleeps.

TABLE 5.6.B– TOG UNITS OF DAYTIME BEDDING

TOG UNITS	NUMBER OF SUBJECTS
<6	21 (30%)
6 to 8.9	19 (27.1%)
9 to 12	21 (30%)
12+	4 (5.7%)

* 5 (7.1%) subjects = 0 tog units

The band of 9 to 12 togs as with night sleeps represents the use of duvets either thin 4 to 6 togs or thick 10 to 12 togs with or without other wrappings ie. blankets. The highest range representing fewer subjects consists of bedding of a variety of thick blankets and thicker duvets.

Factors Influencing Parental Choice of Clothing and Wrapping

Parental decisions of clothing, wrapping and heating during the day were made by examining the 4 groups of bedding for the following variables: month of monitoring, social class, sex, birth weight, maximum and minimum room temperature, choice of day clothing and use of heating (Table 5.6.C, 5.6.D).

TABLE 5.6.C– FACTORS ASSOCIATED WITH PARENTAL CHOICE OF TOG UNITS

TOG BEDDING	SEASON	HEATING Y/N	MAXIMUM ROOM TEMP.	MINIMUM ROOM TEMP.	TOG CLOTHES
<6.0*	w=19 s=7	y=17 n=9	21°C	18.6°C	4.7
6 to 8.9	w=18 s=1	y=12 n=7	20.2°C	17.3°C	4.9
9 to 12	w=18 s=3	y=15 n=6	20.1°C	17.1°C	4.9
>12	w=4 s=0	y=2 n=2	22.2°C	16.6°C	5.7

* including 5 subjects = 0 togs bedding

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TABLE 5.6.D- FACTORS ASSOCIATED WITH PARENTAL CHOICE OF TOG UNITS

TOGS	SOCIAL CLASS non-manual, manual	BIRTH WEIGHT	SEX
<6.0*	m=8 nm=18	3640g	m=15 f=11
6 to 8.9	m=12 nm=7	3413g	m=8 f=11
9 to 12	m=7 nm=14	3460g	m=14 f=7
>12	m=2 nm=2	3652g	m=1 f=3

* including 5 subjects = 0 togs bedding

Babies with light bedding were more likely to have warmer ambient temperatures due to the use of heating during the day. These babies experienced the warmest ambient temperatures, the minimum average being 18.6°C. The lightly clothed had the lowest average togs for clothing of 4.7 togs. They were dominated by the higher social classes.

Babies with bedtime togs of 6 to 8.9 units were again in warmer rooms (mean minimum temperature 17.3°C) and were again more likely to be moderately dressed (mean togs clothing 4.9). They were all predominantly monitored during the winter months. This group was dominated by the manual social classes and had the lowest birth weights of any of the four groups.

The third group of babies who were more heavily wrapped when asleep (togs bedding 9 to 11 units) were also in warm rooms (mean ambient minimum temperature 17.1°C) and were predominantly monitored in the winter. They were more heavily clothed with a mean of 5.1 tog units. They were dominantly male babies of the higher social classes.

The last most heavily wrapped babies experienced the coolest ambient temperatures

(mean minimum temperature 16.6°C). The two homes in this group using central heating did so to good effect distorting the maximum readings (maximum temperature of the unheated homes 16.2°C, mean maximum temperature for this group 22.2°C). All four of these babies were monitored in the winter.

It would appear that parents consider the warmth of the environment before placing layers of wrapping onto the sleeping baby, which is apparent when comparing babies clothed with less than 6 togs to those with greater than 12 togs. Parents choosing the middle ranges of wrappings appear to either prefer their babies to be lightly or more heavily insulated as the ambient temperatures follow similar ranges.

Comparison of Parental Choice of Clothing, Wrapping and Ambient Temperature.
A measure of the chosen thermal environment was made by adding for each subject the total tog (clothing and wrapping) with the minimum room temperature experienced during daytime sleep. Adding both measures together reveals the majority of subjects experienced similar thermal environments. There were two groups who were different, those with lower and higher scores than the average (see Table 5.6.E).

TABLE 5.6.E– THERMAL SCORE – DAYTIME SLEEP

THERMAL SCORE (Tog Tot+ Min Temp)	NUMBER OF SUBJECTS
Less than 25	10 (14.3%)
25 to 30	44 (62.8%)
31 to 36	16 (22.8%)

Social Factors Relating to Thermal Scores
Parents who chose cooler or warmer conditions than the majority, were analysed for social descriptive associations. There were very few variations to distinguish the two groups (see table 5.6.F), but 6 babies had high scores at night and also during the day. Although there were some parents whose behaviour during the day was similar to the night, most were not. The social spread of families was wide, with more of the professional parents choosing warmer conditions during the day.

TABLE 5.6.F– COMPARISON OF HIGH AND LOW THERMAL SCORES, TO SOCIAL FACTORS

TYPE	SOCIAL CLASS nm/m	ILLNESS	BREAST FED BOTTLE FED	SOCIAL CARE	NO CHILDREN
Warm	NM=9 M =5	4	Br = 4 Bot= 10	Good=11 Bad = 3	1 =9 2+=4
Cool	NM=6 M =4	4	Br = 3 Bot= 7	Good= 7 Bad = 3	1 =6 2+=4

The Effect of Thermal Environment

The 10 subjects with the low scores were compared with the 16 in the higher range to establish any differences in ability to thermoregulate during sleep. The mean score of the 10 subjects in the low group was 20.3, the high group 33.95. There are no differences in the body temperature patterns of these two extreme groups, during 90 minute daytime sleeps (Fig 5.6.2).

5.7 OTHER PARENTAL DECISIONS

Choice of Sleeping Place

Sleeping place during the day varied enormously, with many parents choosing an entirely different environment from that of the night. This included the use of prams in the hall, and carry–cots, prams or moses baskets, in the lounge. Often the choice of sleeping place was determined by the baby who fell asleep on the settee or in a recliner chair. Many parents continued to use the baby's nursery cot or crib (see Table 5.7.A).

TABLE 5.7.A– SLEEPING PLACE

SLEEPING PLACE	NUMBER OF SUBJECTS
Bedroom/cot	29 (41.4%)
Lounge	35 (50%)
Hall	6 (8.6%)
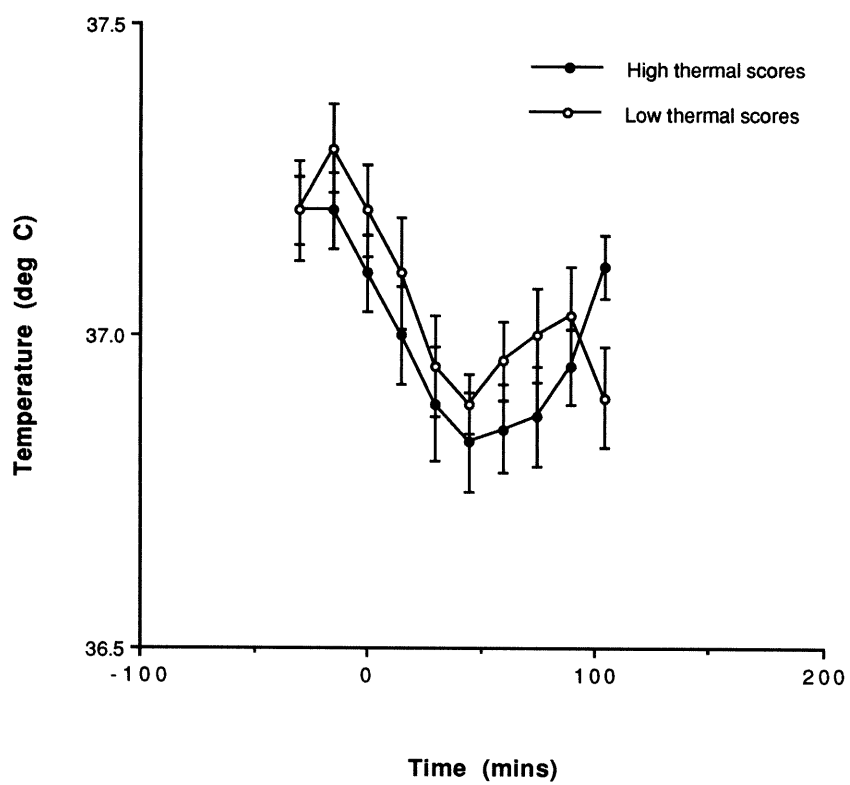
Figure 5.6.2 A comparison of the mean (±SEM) rectal daytime temperature between babies with high and low thermal scores during sleep.

Choice of Sleeping Position

There was greater variability in parental choice of sleeping position in the day than at night, possibly due to the variable sleeping place. More babies were found sleeping in the lateral and supine position (see Table 5.7.B).

TABLE 5.7.B– SLEEPING POSITION

SLEEPING POSITION	NUMBER OF SUBJECTS
Prone	43 (61.4%)
Lateral	16 (22.8%)
Supine	11 (15.7%)

5.8 TEMPERATURE CHANGES ASSOCIATED WITH FEEDING DURING THE DAY

Of the 70 subjects monitored 30(42.9%) were breast fed, 39(55.7%) bottle fed and 1(1.4%) both breast and bottle fed at alternate feeds. Of the breast fed babies 4 received bottles as an occasional supplement. There were only three breast fed infants not receiving some solid, but babies aged 16 to 20 weeks and bottle fed babies of all ages were having more solid than those age 12 weeks and breast fed.

Data were scrutinised for evidence of disturbance of the rectal probe. Feeds were identified on the raw data computer print–outs. Averaged data at 10 minute intervals, for 30 minutes prior to the stated onset of the feed and for 60 minutes after were tabulated, and synchronised for each subject at the time identified as the beginning of the feed. As with daytime sleeps, feeds were associated with other daytime events, of sleeps or wakeful activity, identified from the parental activity sheet. Obviously the time of feeds for each subject varied although in general they were linked to the times in the day when adults eat, such as breakfast, dinner and tea. For each feed event the following categories were identified;

a) Breast feeds followed by a period of wakeful activity,

b) Breast feeds followed by sleep,

c) Bottle feeds followed by a period of wakeful activity,

d) Bottle feeds followed by a sleep.

Most feeds followed by sleep were preceded by wakeful activity and vice versa.

Comparison Between Feeds Followed by Sleep and Activity

Feeds were analysed according to whether breast or bottle and whether followed by sleep or activity. It was possible to separate the first feed of the day, from the last feed of the day prior to bedtime, leaving a large number of daytime feeds from the morning and afternoon for separate analysis.

There were 40 bottle fed babies who fed and then remained active, and 26 who slept within an hour of feeding. Of the breast fed babies in the same time period, 23 were awake and active after feeding, and 22 slept within an hour of feeding. The rectal temperature patterns for these feeds (Figs 5.8.1 and 5.8.2) show that for both breast and bottle fed babies rectal temperature 50 minutes after feeding is significantly raised if the baby remained awake, but significantly reduced if the baby slept: for bottle fed babies who remained active a mean (SEM) rectal temperature of $37.16°C$ (0.04) at feed onset, and $37.4°C$ (0.04) 50 minutes later (paired t test, t=7.40 p<0.001 df=39), and similarly for breast fed babies at feed onset a mean (SEM) $36.96°C$ (0.05) and 50 minutes later $37.13°C$ (0.04) (paired t test t=-2.60 p<0.05 df=22). For bottle fed babies at feed time who then slept, the mean (SEM) rectal temperature was $37.23°C$ (0.04) and $36.98°C$ (0.05) 50 minutes later (paired t test t=3.32 p<0.01 df=25); and similarly for breast fed at feed onset, who then slept $37.05°C$ (0.04) and 50 minutes later $36.86°C$ (0.05) (paired t test t=3.33 p<0.025 df=21). The rectal temperature of bottle fed babies rose faster if they stayed awake, and fell more slowly if they slept. Bottle fed babies temperatures were generally higher than breast fed babies both 50 minutes after feeds where the baby remained awake and 50 minutes after feeds where the baby slept. The mean (SEM) for breast fed babies awake, 50 minutes after the feed, $37.13°C$ (0.02)), and bottle fed babies awake $37.4°C$ (0.02) a significant
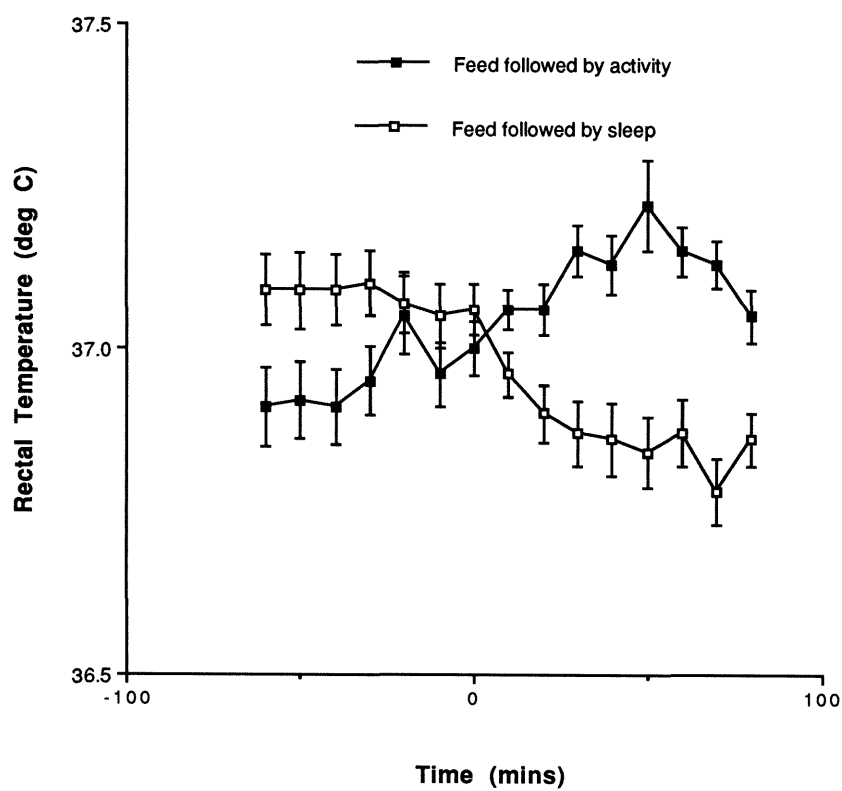
Figure 5.8.1 The mean (±SEM) rectal temperature changes in breast fed babies followed by either a period of wakeful activity or sleep during the day.
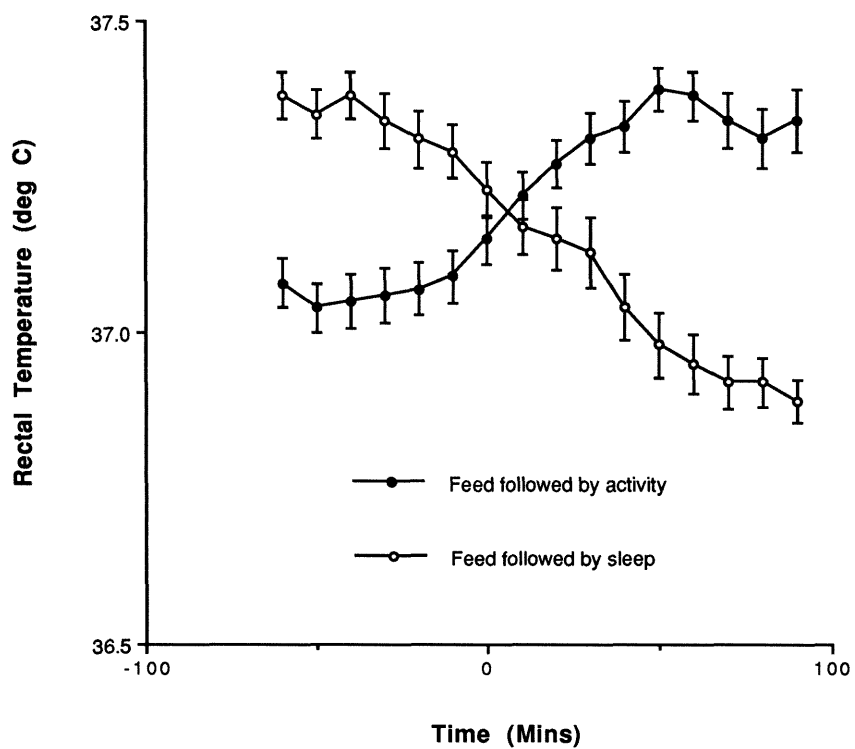
Figure 5.8.2 The mean (±SEM) rectal temperature changes in bottle fed babies
followed by either a period of wakeful activity or sleep during the day.

difference (unpaired students t test t=3.88 df= 61 p<0.05), and for breast fed babies asleep a mean (SEM) 36.85°C (0.03) and bottle fed asleep 37°C (0.04) not significant.

Data were obtained for feeds in the early evening which were followed by night time sleep. There were 33 bottle fed and 27 breast fed babies (see Fig 5.8.3). The fall in temperature reflects the night time temperature pattern associated with sleep discussed in chapter 4, and shows that bottle fed babies have higher temperatures.

Data from 18 breast fed babies and 14 bottle fed were obtained for the first feed of the day after waking from the nights sleep. These show for both breast and bottle fed babies (see Fig 5.8.4) the pattern of temperature rise to day time levels from night time sleep. Bottle fed babies are seen to have higher temperatures. It can be seen that a large proportion of bottle fed babies in this group appear to be entering sleep 80 minutes after feeding.

5.9   DAY TIME ACTIVITY

For each of the 70 subjects monitored during the day, periods of indoor play or activity could be identified. The activity period occurred between sleeps or feeds, and often included a nappy change or small wash. Parents recordings on the activity sheet were often detailed, describing periods of obvious excitement for the baby who was engaged in vocalizations and active limb movements.

In order to identify the range of body temperatures experienced during activity 15 minute averaged rectal temperatures were taken for a period of one hour's activity for each subject. As the majority of daytime recordings were in the afternoon, where possible these activity periods were taken from between 12 mid–day and 3pm, or alternatively late morning between 10am and 12 mid–day. The average maximum daytime rectal temperature within this time scale was 37.4°C, with an average minimum of 37.1°C. Bottle fed babies were significantly warmer, with a mean (SEM) maximum rectal temperature 37.51°C (0.035°C), compared with a mean (SEM)
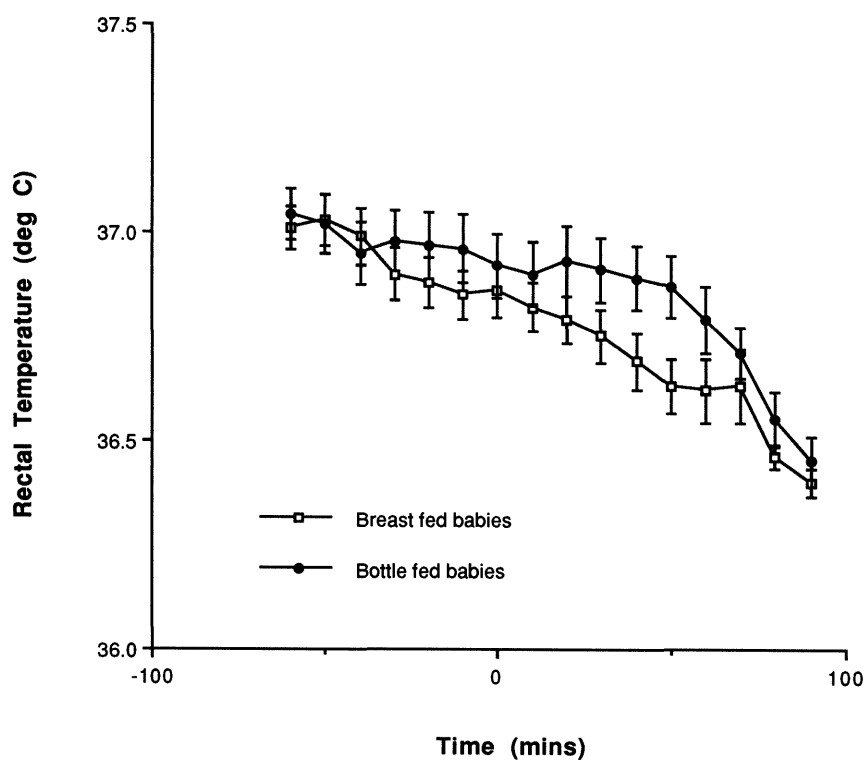
Figure 5.8.3 The mean (±SEM) rectal temperature pattern in breast and bottle fed babies prior to night time sleep.
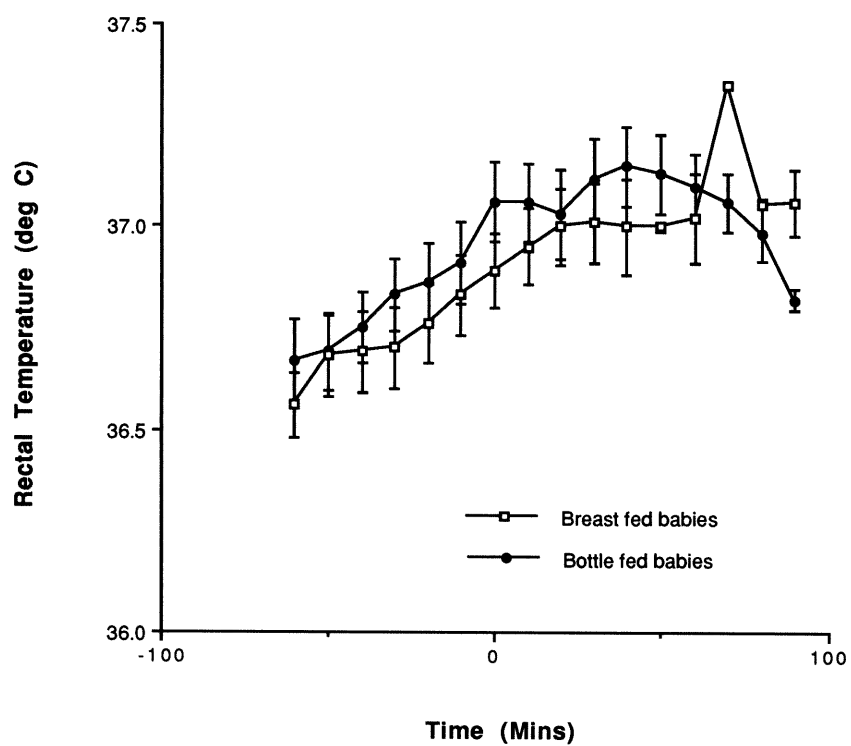
Figure 5.8.4. The mean (±SEM) rectal temperature pattern in breast and bottle fed babies after the first feed of the morning.

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maximum temperature in breast fed babies of 37.25°C (0.04) (unpaired t test t=4.26 df=68 p<0.001), and a mean (SEM) minimum 37.17°C (0.037°C) in bottle fed infants compared to mean (SEM) minimum 37.04°C (0.034°C) in breast fed babies (unpaired t test t=2.55 df= 68 p<0.025), see Figure 5.9.1.

From scanning all the rectal temperature data, deep body temperature was seen to rise to heights of 37.8°C during activity periods in some babies, at varying times of the day. For each baby the maximum rectal temperature associated with wakeful activity in the day was recorded. Dividing subjects according to breast or bottle feeds produced a marked difference between the two groups, the mean (SEM) maximum rectal temperature for breast fed babies throughout the day was 37.4°C (0.02°C), and in bottle fed babies 37.6°C (0.016°C). The maximum temperature reached by breast fed baby was 37.6°C (range 37.1°C –37.6°C) and the maximum attained by a bottle fed baby was 37.8°C (range bottle fed 37.3°C –37.8°C) see Figures 5.9.2. It can be seen that the majority of subjects reached these points during the early afternoon between 2–3pm, where the range was from 8am to 7 pm, see Figure 5.9.3.
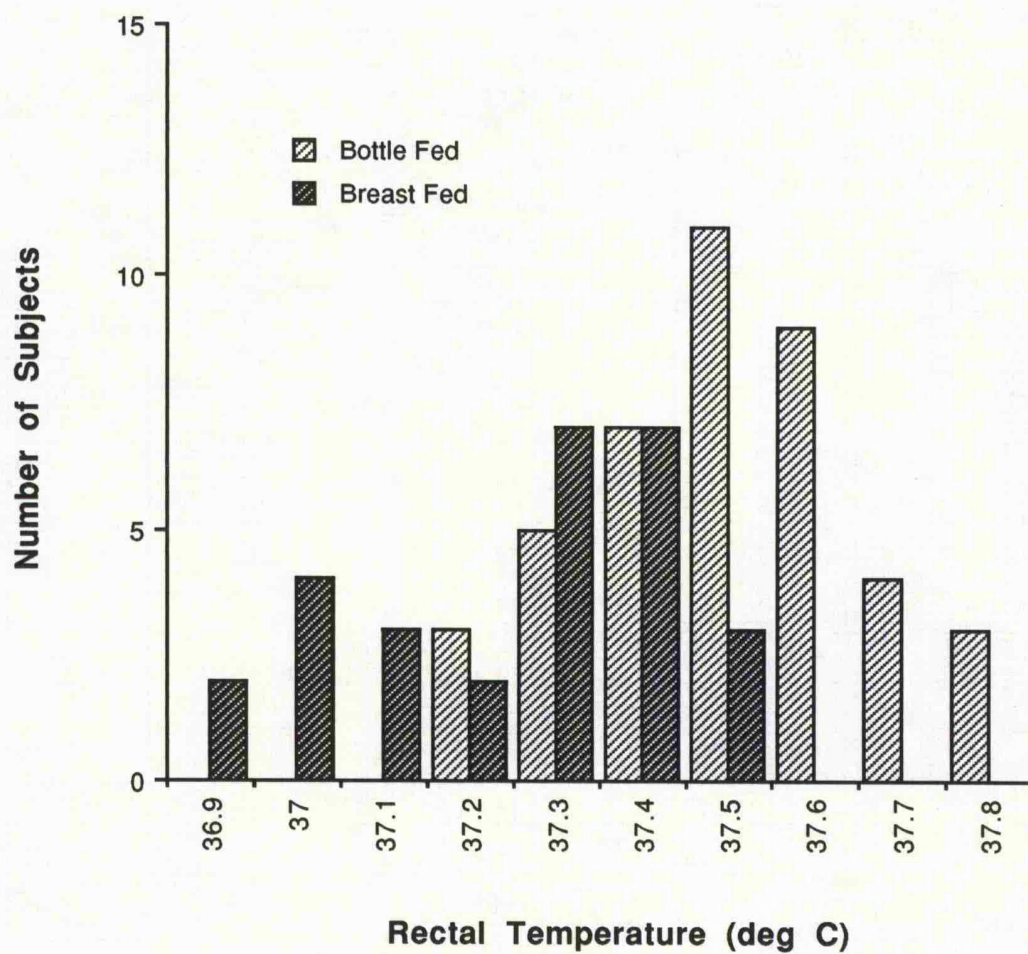
Figure 5.9.1 The distribution of rectal temperature during a period of
daytime activity, in breast and bottle fed babies.

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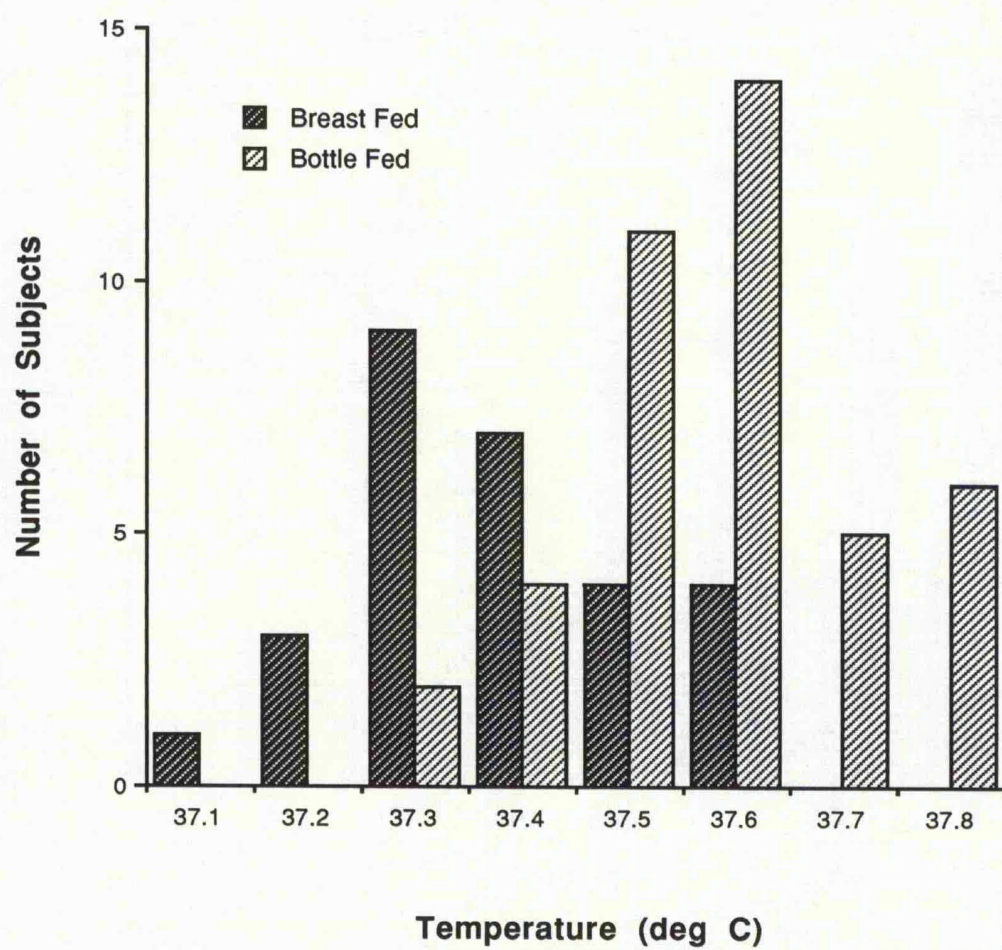
Figure 5.9.2. The distribution of maximum rectal temperature in breast and bottle fed babies during daytime activity.
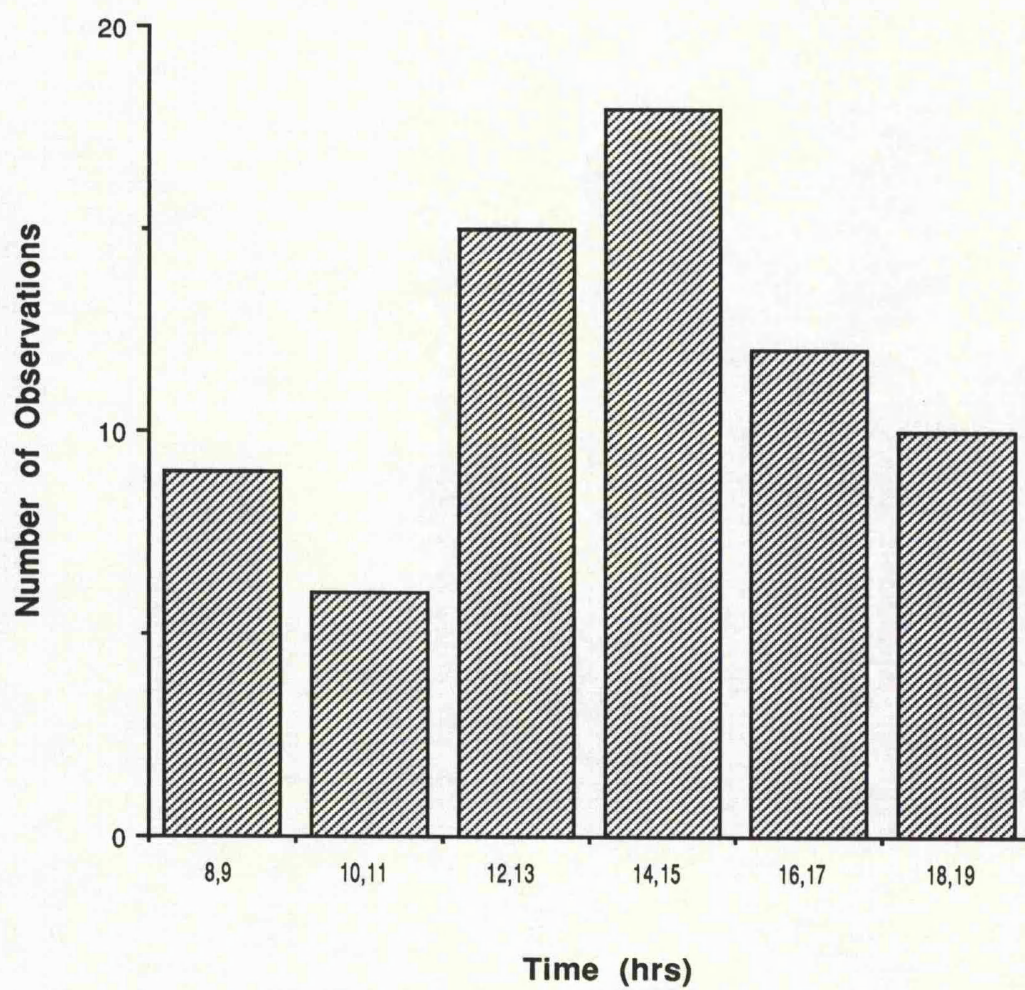
Fig 5.9.3 Distribution to show the time of day in which the rectal temperature was at its highest.

5.10 SUMMARY : RESULTS CHAPTER 5:

OBSERVATIONS OF PARENTAL BEHAVIOUR AND PHYSIOLOGICAL MEASUREMENTS OF RECTAL TEMPERATURE OF BABIES AGED 3 to 4 MONTHS DURING THE DAY.

DAY TIME SLEEP

1. Rectal temperature fell shortly after bedtime to a level 0.3°C–0.5°C lower, a much smaller fall than found with night time sleep, with a temperature rise occurring before waking.

2. The pattern of rectal temperature with sleep was similar between all subjects despite the wide range of parental behaviours and a wide range in individual babies sleep requirements.

3. Parental choices of clothing, bedding and room temperatures revealed greater variation between parents in the day, than at night.

4. There was no difference in body temperature patterns between babies sleeping in the warmest, and coolest environments during the day.

* There was no evidence that different thermal environments affect deep body temperature during daytime sleeps.

DAY TIME FEEDS

1. Feeds elevated rectal temperature when babies remained active, but in babies who slept after a feed, temperature fell.

2. Bottle fed babies had significantly greater rises in temperature associated with a feed than breast fed babies.

* The ability of feeds to elevate rectal temperature is inhibited by sleep. Parental feeding choices influence physiological responses.

DAY TIME ACTIVITY PERIODS

1. Periods of play and wakeful activity, elevated rectal temperature to its highest limits throughout the baby's day and night.

2. Bottle fed babies exhibited higher rectal temperatures than breast fed.

* Parental choices of feeding affected temperature limits in an active baby. Bottle fed babies had higher temperatures than breast fed babies when awake.

CHAPTER SIX

PERIPHERAL BODY TEMPERATURE

6.1 THE ABDOMINAL TEMPERATURE

The abdominal probe was used on 40 subjects. Analysis was completed on 23 subjects, as reports of disturbance to clothing during the night, loss of the probe or technical failures, flawed the remaining data sets. These subjects slept for 8 hours undisturbed with a minimum of 6 tog units of bedding. Abdominal temperatures recorded at minute intervals were taken for analysis at half hourly averages.

Abdominal temperature rose when the baby was placed down to sleep (Fig 6.1.1). Half an hour prior to bedtime the mean (SEM) abdominal temperature was 35.25°C (0.21), with a range of 33°C to 37.05°C, with a normal distribution of data (Fig 6.1.2). Half an hour after bedtime the mean (SEM) abdominal temperature was 35.86°C (0.14) with a range 36.75°C to 34°C. One hour into the sleep the abdominal temperature reached its highest level of mean (SEM) 35.99°C (0.12) with a range of 34°C to 36.85°C the distribution of which shows the data more tightly packed around 36°C (Fig 6.1.3). For the remainder of the sleep the temperature remained just below 36°C, being a mean (SEM) 35.99°C (0.11) 7 hours after bedtime. The relationship between the abdominal probe and the rectal probe appears to be opposite. At the onset of sleep, rectal temperature falls, and abdominal temperature rises.

The abdominal probe was expected to reveal changes in skin temperature reflecting heat flow through the body. Estimation of heat loss from the resting baby has been investigated with no clear formula able to relate all the variables involved (Kerslake D, 1991). Relating one of these formulas to produce an understanding of heat loss could not be achieved in this study (see Appendix 10).
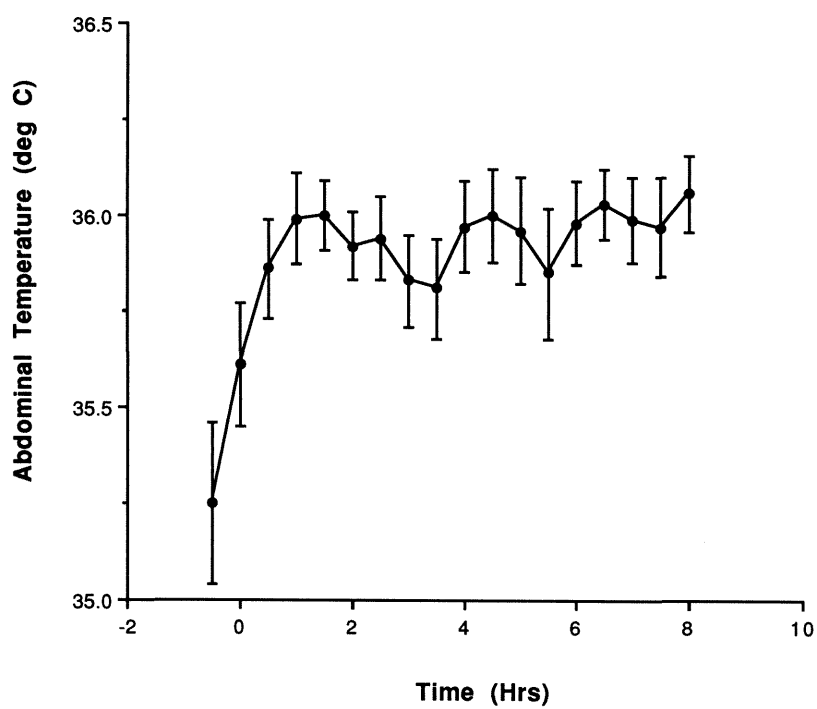
Figure 6.1.1 The mean (±SEM) abdominal temperatures of 20 subjects during an eight hour night sleep.
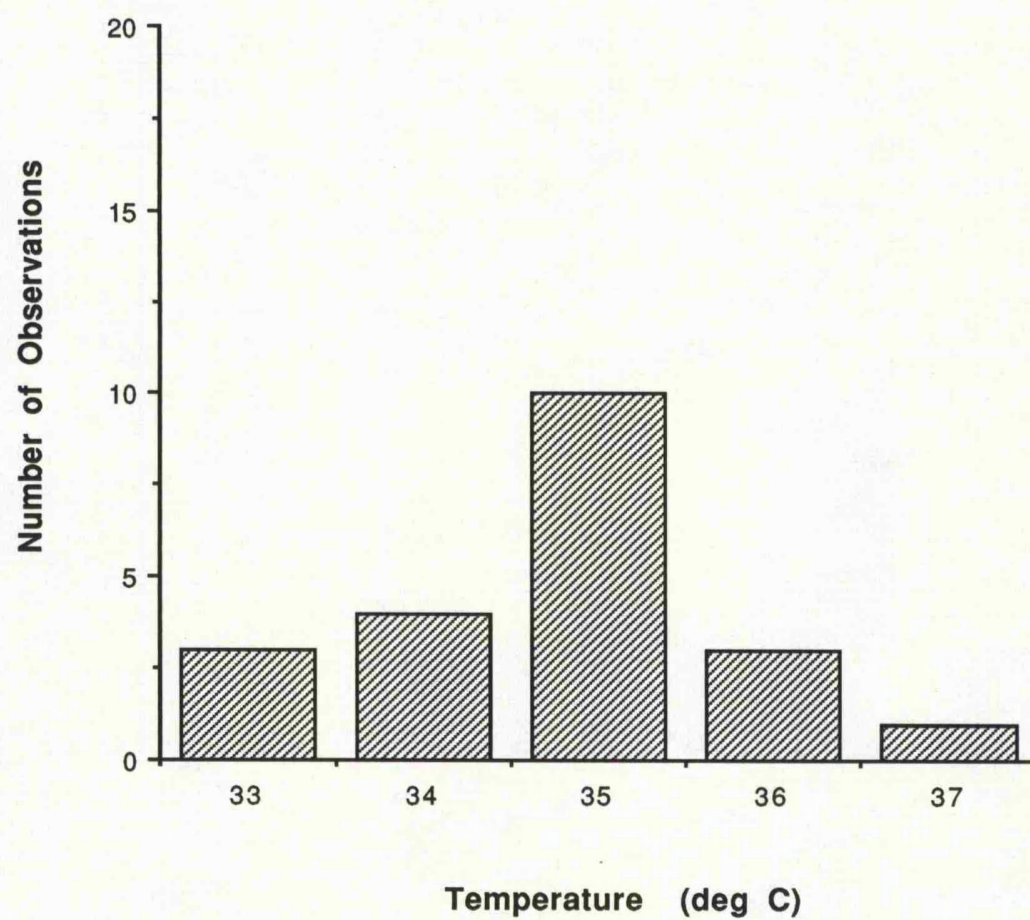
Figure 6.1.2 The distribution of abdominal temperature, from 20 subjects, half an hour before bedtime.
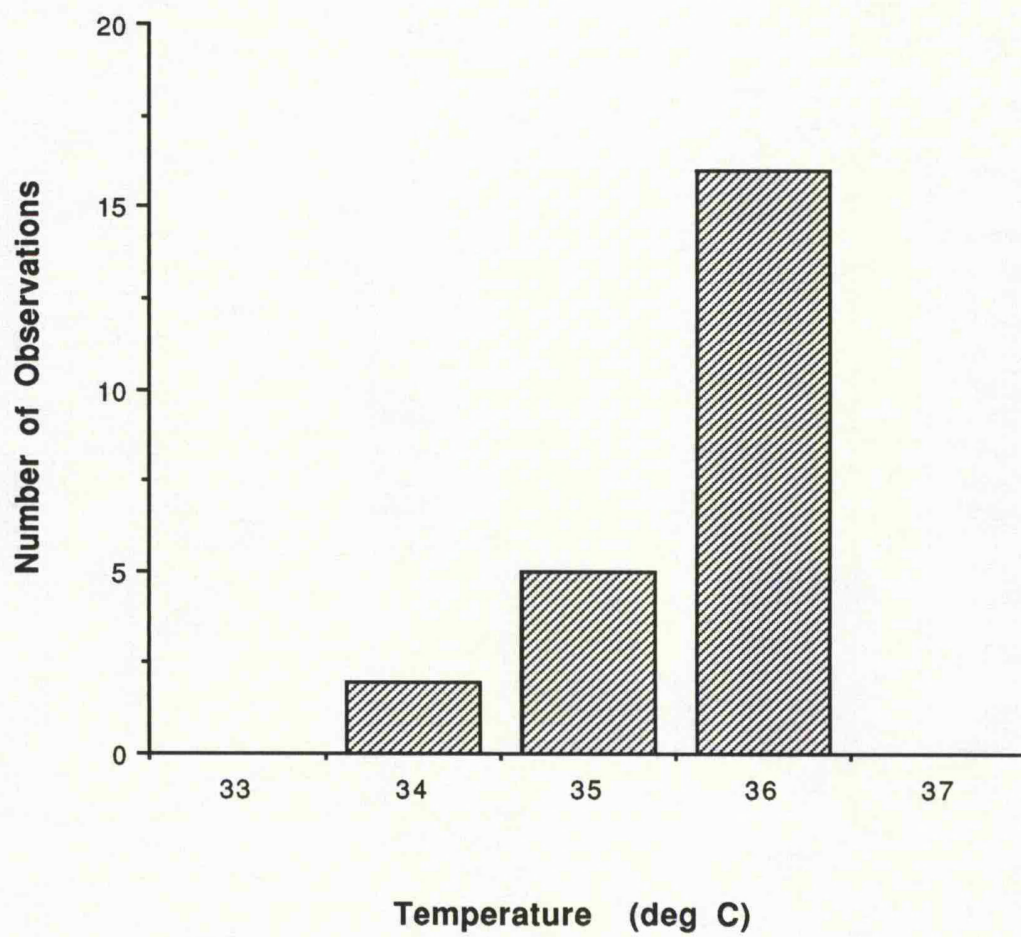
Figure 6.1.3   The distribution of abdominal temperature, of 20 subjects, one hour after bedtime.

6.2 THE HEAD TEMPERATURE

The head probe was used on 38 subjects but often became detached from the baby especially when awake. There were some reports of the probe becoming detached during sleeps when the parents were not continually observing their infant. All raw data on the computer print outs were examined with parental diary reports for evidence of detachment, before being used for analysis.

Only 14 data sets were found to be of value for night time sleep. Head probe readings on night sleeps of 24 subjects, from another data set monitored in the same way, were analysed to give a broader set of results for analysis.

The averaged data at half hourly intervals were examined producing a mean (SEM) head temperature at bedtime of 31.8°C (0.36) and at 4 hours into the night 30.9°C (0.31). Prior to sleep the mean (SEM) head temperature was 32.6°C (0.31) and appears to fall with onset of sleep remaining at a level approximately 1°C (0.9°C) less throughout the night (see Fig 6.2.1).

The data sets of babies in warm thermal environments were compared to those in cool environments by using the thermal score of tog total and room minimum temperature. Those in the cool environments (thermal score < 27) totalled 21, and warm (thermal score >32) totalled 12. There were no significant differences between the two groups (see Fig 6.2.2).
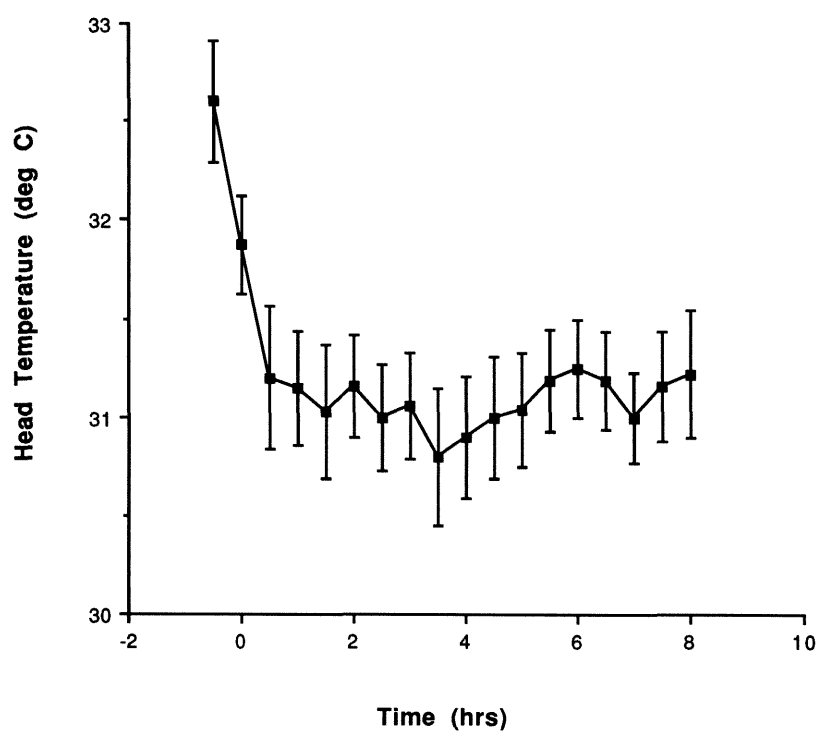
Figure 6.2.1 The mean (±SEM) of skin temperature taken from the head, during night sleep.
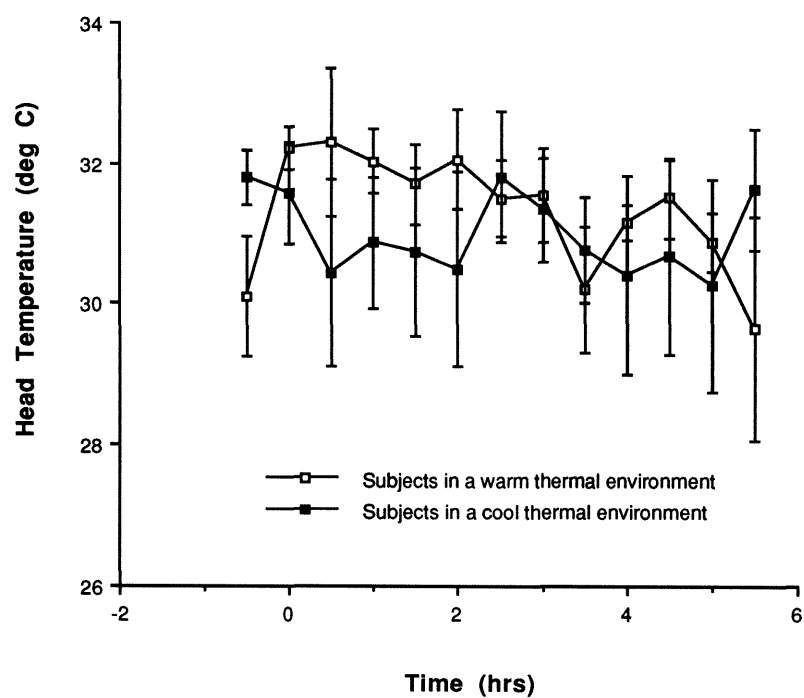
Figure 6.2.2 Comparison of the head temperatures of subjects in different thermal environments, during night time sleep.

6.3   THE LEG TEMPERATURE

There were 35 subjects who were not monitored with the head probe but the parents
accepted the leg probe. There were no reports of probes becoming detached and this
site was popular with the parents. A data set of 35 leg probes at half hourly intervals
associated with night sleep were tabulated. The mean (SEM) temperature at bedtime
was 32.21°C (0.32) and 4 hours into the sleep the mean temperature was 34.45°C
(0.27). The pattern seems to be the reverse of that found with the head probe in that
the leg temperature increases after bedtime by about 2°C (2.24°C) (see Fig 6.3.1).

A comparison of babies with differing togs of bedding were analysed. Those sleeping
with togs of bedding < 6 tog units were compared with those >12 tog units, values
found to be the extremes of parental choice. There were 12 in the cool group and 11
in the warm group. It can be seen that (see Fig 6.3.2) those with more togs reach
higher ranges than those with less togs but there is no significant differences.

6.4   COMPARISON OF PERIPHERAL TEMPERATURES

Subject 38

Subject 38 was monitored under free choice conditions with both the head and leg
probe. In Figure 6.4.1, the relationship between the peripheral probes and deep body
temperature can be seen in the night time recording under free choice conditions.
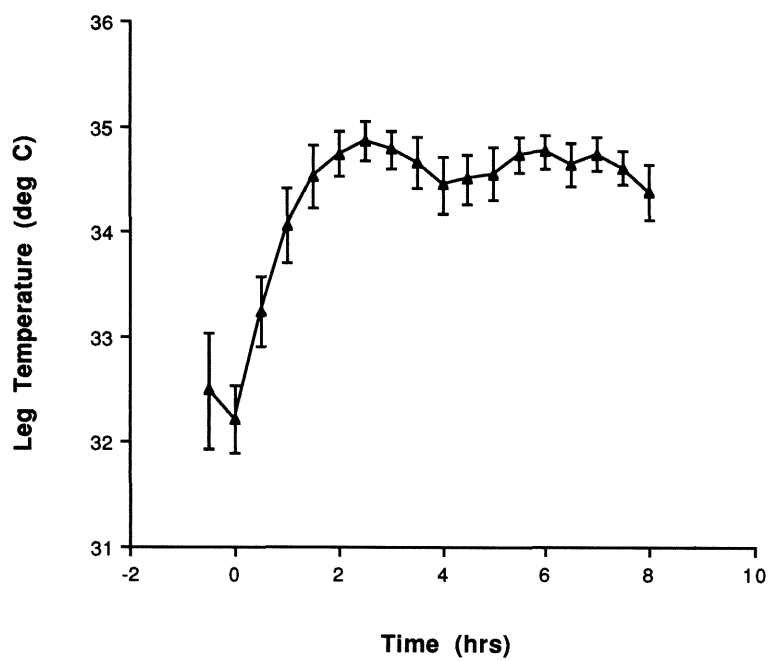
Figure 6.3.1   The mean (±SEM) leg temperatures of 35 subjects during night time sleep.
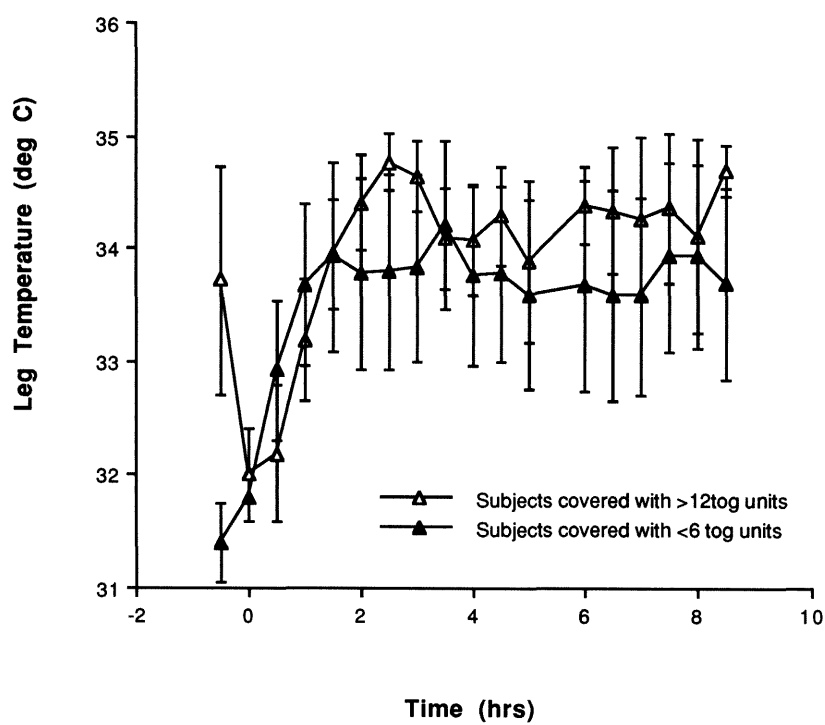
Figure 6.3.2 Comparison of leg temperatures during night sleep, between babies experiencing differing amounts of bedding.
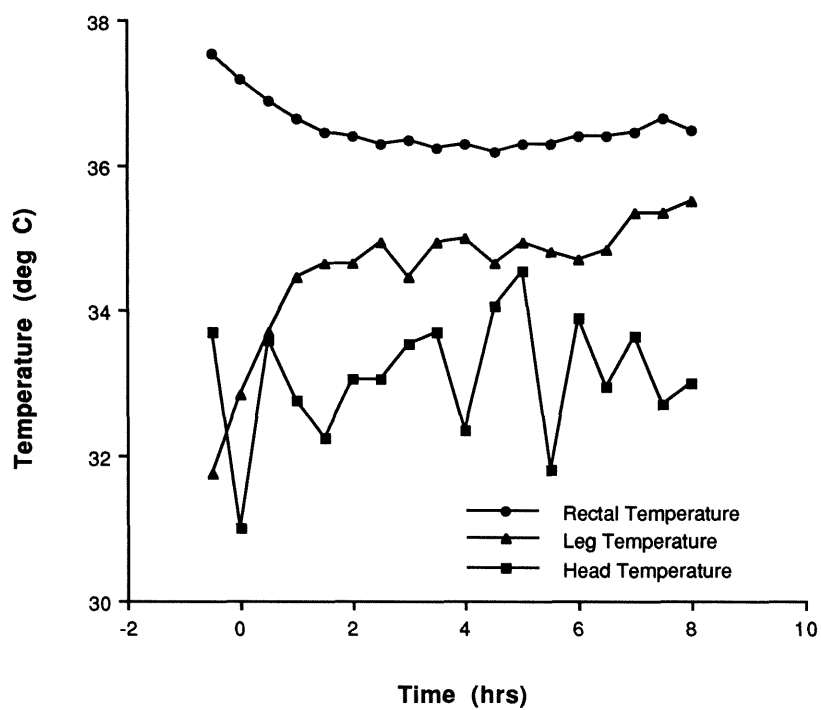
Figure 6.4.1 Comparison of the peripheral body temperature measurements, on one subject during a night time sleep.

6.5 SUMMARY:RESULTS CHAPTER 6:

PHYSIOLOGICAL MEASUREMENTS FROM OTHER BODY THERMISTOR PROBES.

1. The abdominal probe revealed a rise in temperature associated with the onset of sleep. It proved to be a poor indicator of the measure of thermal resistance from the core to the skin.

2. Peripheral skin temperature measured on the forehead showed a lowering of temperature with sleep. There were no differences in temperature fall between babies in warmer or cooler environments.

3. Peripheral skin temperature measured at the leg site revealed a rise in temperature with sleep. There were no differences in temperature rise between babies covered with light bedding opposed to heavy bedding.

* Differing thermal environments did not affect measures of body temperature at the skin surface.

CHAPTER SEVEN.
THE DEEP BODY TEMPERATURE IN ALTERED THERMAL ENVIRONMENTS.
Constrained Choice Conditions.

7.1   NIGHT TIME SLEEP

In order to investigate the stability of thermoregulation in babies 3 to 4 months of age, wherever possible, changes to the normal thermal environment of the baby were made. There were two methods of change; First, an alteration in the total tog value, second a change in the ambient temperature. These changes required parental consent, and many parents were reluctant to lose control of their baby's care.

Of the 70 subjects who participated in this study, 49 babies were monitored under "constrained choice" conditions. The change in the thermal environment for each baby depended upon the parent's choice of clothing, wrapping and room temperature under "free choice conditions". Each individual baby acted as a control for itself, with the overall findings from the original 70 subjects providing the average range of conditions within which change was ethically possible.

As previously identified some parents chose lower ambient temperatures than others. Ambient temperatures under free choice conditions identified a range of minimum temperatures, from 12°C to 18°C, where the mean minimum ambient temperature was 17.74°C. The total tog value identified an average tog for clothing of 4.13 units, with a range from 2 to 7.5 tog units, the average bedding was 9.37 tog units, with a range of 3 to 18 tog units.

Homes with ambient temperatures below the mean and insulation of average or less tog units, were warmed with the use of a thermostatically controlled heater set to maintain an ambient temperature at 19°C. Where the ambient temperature was average but the total togs were low, the tog value was increased by adding 2.0 tog blankets. Occasionally, in cold weather, home conditions made it possible to both increase the ambient temperature and add extra togs. There were a small group (9 in total) who although willing to help in this part of the study wished to contain some control over the events. They took part when the outside weather became unusually milder than at their previous monitoring to naturally produce warmer home conditions. Several consented to increase the ambient temperature by keeping their central

heating on throughout the night thermostatically controlled to 19°C, see table 7.1.A.

TABLE 7.1.A– NUMBER OF SUBJECTS IN ALTERED THERMAL CONDITIONS

CONDITION	NUMBER OF SUBJECTS
HEATER ONLY	18(45%)
BLANKETS ONLY	14(35%)
HEATER & BLANKETS	11(27.5%)
OTHER	6(15%)

On examining the results for each baby the degree of effectiveness was related to how much change had actually occurred. In some instances, despite the heater working well, the degree of change in the ambient temperature was less than anticipated. Also for several of the babies who experienced an increase in tog values, this effect was cancelled out by an unexpected decrease in ambient temperature. The mean (SEM) thermal scores (tog total + minimum ambient temperature), for the 40 subjects **under free choice conditions was 29.62** (0.63) and, directly under the researcher's control **under constrained choice conditions was 32.52** (0.5), a significant difference (paired t test t= 6.23 df=39 p<0.0005).

In order to assess any change in thermoregulation during the night for each subject a score was achieved to establish the cumulative affect of changes to the thermal environment. The number of extra tog units on the baby were added to the number of degrees difference in minimum ambient temperature during the night's sleep. These scores could be used to establish those subjects who were exposed to a real difference in thermal environment, their range was 0–8; Subjects achieving 4 and above were felt to have been successfully monitored under "constrained choice conditions", giving a final total of 24 subjects. The mean (SEM) thermal scores for these 24 subjects **under free choice was 29.2 (0.89)**, and **under constrained choice 33.49 (0.7)**, a significant difference (Paired t test t= 4.34 df=23 p<0.025). This placed a baby who had previously been in the average thermal score bracket of 27–32, into the warm thermal score group range >32.

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The First 8 Hours Sleep

Rectal temperature averages, at half hourly intervals, were recorded for all 49 subjects monitored under constrained choice, and synchronised to bedtime.

Data from the 24 subjects experiencing the greatest change was compared to the remaining subjects monitored under "constrained choice conditions" and the 70 data sets for all subjects under "free choice conditions" see Figure 7.1.1. Subjects who slept under different thermal conditions enter the normal pattern of deep body temperature, there were no significant differences between subjects monitored in free choice and those in constrained choice. The 24 subjects experiencing the greatest change were compared to their earlier nights monitorings under cooler free choice conditions. No significant differences in rectal temperature patterns were found. At bedtime the mean (SEM) rectal temperature of free choice was 37.3°C (0.02), and constrained choice 36.96°C (0.08). After four hours the rectal temperature free choice had fallen to a mean (SEM) 36.28°C (0.028), and constrained choice a level of 36.46°C (0.06).

The Last 4 Hours Sleep

Data from all subjects monitored under "constrained choice conditions" were tabulated at half hourly averages synchronised to waking time. Again comparisons were made between subjects under "free choice" and "constrained choice" (see Figure 7.1.2). Subjects who experienced a change from their usual thermal conditions, warmed earlier. The mean (SEM) waking temperature of subjects under "free choice" conditions was 36.93°C (0.03°C) and under "constrained choice" 37.02°C (0.05°C). The subjects who experienced the most change had a mean (SEM) waking temperature of 37.08°C (0.06°C). An hour before waking the mean (SEM) temperature under "free choice" was 36.69°C (0.04°C) and under "constrained choice" was 36.82°C (0.05°C), with subjects who experienced the warmest conditions having a mean (SEM) 36.82°C (0.07°C). These differences were not statistically significant.

37.5 —

Free choice conditions

Constrained choice conditions

Free choice warm conditions

37.0 —

36.5 —

36.0 —

Temperature (deg C)

-2   0   2   4   6   8   10

Time (hrs)
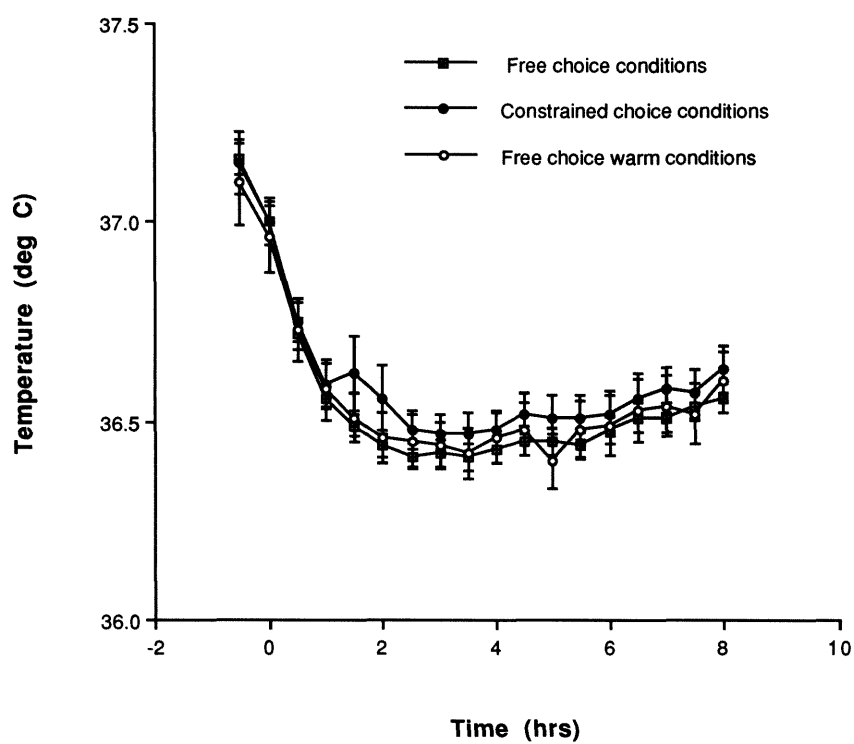
Figure 7.1.1 The mean (±SEM) temperature patterns during night time sleep of babies monitored in warm conditions chosen by their parents, warm conditions chosen by the experimenter, and the average thermal environment.
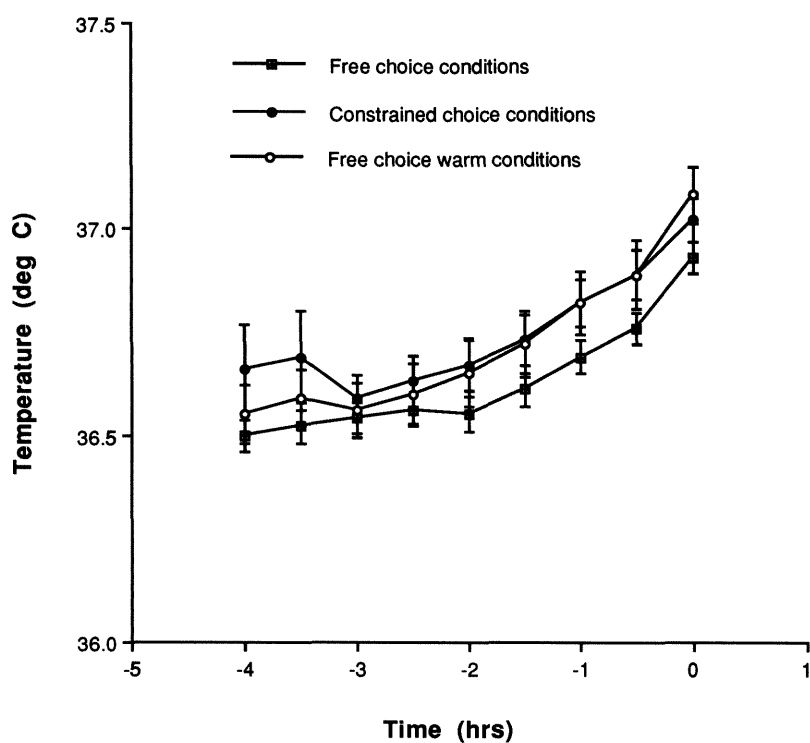
Figure 7.1.2 The mean (±SEM) temperature patterns prior to waking in
babies in warm conditions chosen by their parents, warm conditions
chosen by the experimenter, and the average thermal environment.

7.2 DAYTIME SLEEP

There were 17 subjects who participated with a daytime sleep under different thermal conditions to those chosen by the parents. Several parents were willing but their babies failed to co-operate and sleep on the day chosen for monitoring.

As with night time sleep the degree of change depended on findings from the daytime monitoring under free choice conditions. Again the method of change was to add extra tog units (blankets of 2.0 tog units) or increase the ambient temperature. In many cases homes with heat, such as central heating, used this rarely during the day with many parents willing to use their heat sources for the constrained monitoring rather than accept the heater, see table 7.2.B.

TABLE 7.2.B– THE NUMBER OF SUBJECTS IN ALTERED THERMAL CONDITIONS DURING DAYTIME SLEEP.

CONDITION	NUMBER OF SUBJECTS
HEAT ONLY	6(35.3%)
EXTRA TOG ONLY	7(41.2%)
HEATER & EXTRA TOG	4(23.5%)

The mean (SEM) thermal scores under free choice day recordings were 28.2(0.75), and under constrained choice the mean (SEM) were 32.8(0.7), (paired t test t=7.23 df= 16 p<0.0005). The degree of success with this monitoring again varied between subjects, with an increase in the differences of thermal scores ranging from 1.75 to 9.67 with a mean of 4.62. As for daytime sleep under free choice rectal temperature averages were taken at 15 minute intervals prior to bedtime until 90 minutes into the sleep. The findings were compared to daytime sleeps under free choice conditions, there were no significant differences (Fig 7.1.3).
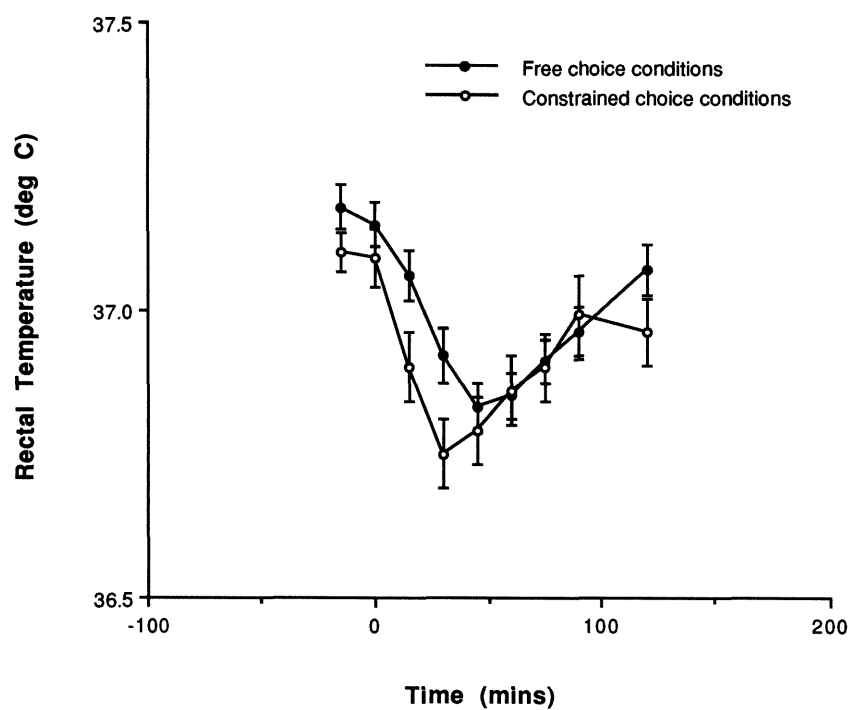
Figure 7.1.3 The mean (±SEM) temperature patterns during day time sleeps.
A comparison of individual subjects monitored under two different types
of thermal environments.

7.3 SUMMARY: RESULTS CHAPTER 7:

PHYSIOLOGICAL MEASUREMENTS OF RECTAL TEMPERATURE DURING NIGHT AND DAYTIME SLEEPS UNDER "CONSTRAINED CHOICE CONDITIONS".

1. Parents were reluctant to allow the researcher to change their choice of sleeping environment for their baby.

2. Changed thermal environments during day and night time sleeps did not affect the temperature patterns of each individual baby.

* The response of deep body temperature to sleep at 3 to 4 months of age is not affected by changes, within limits of acceptable behaviour, in the thermal environment.

CHAPTER EIGHT
OBSERVATIONS OF PARENTAL FEEDING CHOICES FROM BIRTH TO 3 MONTHS.

8.1 INTRODUCTION

Parental behaviour was observed by the researcher at birth and some weeks later at monitoring, with parents keeping accurate prospective diaries of child care. This data provided information concerning different patterns of child care, which could be linked with the thermoregulation data. In order to examine these factors in greater detail it was felt that the sample of 70 babies monitored for the objectives in this project would be too small and a larger population would be required.

During the period between December 1988 and August 1990 monitoring of babies aged 3 to 4 months took place within a team of research health visitors individually collecting a source of information common to the group, although the temperature recordings were for clearly defined different projects. This data base of information contained details of the way in which each baby had been fed from birth to the point of contact for monitoring at 3 to 4 months and other factors such as illness, immunisation history, and social details concerning the parents, such as occupational class and age. This group provided information on 209 babies (including the 70 subjects reported in this study) which was felt to be a large enough sample for analysis.

The data base had not been designed to contain every detail recorded by parents in their daily diaries, but feeding behaviour was a constant factor observed by each researcher after birth and during the monitoring period at 3 to 4 months.

8.2 AT BIRTH

The data extracted included first, factors concerning the baby's birth weight, gestation, sex, and second factors concerning the parents such as maternal age, social class, feeding choice and type of delivery.

Of the 209 subjects whose data were analysed from the pooled data base 143 (65%)

were breast fed at birth, and 66 (32%) were bottle fed. There were 115 male infants and 94 female, of whom 75 males were breast fed, 40 bottle fed, 68 females breast fed, and 26 bottle fed. There was a significant difference suggesting that females were more likely to be breast fed (Chi^2=3.9 df=1 p<0.05). Equal proportions of both breast and bottle fed infants were spontaneous vaginal deliveries (66%), with birth weights reflecting gestational age ranges.

Social class data were analysed according to the Registrar General's classification on male occupation and grouped into non-manual (classes 1-3) and manual (classes 4-7). A large proportion of non-manual (total=75 35.8%) and manual (total=65 31.1%) parents chose to breast feed at birth (see table 8.2.A). When examining the choice of breast feeding against bottle feeding, non-manual parents chose breast feeding significantly more often than bottle feeding (Chi^2=7.45 df=2 p<0.01).

There were no significant differences between the type of delivery, with equal proportions of normal deliveries in each group. There were no significant differences in birth weights.

TABLE 8.2.A– COMPARISON OF DATA BETWEEN BREAST AND BOTTLE FED BABIES AT BIRTH

Feeding	Birth Weight	Gestation (to 40wks)	Sex	Social Class nm/m
BREAST	3375g m=3355g f=3396g	39.84 range (30–42)	m = 75 f = 68	nm= 75 m = 65
BOTTLE	3206g m=3216g f=3192g	39.5 range (27–42)	m = 40 f = 26	nm= 22 m = 43

8.3 AT MONITORING

Data from the pooled data base for these 209 babies were then extracted for the age period of 3 to 4 months. The first recording from age 12 weeks was used to prevent large differences of age, the majority of data placed the infants in their third month. By 12 weeks of age some parental decisions made at birth on infant feeding had changed. Data extracted for analysis included factors concerning the baby such as age, sex, weight, history of upper respiratory tract infections since birth, length of non-disturbed night time sleep, and parental factors such as maternal age, social class, feeding practice, and choice of room temperature and tog units of insulation.

The total number of babies who produced useful data up to and beyond 12 weeks was 178. The missing babies included 15 who were not monitored at 12 weeks, 15 who became mixed feeders and one baby who had been bottle fed at birth and changed to breast feeding. They formed three main groups; First those who had continued to totally breast feed (60, 33.7%), second those who had breast fed at birth but changed to bottle feeding (65, 36.5%), and third those who had bottle fed at birth and continued to bottle feed (53, 29.7%).

The mean (SEM) age of data collection on babies who were consistently breast fed was 14.2 (0.45), where the range was from 12 to 20 weeks. The mean (SEM) age of data collection for babies who had changed from breast to bottle feeding was 15.95 (0.56) weeks, where the range was from 12 to 20 weeks. The mean (SEM) age of data extraction for bottle fed infants was 14.8 (0.54) where the range was from 12 to 19 weeks gestation. The only significant difference between these ages was that babies who changed from breast to bottle feeding were older than the breast fed babies at the point of data collection (unpaired t test t=1.7 df=123 p<0.05).

There were significant differences between these groups in age of mother (Chi^2=8.72 df=2 p<0.02), social class (Chi^2=18.18 df=2 p<0.01), number of children (Chi^2=10.15 df=2 p<0.01), and the incidence of upper respiratory tract infections (Chi^2=11.79 df=2 p<0.005). The interactions of these factors between the groups were further analysed.

Comparison of Mothers Who Continued to Breast Feed With Those Who Changed to Bottle Feeding.

a) Mothers who chose to breast feed were significantly older than those who changed to bottle feed (unpaired t test t=2.04 df=123 p<0.025), their mean (SEM) age was 30.2 (0.54) with an age range 23 to 39 years, and those who changed to bottle feeding had a mean (SEM) age of 28.4 years (0.66) with an age range of 18 to 41 years (Chi^2=4.87 df=1 p<0.05).

b) Mothers who chose to breast feed were more likely to come from the non-manual classes (Chi^2=4.35 df=1 p<0.05). There were 41 non-manual and 19 manual, and for mothers who changed to bottle feed 26 were non-manual and 39 manual, see table 8.3.A.

c) Mothers who chose to breast feed were more likely to have one child (Chi^2=4.03 df=1 p<0.05). The babies were more likely to be females and were more often first children. Those mothers who changed to bottle feeding were more likely to have several children, see table 8.3.A.

TABLE 8.3.A– COMPARISON BETWEEN SOCIAL FACTORS AND FEEDING CHOICE AT 3 TO 4 MONTHS OF AGE

FEED TYPE	DELIVERY nsd/other	MATERNAL AGE <25 >25	SOCIAL CLASS nm/ m	SEX m f	CHILDREN 1 2+
BREAST	48 12	7 52	41 19	23 37	33 27
CHANGE	47 18	16 49	26 39	38 27	29 36
BOTTLE	44 9	18 34	16 37	33 20	19 34

d) Breast fed babies were less likely, than those who were changed to bottle feed, to have experienced an upper respiratory tract illness since birth (Chi^2=4.35 df=1 p<0.05)

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(see table 8.3.A).

Comparison Between Consistent Bottle Feeders and Consistent Breast Feeders

A) The parents who continued to bottle feed their babies from birth were significantly younger than those who breast fed (unpaired t test t= 3.78 df=111 p<0.005), their average age was 26.7 years (SEM 0.67) with an age range 17 to 39 years, having more mothers under 25 years than any other group (Chi^2=4.5 df=1 p< 0.05).

B) They were significantly more likely to be from the manual social classes, non-manual 16, manual 37 (table 5.8.A) (Chi^2=4.65 DF=1 p<0.05 .

C) This group were mostly male unlike the breast fed babies who were mostly female (Chi^2=4.21 df=1 p<0.05).

D) These babies had a high reporting of upper respiratory tract infections, when compared to breast fed babies, but were low when compared to babies who were changed from breast to bottle feeding (Chi^2= 3.99 df=1 p<0.05: Chi^2=11.79 df=2 p<0.001).

Other Findings

The weight gain of breast fed infants compared favourably with other groups with a mean (SEM) weekly weight gain of 194 grams (5.7), with breast fed male infants 207 grams (6.1) and females 187 (5.3) grams. The changers had a mean (SEM) weekly growth of 187 (6.5) grams, with a weekly mean (SEM) weight gain for females of 163 (4.9) grams and males 202 (7.0) grams, this was the lowest weight gain for any group especially females. Bottle fed infants growth reflected by mean (SEM) weekly weight gain was 203 (4.3) grams, the highest of all groups for both male and female infants, female 191 (4.1) grams male 206 (4.7) grams (see Table 8.3.B and Figure 8.3.1). Babies who were consistently bottle fed were more likely to have gained more weight than those who changed from breast to bottle feeding (Unpaired t test t= 1.89 df=116 p<0.05). There were no other significant differences between the groups.

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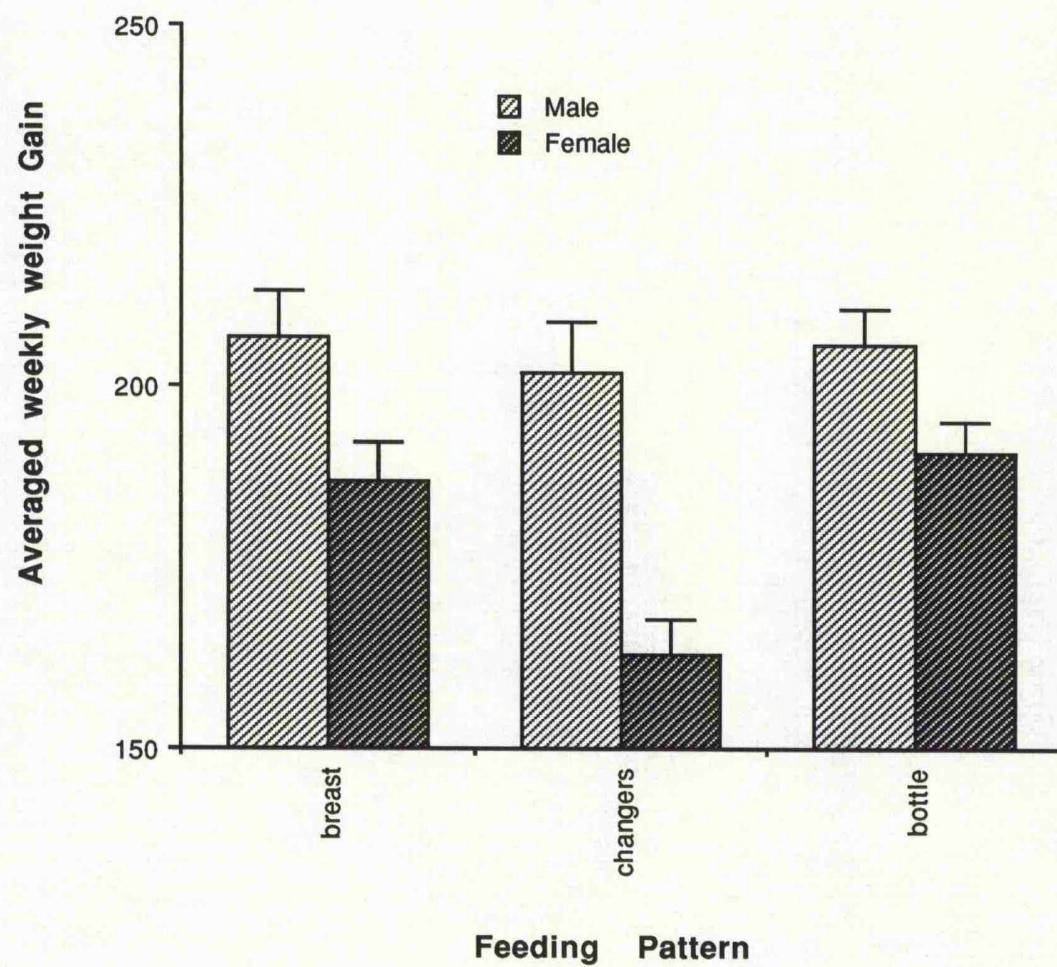
Figure 8.3.1 A comparison of the mean (±SEM) weekly weight gain
from birth to age 3 to 4 months in babies with different feeding patterns.

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There was very little difference in deliveries, although mothers who changed from breast to bottle feeding had a higher proportion of abnormal deliveries than any other group but this was not a significant finding (see table 8.3.A).

TABLE 8.3.B– COMPARISON OF GROWTH AND MORBIDITY IN BABIES WITH DIFFERENT FEEDING BEHAVIOURS AT 3 TO 4 MONTHS OF AGE.

FEEDING GROUP	MORBIDITY		WEEKLY WEIGHT GAIN	
	NOT ILL	ILL	MALE	FEMALE
BREAST FED	25	12	207(6.1)g	187(5.3)g
CHANGERS	13	29	202(7.0)g	163(4.9)g
BOTTLE FED	18	12	206(4.7)g	191(4.1)g

The length of longest night time sleeps varied between the three groups. Breast fed babies disturbed their parents under 8 hours, mean (SEM) of 7.7 hours (0.26) the shortest sleep duration of any group. Babies who had been changed from breast to bottle feeding averaged over 8 hours of nights sleep before disturbing their parents, the mean (SEM) 8.5 (0.32). Bottle fed babies slept for over 9 hours at night before disturbing their parents mean (SEM) sleep duration of 9.1 (0.3) hours (see Fig 8.3.2).

Choice Of Thermal Environment

Examining parents choices of thermal care for their infants according to their choice of feeding from birth to 3 to 4 months, did not reveal any significant patterns.

The mean thermal score for breast feeders being 29.08 the lowest of all three groups, from a mean (SEM) tog total of 11.6 (0.52) and mean (SEM) room minimum temperature of 17.48°C (0.38). The thermal score for changers was 30.1, slightly higher than of the other groups, comprising a mean (SEM) tog total of 12.5 togs (0.52) and a mean (SEM) minimum ambient temperature of 17.6°C (0.33). The thermal score of bottle feeders was 29.3, with parental choice of thermal environment being
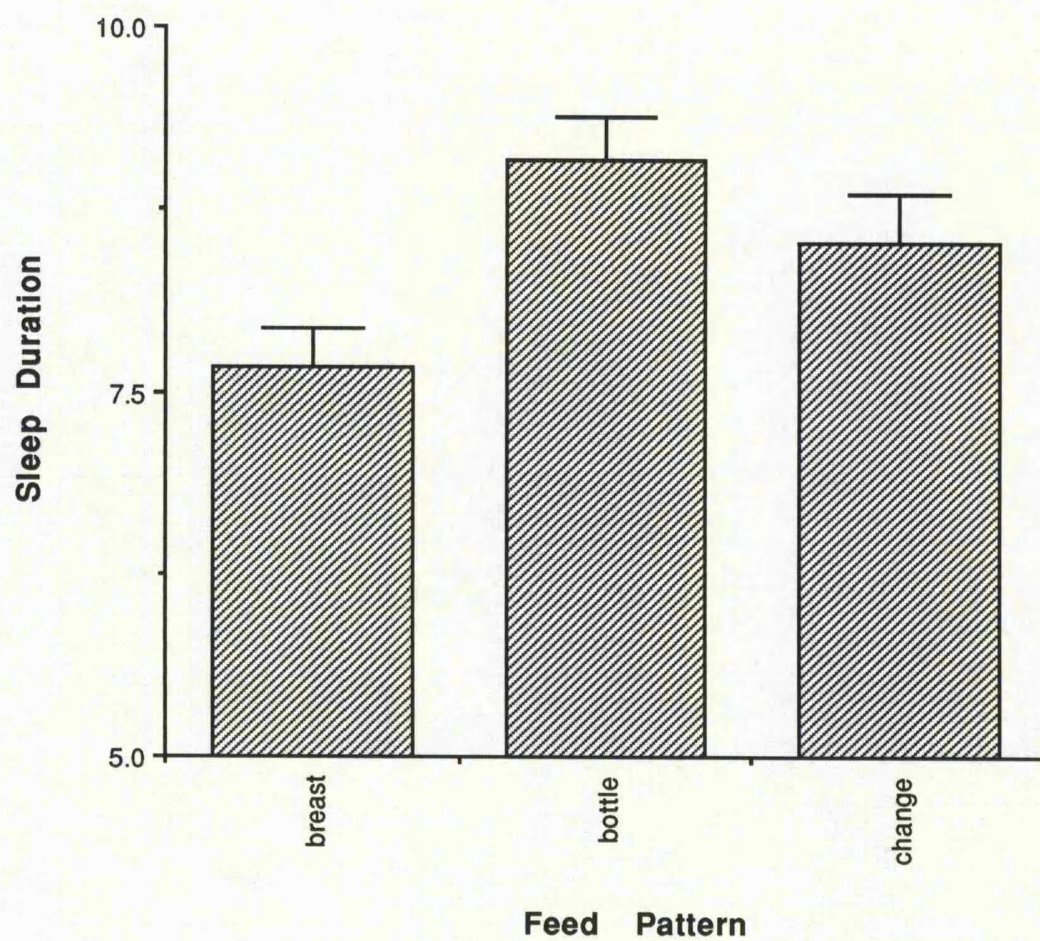
Figure 8.3.2 Comparison of the mean (±SEM) between breast feeders bottle feeders and those who changed from breast to bottle feeding, for duration of night time sleep at 3 to 4 months of age,

remarkably similar to the other groups, where the mean (SEM) tog total was 11.4 (0.62) and mean (SEM) minimum room temperature was 17.9 (0.43) see table 8.3.C.

TABLE 8.3.C- COMPARISON OF MEAN(SEM) THERMAL ENVIRONMENTS OF BABIES EXPERIENCING DIFFERENT METHODS OF FEEDING FROM BIRTH TO 3 to 4 MONTHS OF AGE.

TYPE	TOG TOTAL	MINIMUN AMBIENT TEMP	MAXIMUM AMBIENT TEMP
BREAST	11.6 (0.52)	17.48°C (0.38)	20.8°C (0.49)
CHANGERS	12.5 (0.52)	17.6°C (0.33)	20.7°C (0.59)
BOTTLE	11.4 (0.62)	17.90°C (0.43)	21.4°C (0.54)

TABLE 8.3.D- COMPARISON OF THE THERMAL ENVIRONMENTS CHOSEN BEFORE AND AFTER ILLNESS IN BABIES WHO EXPERIENCED DIFFERENT FEEDING METHODS FROM BIRTH TO 3-4 MONTHS OF AGE.

FEEDING TYPE	TOG TOTAL NOT ILL	ILL	ROOM MIN TEMP NOT ILL	ILL
BREAST FED	12.0(O.8)	11.9(I.3)	17.4(0.5)	16.0(I.2)
CHANGERS	14.6(1.0)	12.8(0.96)	16.6(0.7)	17.5(0.5)
BOTTLE FED	13.3(1.2)	11.8(0.8)	16.2(1.2)	17.8(0.8)

Although there were no significant differences in thermal environment between the three feeding groups of babies at 3 to 4 months, parents' decisions about the use of clothing, wrapping and room temperature appear to change with the experience of upper respiratory tract infection. The thermal score of breast fed babies after respiratory infection was 27.9 and before 29.4, indicating a small reduction after the illness. For babies who became bottle feeders, a thermal score of 31.3 prior to illness and 30.2 after illness, a small reduction. Parents of bottle fed babies do not change their behaviour with a thermal score of 29.6 before and after illness 29.5 see table 8.3.D.

8.4 SUMMARY: RESULTS CHAPTER 8:

OBSERVATIONS OF PARENTAL FEEDING CHOICES FROM BIRTH TO 3 to 4 MONTHS.

1. Many parents made feeding choices at birth which had changed by the time the baby was 3 to 4 months of age. A large proportion of parents changed from breast feeding to bottle feeding.

2. The parental choice of breast feeding at 3 to 4 months was associated with older mothers of non-manual social class.

3. There was more morbidity in babies who changed from breast to bottle feeding.

* Parental feeding behaviour can change within the first 4 months after birth. Changes from breast to bottle feeding were common. Some babies who experienced a change appear to have slower weight gain and a higher incidence of ill health.

CHAPTER NINE

DISCUSSION

This project set out with the following aim, and objectives:

Aim
To examine the influence of parental choices, of clothing, wrapping and room temperature, on the body temperature patterns of babies aged 3 to 4 months, during the day and night.

Objectives

1) To measure the deep body temperature of babies aged 3 to 4 months throughout the night.
2) To measure the deep body temperature of babies aged 3 to 4 months during the day, for the effects of sleep, feeding, and wakeful activity.
3) To measure temperature changes at the skin in association with deep body temperature, and body insulation.
4) To observe parental choices of clothing, wrapping and infant feeding in relation to thermoregulation.
5) To examine whether a change in the normal thermal care of babies will alter observed temperature patterns.
6) To formulate the optimum requirements of bedding and room temperature for babies aged 3 to 4 months of age.

The subjects met the criteria required for obtaining physiological measurements of thermoregulation. However, when compared with the population of Leicester they were primarily non-manual and failed to represent the full range of social class groups resident in the City and County. This imbalance made interpretation of social data more difficult. Despite random selection of parents when seeking subjects for the project, the non-manual classes were more willing to participate in this work in its early beginnings. Now that several years of similar study in Leicester have been completed dissemination of knowledge concerning the work has reached the majority of Primary Health Care Teams, and parents themselves have made the project local

news. The current populations under study have now redressed this imbalance of social classes and provide a reference for this earlier work.

Measurement of Body Temperature of Babies Aged 3 to 4 Months Throughout The Night.

The first objective was assessed from the measurement of core temperature by using the rectal probe. This was found to be the best choice for continuous measurement of deep body temperature in the home and was accepted by parents. The ideal site for recording core temperature has been the subject of debate for some time. The choice of the oesophagus at the cardiac level has been suggested as an optimal site which sensitively follows the temperature changes of central blood, indicating more rapid changes in body temperature than the rectum (Aikas E, Karvonem J, Piironen P, Ruosteenoja R, 1962). In neonates under laboratory conditions, the external auditory meatus is thought by some workers to be a more suitable site for accurate measurements of core body temperature compared to the rectum and oesophagus (Stratton D, 1977). However, both the oesophagus and auditory meatus remain unsuitable for continuous home monitoring. The rectal site has been used to estimate core temperature in rats, where despite a lack of rapid sensitivity, measurements offered a reliable continuous pattern of deep body temperature (Poole S, Stephenson JD, 1977).

The safety of the rectal site in newborns for mercury glass recordings of body temperature has been challenged because rectal perforation has occurred leading to pneumoperitoneum (Buntain W, Pregler M, O'Brien P, Lynn H, 1977). With the use of slim soft rectal probes correctly inserted, the rectum remains a safe site for continuous monitoring of core body temperature in babies aged 3 to 4 months. Correct procedure advocates gentle insertion at an angle of 30° backwards to within 5cm of the anal margin. The possibility of anal perforation is then negligible (Morley CJ, Hewson PH, Thornton AJ, Cole TJ, 1992). The alternative site for a home study of this nature is the axilla, which has been used as an alternative to the rectum (Shann F, Mackenzie A, 1981). In practice the axilla is a poor measure, lacking sensitivity in

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the identification of fever, with a low positive predictive value (Kresh MJ, 1984). Temperature readings from the axilla taken by a mercury glass thermometer can take eight minutes or longer (Nicholas GA, Ruskin MM, Glor BAK, Kelley WH, 1966), highlighting the advantage of the rectal site for continuous temperature recordings.

Findings– Physiological Measurements

The time of sleep varied for all the 67 babies monitored at night, each baby faced with a different set of circumstances relating to bedtime. All subjects varied in their sleep patterns, under half slept through the night without waking, the remainder requiring feeds or parental reassurance. Waking time also varied between subjects. The most popular sleeping place chosen was a cot in a separate room from that of the parents. The dominant sleep position in which a baby was placed to sleep was prone.

Despite these variations when bedtime was synchronised for all the subjects, the pattern of rectal temperature was remarkably similar, temperature fell from a level of 37°C or above at bedtime to 36.4°C during the first two hours of sleep where it remains until a gradual rise before waking, in a way similar to other studies of babies aged 3 months and older (Wailoo MP, Petersen SA, Whittaker H, Goodenough P 1989).

A diurnal variation in body temperature was first recognised over 200 years ago (Hunter 1778: Gierse A, 1842: Davy J,1845), whereby temperature peaks in the day and falls at night. In adult man temperature falls in the evening and continues into the early part of sleep, it then begins to rise in the latter part of sleep to waking, and on through the day to reach a peak in the early evening. These daily temperature fluctuations have an amplitude between 0.7°C and 1.5°C daily, in adult man (Minors DS, Waterhouse JM, 1981). The 24 hour rhythm of body temperature is due to changes in the body set point, demonstrated in behavioural responses to warm and cold at different times of the day and night (Cabonic M, Hilderbrandt G, Massonnett B, Strempel H 1976). The hypothalamic thermostat regulates body temperature around a higher level in the afternoon and a lower level in the small hours of the morning (Mills JN, Minors DS, Waterhouse JM, 1981). The rhythmic "set" changes

result from heat loss not heat production, but the exogenous component, particularly the effect of light, plays some role.

Early work which did not continuously monitor deep body temperature failed to find any rhythmical changes in the perinatal (Aschoff J, 1955; Hellbrugge T, 1960) or neonatal period (Mills JN, 1975). However, with the survival of many preterm infants who are continuously monitored in intensive units, has come evidence for temperature variations which alter throughout the day and night. Pre-term infants continuously monitored for body temperature, heart rate and rest/activity cycles, were found to exhibit a small rhythmic change in body temperature between 36.5°C and 38°C throughout the 24 hour period, along with cyclic changes in heart rate (Mirmiran M, Kok JH, 1991). There is no such pattern in the full term newborn. More recent work has identified rhythmic patterns in the human fetus from mid-gestation, which are explained by the rhythmicity exerted on the fetus at the fetal-placental unit, and the daily rhythms of the mother (De Vries JIP, Visser GHA, Mulder EJH, Prechtl HFR, 1987). These findings support the hypothesis of a functioning biological clock in early human development. We do not know whether these early uterine rhythms re-appear with development or some other rhythm appears in the developing neonate.

Animal experiments have shown that the neural activity in the suprachiasmatic nuclei of the anterior hypothalamus (SCN, the biological clock) of the fetus, responds to daily light/dark cycles (Reppert SM, Schwartz WJ, 1983). The SCN later becomes the endogenous centre for the generation of circadian rhythms in older mammals (Rusak B, Zucker I, 1979). The rhythmic changes of temperature being under the control of the hypothalamus at the SCN. Destruction of this site does not alter the temperature rhythm, which is thought to be also controlled by the Ventromedial Hypothalamus and the lateral hypothalamic nuclei (Moore-Ede MC, Sulzman FM, Fuller CA, 1982).

Night produces direct changes in most physiological variables rising growth hormone, lowers cortisol secretion and causes body temperature and urinary potassium to fall (Minors DS, Waterhouse JM, 1986). In man night time sleep acts as an exogenous influence on the body's internal clock, being part of the normal circadian rhythm of

sleep/wakefulness, under hypothalamic control of the SCN. In general the oxygen requirements of tissues lowers with sleep, with a corresponding fall in basal metabolic rate. During periods of rapid eye movement sleep basal metabolic rate is elevated, this type of sleep is more frequent in the premature infant, decreasing in the post-neonatal period (Kleitman N, Engelmann TG, 1953). In adult man sleep state is dependent upon the temperature cycle at sleep onset, with long sleeps occurring when the body temperature is above its mean level (Czeiler CA, et al 1980).

As the baby matures during the early weeks of life so the sleep/wake pattern changes. The newborn baby encounters environmental stimuli which promote wakeful activity in day time, and sleep with rest at night. A temperature pattern emerges, with evidence of changes in core body temperature from the first to the second month of life (Minors DS, Waterhouse JM, 1981), but precisely how was unknown. Recent studies have now identified the progression of temperature fall associated with sleep from birth to sixteen weeks post-delivery (Lodemore MR, Petersen SA, Wailoo MP, 1991).

Continuous recordings of night time rectal temperature, taken at regular intervals over the first 6 months of life have identified the development of a temperature rhythm occurring in stages. The first stage occurs during the first few weeks of life, when the new born baby's rectal temperature remains at around 36.8°C throughout the night. At six weeks of age the waking rectal temperature had risen to 37.2°C, falling to 36.8°C with sleep, indicating the beginnings of fluctuations. The second or mature stage is preceded by a period of transition, occurring at around 4 to 16 weeks whereby the temperature drop associated with sleep is from above 37°C to a level of 36.7°C within one hour of sleep, a pattern found also in the day. There is then a sudden change within two to three days, after which the temperature pattern reveals that of the second or mature stage as identified in this study. In this stage temperature drop associated with night sleep is from 37°C at bedtime, to 36.5°C within an hour of sleep. Development of these temperature patterns varies between babies (Lodemore MR, Petersen SA, Wailoo MP, 1992).

There were four babies in this study whose rectal temperature after sleep reached levels of 36.6°C and 36.7°C which can now be identified as typical of the period of transition prior to the appearance of the mature rhythm. All the remaining subjects showed the 'mature' rhythm. The remaining two subjects who were ill showed a pattern of temperature fall with sleep, but the fall then reversed taking the temperature level to above 37.5°C. This pattern has been identified as typical of incubation of infection as studied in the experimental model of babies post immunisation at 3 to 4 months (Rawson D, Wailoo MP, Petersen SA, 1990).

Changes in body temperature emerge during the first 3 to 4 months of a baby's life as circadian influences exert a pattern of temperature variation with sleep which is similar to adults. As the baby sleeps longer, so temperature fall deepens to a level of 36.3°C present in all babies by 5 months. Earlier work had only identified this phenomena at 5 years of age (Minors DS, Waterhouse JM, 1981) as measurements were taken relative to the time of day and not onset of sleep in the individual infant. These early changes in the infant indicate a linking of the sleep and temperature rhythm, suggesting that the rhythm for sleep and temperature develop at the same time (Lodemore MR, Petersen SA, Wailoo M 1992). For the developing neonate the effects of exogenous signals regarding light, which play a part in temperature development, and affect the sleep/wake cycle, are in their early stages and may be limited by parental behaviour, which in terms of bedtime in this study showed a wide variation between subjects.

SUMMARY

This objective was fully achieved. The pattern of deep body temperature identified in this study mimics that of adults, and has become associated with the first mature stage in the development of a circadian temperature rhythm in the developing infant.

Parental Choice of Thermal Environment Associated With Night Time Sleep

The fourth objective was to relate parental behaviour to the measured temperature patterns. At night parents used a range of clothing, wrapping and room temperatures that were far wider than could be allowed in a laboratory. To assess the total thermal environment a thermal score was calculated by using the total tog and minimal room temperature. This was felt to be a best way of achieving a single number to represent a thermal environment. Though simplistic, it is an adaptable method that is easy to calculate, and does not rely on any mathematical assumptions. Obviously it is a crude measure, which is not exactly that of a one to one relationship, between tog and temperature, although it is not far from this. The alternative is to work from some model of the environment that identifies an ideal to which individual subjects could be compared. At the moment there is no good model from which to work. Heat loss from the body and the effect of insulation cannot be modelled effectively even in laboratory situations (Kerslake D, 1991). With no alternative the thermal score, the sum of insulation and ambient temperature, proved to be the best estimate measure to represent the total thermal environment.

On the whole parents chose a combination of room temperature and thermal insulation of clothing and bedding that produced a thermal score of 30, from the combined total of room minimum temperature (mean 17.2°C) and tog total (mean tog for clothing 4.13, and bedding 9.37). In combining the thermal insulating factors many of the individual differences in one aspect of the total thermal environment were cancelled out so that parents who chose cooler rooms used more insulation and vice versa. This left two small groups of parents who either chose warmer or cooler conditions than the majority. Some findings could be attributed to seasonal influence, but they still revealed two groups of parents with different preferences. However there were no significant differences found between the physiological responses of these babies when entering into a mature temperature rhythm with sleep. The social bias of the subject population of this study towards the non-manual social classes, made any description of these parents difficult. A tendency for the higher social classes to choose cooler conditions and the lower, warmer conditions has been validated by

larger samples (Bacon CJ, Bell SA, Clulow EE, Beattie AB, 1991).

There were indications that parents used certain factors such as room temperature, and size of the baby, in formulating their choices, and were also influenced by social class. The warmth of the room was assessed for its ability to maintain a stable temperature throughout the night. Parents with rooms with the lowest mean minimum room temperature at 15.16°C, placed more layers of insulation on their infants (>12 togs of bedding), while those with highest mean maximum temperatures 20.63°C used less bedding (<6.0 tog units). The heaviest babies at birth were insulated with the least amount of clothing, indicating that parents seem to place more wrappings on smaller babies. The socioeconomic groups 1–3 chose to insulate their infants with less tog units predominantly producing lower thermal scores than the manual classes.

Other work has identified similar findings of parental choice of home conditions for babies of this age range. In a study of 200 babies aged 2 to 6 months at home, attempts were made to quantify parental choice of the total layers of insulation placed on the baby compared with room temperature and outside weather conditions. The daytime study identified that a quarter of parents behaved differently in their choice of more layers of clothing, wrapping and that parents used more layers when outside weather conditions were colder, irrespective of room temperatures (Nicoll A, Davies L, 1986). They identified that 32% of their sample had more insulation than previously suggested for optimal care in an environment of 18°C (Stanton AN, 1984). Other home studies found the greater proportion of mothers to chose a babygro, vest and nappy for clothing their infants, but less use of duvets than found in this study (Eiser C, Town C, Tripp J, 1985). This work identified that over wrapping of a baby, as they perceived it, was frequently found during times of fever when cooling is necessary to prevent the risk of convulsion.

The first work to quantify layers of insulation in babies at home during the night, identified clothing at bedtime of 5.1 tog units, supplemented by 9.6 tog units of cot wrappings, with room temperature falling only slightly by 4.4°C from 18.4°C at bedtime (Waiioo MP, Petersen SA, Whittaker H, Goodenough P, 1989). The study took place

during a very cold winter which accounts for the 1 tog unit increase in parental choice of clothing when compared to this sample, and the lower room minimum temperature. Significant associations were identified for heavier wrappings on small babies, with the suggestion that parents place more layers of insulation on these infants believing they are more vulnerable to becoming cold. In part of a larger study in Newcastle (Bacon CJ, Bell SA, Ciulow EE, Beatie AB, 1991), a mean tog unit was identified for insulation, the combination of clothing and wrapping, of 15.1 tog units, similar to the Leicester study in 1989 where the mean tog for insulation was 14.7 tog units, which compares with this study of 13.5 tog units. Newcastle is colder than Leicester, so that a difference in total scores for insulation of 1.6 tog units, seems small when considering that this study took place in mild winters in Leicester, suggesting similar fairly consistent trends in parental practice of insulation around the country. The Newcastle study identified differences between parents where younger mothers and mothers in the lower socioeconomic groups used more bedclothes over their babies, and kept them in warmer rooms. The choice of more than 10 tog units for insulation has been implicated as a risk factor for cot death in infants who have a viral infection (Gilbert R, et al 1992).

There are as yet no guidelines for the ideal infant thermal care, so the question arises as to what effect parental choices of clothing and wrapping and room temperatures are making to the infants thermal balance. It has been suggested that the appropriate tog value for the insulation of a sleeping baby at 16°C should be 8.8 togs from the formula of Burton and Edholm (Waiioo MP, Petersen SA, Whittaker H, Goodenough P, 1989: Burton AC, Edhoim OG, 1955). A thermal balance model has been devised by the Shirley Institute Manchester based on the formula of Burton and Edholm, suggesting the thermal insulation required for thermal equilibrium in healthy sleeping infants in differing ambient temperatures (Bacon CJ, Bell SA, Ciulow EE, Beattie AB, 1991). The model has been criticised for assuming heat is uniformly lost throughout the body (Kersiake D, 1991). Recent studies continue to emphasise the difficulties of understanding the role of insulation in babies because of several variables. Problems arise in the estimation of heat loss from different parts of the body especially the head, which generally remains uncovered. The effect of posture is also a factor. A baby

who curls up can more than double the effective insulation of bedclothes. The loss of heat through the mattress was previously felt to be negligible, however this may not be the case. Other considerations include variations in sweating which may be absorbed by some clothing materials, and the insulation of the boundary layer of air next to the baby (Kersiake D, 1991). It appears that heat flow is difficult to quantify due to the enormous variations in the micro environment into which each baby is placed.

Despite the lack of knowledge on thermal equilibrium in babies, parents in this study chose remarkably similar thermal environments with few choosing warmer or cooler combinations. No significant differences of deep body temperature could be identified between all the infants studied. The babies themselves were found to appear healthy and well after the period of over night monitoring, with no evidence of extreme physiological stress such as perfuse sweating, and no observations of concern from the parents. It appears as if parents were intuitively placing their infants in environments that were approximately thermal neutral. There is some evidence of parental choices affecting thermoregulative mechanisms in babies without mature temperature rhythms. In the period prior to the emergence of mature rhythms, varying in individual babies from 6 to 16 weeks, babies kept in warmer conditions, have temperature rises towards the end of the night time sleep that are significantly faster and further than those in a cool environment (Lodemore MR, et al 1992). The implications for this are uncertain and need to consider whether this places the developing baby at any disadvantage. It cannot be presumed that despite the lack of any significant findings, babies who have a mature temperature rhythm placed in warm conditions are not facing some physiological risk. Concern has recently focused on the possible combination of fever and thick bedclothes, as placing an infant at risk of sudden unexplained death (Gilbert R, et al 1992).

With the use of thermographic imaging, it is possible to identify heat loss through exposed areas of the body surface during night time sleep, with the particular importance of the head, as a mode of heat loss (Anderson ES, Wailoo MP, Petersen SA,1990). The study identified that, despite a normal deep body temperature, a baby

in warm conditions showed evidence of increased peripheral circulation to the head, an increase in postural changes offering greater surface area for heat loss, and observable sweating, compared with a baby in cooler conditions. The physiological effort required to lose heat by a baby in warm conditions, indicated in this study as a thermal score exceeding 32, requires further study. There is a need to identify whether extra physiological effort is required to control temperature, and whether other factors such as behaviour, sleeping position and the baby's ability to adjust posture could place a baby at risk of unexpected death. Data from this study and a larger sample monitored in the same way, could not identify any relationship between sleeping position and deep body temperature, although babies in the prone position with mature rhythms tended to warm faster at the end of the night (Petersen SA, Anderson ES, Lodemore MR, Rawson D, Waiioo MP, 1991).

This study took place prior to recent Government guidelines (HMSO BTSI/E Reducing the Risk of Cot Death), which advocate the supine or lateral position as safest for the majority of babies. The dominance of the prone position in this study reflects the recommended practice of that time. There is a growing body of knowledge with regard to sleep position and temperature control, which has helped to bring about these government recommendations (Flemming PJ et al 1990: Dwyer T, Ponsonby AL, Newman NM, Gibbons LE, 1991). They seek to establish an interaction between over wrapping, the prone position and the infant's thermal capacity to overheat, that maybe exacerbated by infection (Nelson EAS, Taylor BJ, Weatherall IL, 1989: Gilbert R et al 1992).

SUMMARY

This objective was fully achieved. Parents show remarkable similarity in their choice of clothing wrapping and room temperatures. Their decisions appear to consider the possible fall in ambient temperature throughout the night. A small proportion of parents behave differently, with warmer conditions more likely to be associated with the lower socioeconomic classes, cooler conditions preferred by the higher socioeconomic groups. Although there were no significant differences when

comparing babies in warmer and cooler conditions to the average, the developing neonate has significant physiological changes in its temperature pattern. Babies in warmer conditions have to behave differently to lose heat, and may be under some physiological stress.

Measurement of Deep Body Temperature in Babies Aged 3 to 4 Months in The Day

The second objective was achieved from temperature measurements made throughout the day, from which several patterns of temperature were identified.

Day Time Sleeps: All 70 subjects slept for a period of the day. These sleeps varied in length, from 15 to 250 minutes, and number, from 1 to 7, with the majority of sleeps taken in the afternoon. The average requirement was two sleeps, with the average length of daytime sleep 68.8 minutes. The total sleep required in 24 hours ranged from 11 to 17 hours, with the average generally 13 to 14 hours. Sleeping location varied as parents used different places for day and night sleeps. Choice of sleep position revealed that prone was preferred by the majority of parents at the time of this study.

The day time sleep, which was often short, required more observation from parents to precisely identify waking time. This need for observation could have disturbed some babies earlier than usual. Long sleeps, over 60 minutes, and short sleeps, under 60 minutes, were analysed separately. The results considered different daily activities related to sleep, and identified that whether a baby was immediately active or fed prior to sleep, sleep produced a fall in rectal temperature, from a level above 37°C to that of 36.8°C. Babies previously fed, had higher temperatures before sleep onset, and their temperature fall was not as rapid, they also warmed faster before waking.

Records of observed sleep activity of babies in laboratory situations are numerous, but there are few measurements at home. Early studies documented that infants in the

early weeks of life seem incapable of sustaining a long period of sleep or wakefulness (Kleitman N, Engelmann TG, 1953). The newborn was found to have a significant amount of wakeful time in 24 hours, around 6 to 7 hours, which is broken into many short periods (Parmelee AH, Schutz HR, Disbrow MA, 1961). Parental observations of sleep and wakefulness from birth to 35 weeks of age, identified a gradual decrease in the total sleep taken in 24 hours from 17.8 hours in the first weeks, to 14.4 hours at 35 weeks. A diurnal sleep pattern emerges at approximately 6 weeks of age, becoming a definite feature at 12 weeks of age (Parmelee AH, 1961). This study identified a mean total sleep of 13.6 hours in 24 hours, which corresponds with these earlier findings. Daytime sleep has been found to be more disorganised in the morning than the afternoon, where the afternoon nap remained the strongest day time sleep at 14 weeks of age (Parmelee AH 1961). This was confirmed in this study.

The temperature pattern of daytime sleep differed from the night. During the day, temperature fell with the onset of sleep, by 0.2°C, whereas at night the extent of temperature fall was in the order of 0.8°C. The trough of the temperature fall at night was to a level of 36.4°C/36.3°C and during the day, this was higher at around 36.8°C. A long daytime sleep was completed in 4 hours at which point the temperature level was above 37°C, at night the temperature 4 hours into sleep remained at a level of approximately 36.4°C. The effect of sleep in pushing the temperature down at night is a strong phenomena occurring within an hour of bedtime. The core temperature of babies who woke during a night time sleep after 4 or 5 hours (the equivalent length of a long daytime sleep), never returns to day time levels of over 37°C. After a long daytime sleep, rectal temperature returns to levels above 37°C. Temperature patterns in babies 3 to 4 months of age, are significantly different at night compared to the day. These findings emphasise the emergence of a circadian rhythm in body temperature of the developing infant.

The Hypothalamus in the adult controls the body temperature by altering the `setpoint' for the day within a different range than at night (Mills JN, Minors DS, Waterhouse JM, 1979). Parental influence and the social environment has been found to be the strongest factor in the evolving day/night pattern of neonatal sleep (Sander LW, Julia

HL, Stechler G, Burns P, 1972). These findings suggest that parental actions or socialisation, unknowingly affect the pattern of change which causes the beginning of a marked difference in physiological temperature responses to sleep during the day and night, at 3 to 4 months of age. In this way they play a part in influencing the development of body rhythms. External rhythms exert effects upon circadian rhythms by producing an exogenous component and by entraining the internal clock, with the presence of day light determining which phase the body is in (Minors DS, Waterhouse JM, 1986). Sleep lowers body temperature in the day by a small degree, maintaining temperature control within its normal range, which emphasises the effect of night time sleep in producing a greater change in deep body temperature. However daytime sleep is opposed to the main exogenous control of circadian rhythms associated with sleep at night or during dark hours and wakeful activity in day light hours. Parents are beginning to reinforce daytime wakefulness and activity as opposed to night time quiet and sleep. It must be supposed that the baby at 3 to 4 months of age is adjusting slowly to less sleep during the day, which produces small physiological responses to temperature, as the baby begins to distinguish day/night with sleep/wake cycles.

SUMMARY

Sleep requirements vary among babies with a mean total requirement of 13 hours taken throughout the day and night. Day time sleeps occur most frequently during the afternoon. Physiological measurements of day time temperature with sleep in babies 3 to 4 months of age, confirms the emergence of a diurnal pattern of temperature regulation. Temperature falls with sleep in the day, but not to the same extent identified at night.

Day Time Feeds: There proved to be an abundance of feeds during the day for analysis. This enabled different methods of feeding throughout the day, breast and bottle, with their respective associations in time to other day time events, to be separated for analysis.

Breast and bottle feeds during the middle part of the day followed by a period of

activity, produced a significant rise in rectal temperature after the feed. Babies who slept after a feed exhibit a significant fall in rectal temperature. The temperature of bottle fed babies was higher than that of breast fed babies, so that at the feed event the mean temperature for breast fed babies was 36.96°C, bottle fed 37.16°C. Babies who received a feed during the night did not warm out of the trough, remaining within the limits of the normal pattern described.

The short term effect of food intake on metabolism has been extensively investigated in the newborn and adult, revealing that food ingestion increases the body's heat output above the basal level. This stimulus of food ingestion on the metabolic rate is referred to as its specific dynamic action or thermic effect (Lusk G 1930: Murlin JR, Conklin RE, Mearsch ME 1925). The ingestion of carbohydrate and fats has been found to increase the body's resting energy output by 4% and 6% respectively and the specific dynamic action of proteins by upto 30% (Heim T 1981). The body's metabolic rate is influenced by an interaction of physiological variables which include age, sex, thyroid activity, environmental temperature, sleep state and diet (Heinbecker P 1928). During sleep the basal metabolic rate decreases by about 10% as the oxygen requirement for tissues lowers. Work has now demonstrated that sleep plays an important role in regulating energy expenditure, especially the part played by rapid eye movement sleep (Heim T 1981). Sleep's direct effect on other physiological variables includes the rise in growth hormone secretion, and the lowering of cortisol secretion, while urinary potassium levels fall.

Food ingestion along with other physiological variables has a rhythmic cycle, termed the eating/fasting cycle. Eating during the daylight hours is associated with other rhythms such as urinary excretion which peaks during the day when food ingestion occurs, and enters a trough at night when food intake is at a minimal. Work has identified that the SCN is the control centre for activity and feeding rhythms. Abolition of this region in the squirrel monkey caused the loss of rhythmicity in drinking behaviour and feeding (Fuller CA et al 1979). However the temperature rhythm is not lost after this procedure which suggests the control by another internal clock mechanism. A great deal of work has been done on the control of rhythms with

results pointing to different clocks which adjust to different external influences. The urinary excretory rhythms follow eating/fasting cycles, the temperature rhythm follows the light/dark regimen (Suizman FM, Fuller CA, Moore–Ede MC 1977).

SUMMARY

The effect of feeding upon body temperature is strongly associated with other physiological variables. The effect on temperature, depends on the time in relation to day/night and the presence of sleep. The metabolic effects of food ingestion causes a rise in body temperature. Where sleep follows a feed there must be an increase in heat loss mechanisms whereby the body can lose the heat required to cause a fall in core temperature.

Day Time Activity: During periods of wakeful activity the rectal temperature reached its highest levels recorded within the 24 hour period. These peaks of temperature being up to 37.8°C. The levels were significantly higher for bottle fed infants (mean maximum temperature of 37.6°C) than breast fed infants (mean maximum temperature of 37.4°C).

Metabolic rate will determine heat production and is dependent on many factors such as activity, environmental temperature, feeding, illness and time of day. Basal metabolic rate in infants is difficult to determine but has been found to be associated with body weight (Hill JR, Rahimtulla KA 1965). Metabolic rates in infants have been largely determined from indirect calorimetry, where oxygen consumption (ml/kg– min) is measured and used to calculate the metabolic rate. The calculation depends on the respiratory quotient (RQ), which has been shown to range between 0.9 and 1.0 immediately after birth, to decrease to 0.7 before rising to the adult value of 0.85 at the end of the first week (Brück K 1961).

Heat balance depends upon heat loss from the body matching heat production. That activity increases metabolic rate and hence effects heat balance, is well documented. Activity is to some extent under voluntary control, and is a behavioural mechanism for

heat production. A high level of activity will be accompanied by a similar proportion of heat production. Detailed studies of activity on the physiological mechanisms of children have only been possible with controlled tests for children over five years (Godfrey S, 1981). The sleep/wakeful patterns of preterm and full term infants have been studied (Parmelee AH, 1961), but compared with sleep there is less information on the `awake state'. The wakeful periods have been described according to the observed state of the infant including alert awake, crying awake, and by use of the terms active awake and quiet awake (Shulte FJ, 1981). This study did not measures the extent of physical activity engaged in by the baby.

Adaptations to varying levels of energy intake may affect an infant in several ways. Energy intake is adjusted by changes in basal metabolism, activity, thermogenesis and possible changes in the infant's body mass or composition, although the response to energy intake in infants is poorly understood (Butte NF, Smith EO, Garza C, 1990). Body size and growth are determining factors in energy intake, where physical activity and the energy cost of growth amount to 170–210 kj/kg day (40–50 kcai/kg day) (Widdowson EM, 1981). Infants have been found to take different amounts of food for their requirements (Fomon SJ, Owen GM, Thomas LN 1964) with male infants identified as taking more milk and gaining weight faster after birth (Fomon SJ, Filer LJ, Thomas LN, Rogers RR, Prksch AM 1969). There were more male infants bottie fed in this study but gender was not assessed in the activity data.

The highest temperatures were achieved by formula fed infants whose core temperature was $0.2^{\circ}C$ higher than that of breast fed infants. There were no means of fully evaluating the total content of each feed as mothers were not asked to describe feeds in detail, although it had been noted that bottie fed babies were more likely to be having solids, than breast fed infants. Bottie fed milk contains more amino acids which produce a higher metabolic rate during the process of deamination by the liver to form urea. One of the unique properties of breast milk is easily absorbed amino acids (Whittlestone WG, 1983). Studies have highlighted differences between the energy intakes of breast fed and formula fed infants (Whitehead RG, Paul AA 1985: Butte NF, Smith EO, Garza C, 1990). Bottie fed infants are seen as less

efficient, consuming more food for similar weight gains with excess intake affecting basal energy requiring processes at 3 to 4 months of age (Butte NF,et al 1990). This confirms the findings in this study, with bottle fed infants utilising the excess intake by a rise in body temperature. Any introduction of unmodified cows milk would have greatly enhanced the specific dynamic action of proteins, which are present in greater number, hence adding to the increase in body temperature. The protein content in 150ml of breast milk is between 1.8–2.9g, and in the same quantity of unmodified cows milk the content is doubled to 5.2g (Richie CD, Naismith DJ, 1975).

Activity levels between individuals affects energy needs, as seen by evidence that crying requires more energy, increasing the metabolic rate by as much as 3 to 4 times the sleep level. There are inherent metabolic differences between individuals which are not fully understood (Widdowson EM 1981).

SUMMARY

A full description of wakeful activity was not obtained in this study so that its relationship to variables like crying and body movement were not possible. The findings indicate that a period of wakeful time in the day elevates rectal temperature to its highest levels. We can speculate that this effect will be greater where babies are bottle fed as they have a greater quantitative and qualitative food intake. Bottle fed infants are therefore less efficient utilising excess food by producing a rise in daytime body temperature levels which is not necessary in breast fed infants.

The second objective to obtain measures of body temperature during day time events was fully achieved from the patterns of core temperature identified with day time sleeps, feeds and activity.

Parental Choice of Thermal Environment During The Day
The fourth objective to observe parental choices of thermal care for their infants was achieved from observations of clothing, wrapping and room temperatures during day time sleep. The subjects were placed to sleep in more varied thermal environments

during the day, than at night. This possibly reflected the greater choice of day clothes available and the different parts of the home in which the baby could sleep, from the hall through to bedrooms, which in turn all had different sources of local heat. Central heating systems were generally off during the day, especially in the spring and summer. Despite this a majority (62.8%) of parents chose similar thermal environments, whereby thermal scores fell within a central range of 25 to 30. The mean tog for clothing was 5.15 tog units and wrappings 7.07 tog units, with the average minimum temperature 17.49°C. The daytime thermal scores were lower than at night due to the majority of parents using less bedding, especially duvets. Again there were two small groups who chose a warmer and cooler thermal environment than the majority. When analyzing the deep body temperature patterns of babies in cooler and warmer environments to the majority, no significant findings were identified.

Parents were generally making choices based on their estimates of thermal comfort with the result that more layers of insulation were on babies in cool rooms and less on those in warm rooms. In the Nottingham observation study a wide range of parental choice of clothing and bedding was observed but not quantified as tog values. A mean daytime temperature of 21.2°C was also identified but not associated with sleep (Nicoll A, Davies L, 1986). In the Newcastle study, a mean daytime tog of 8.71 was found in the summer and 10.31 in winter, with mean room temperatures of 19.7°C in summer and 18.3°C in winter (Bacon CJ, Bell SA, Clulow EE, Beattie AB 1991). These studies failed to make rigid comparisons of the different use of local heat sources but suggest some similarities. The Newcastle winter group with higher ambient temperatures (17.49°C to 18.3°C) had lower tog totals (12.22 to 10.31) than in this study population.

Subjects in cooler or warmer environments in the day had less factors in common than those in similar groups at night. There were six babies cared for in warm conditions during the day who were also warm at night. This suggests that a few parents make consistent choices throughout the day and night. In general parents behaved differently during the day, with more parents from the higher social classes choosing warmer conditions than at night. These findings could not be validated with a larger

sample but the more numerous choices available to parents in the day may lead some parents who normally make average choices at night, to make warmer choices in the day. There is now some evidence that warm conditions may effect temperature rhythms at night which may bring risk (Lodemore MR, et al 1991). Further work to fully explore these situations during the day is required, and as previously acknowledged a full understanding of ideal thermal conditions for infants is required which can also take account of day time conditions. Again there was no evidence that babies were not sleeping in thermal neutral environments during the day.

SUMMARY

Parents tended to chose different thermal environment during the day to those at night, probably because there were more options available. Despite this greater choice, parents worked out a combination which remained very predictable. There were some parents who appeared to work to a different formula and chose warmer or cooler conditions. No physiological differences were found between these groups, and the small numbers made differentiating between them more difficult.

Measurements of Peripheral Body Temperature- Associated With Night Time Sleep

The third objective was achieved from temperature measures taken from different peripheral body sites. The three sites chosen for measurements of peripheral temperature were expected to reveal the processes whereby heat is lost and gained from the body to maintain the core temperature, within the thermoneutral range when placed in different thermal environments. The measures also hoped to reveal the various routes of heat loss from the infant. However these measurements were fraught with difficulties associated with heat flow at the sites.

The flow of heat from the central core of the body to the peripheral skin layer is analogous with Ohm's Law for the flow of electricity through an electrical circuit ($V=IR$). In the steady state, the flow of heat from the body core to the outside air is constant.

As heat flows from the body it passes through two resistances the body itself comprising peritoneum, capillary networks etc, and the layer of clothing and wrapping (the tog total). Where two resistors are connected in a series heat flow across them must be the same.

diagram

T core   T skin   T ambient

HEAT FLUX
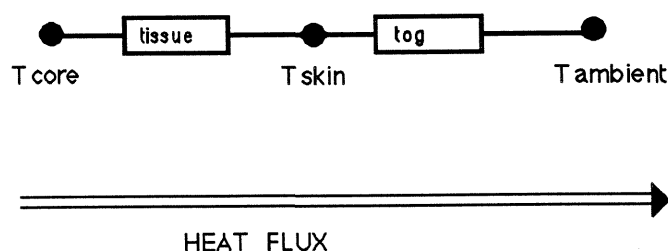
Changes in the first resistance such as a change in blood flow to the skin will alter the level of resistance at this point, vasodilation will reduce the resistance, vasoconstriction increase the resistance. Similarly changes with the tog total, the second resistance will effect heat flow. From these principles it can be seen that the skin temperature is determined by a potential division of the temperature gradient between core and abdomen. This allows the body resistance to be calculated if the tog value and temperatures T core, T skin, T ambient are known.

The abdominal probes of 23 subjects were further analysed to calculate the thermal resistance (R). As the probe was used as a measure of thermal resistance at the skin in relationship to clothing and wrapping, the above formula was applied for readings obtained one hour before bedtime, bedtime and at hourly intervals up to 3 hours into night time sleep. These were related to the tog and ambient temperatures (see Appendix 10). It has been suggested that the measure of R should be 1 (Burton AC, Edholm OG 1955). The results were not far from the expected, although the large score of 1.37 at bedtime indicates vasoconstriction when in fact vasodilation would be

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occurring.

The mathematical formula although sound in principle, becomes invalid when applied to the real life situation. The resistance of tog is affected by how quickly bed clothes and adjacent mattress heat up, the extent of influence sweating may have upon clothing becoming moist and its relationship to the baby which may alter with movement. The very siting of each individual abdominal probe although prescribed to be 2cm to the left of the umbilicus, varied between the size and shape of each baby, appearing either inside or outside the nappy. Ambient temperature in this study is not a measure obtained directly adjacent to the infant, and may also introduce error. These variables in effect act as a capacitor to the resistor, the abdominal probe being affected by many influences is a poor indicator of temperature variability at this body point, as previously outlined (Kersiake D. 1991).

The measures from the head proved to be too few in number for any real understanding of heat flow. The use of thermographic imagery has confirmed the importance of the head for heat loss from the baby, along with peripheral body parts which can be exposed from clothing and bedding to the outside air, such as the hands (Anderson SE, Waiioo MP, Petersen SA, 1990). A fuller understanding of heat flux mechanisms is required to establish whether heat loss is due to increased cutaneous perfusion and sweating at these exposed body sites.

The leg site was more popular than the head with parents, as the probes were not visible and unlikely to be found accidentally by the infant. There were no differences observed for heavy or light insulation, but little evidence for the mechanism of heat flow to this part of the body were obtained. As already noted, far more understanding of the relationship of clothes and wrappings to the posture and micro environment of the sleeping infant is required.

SUMMARY

The third objective was not fully achieved as a full understanding of heat balance in

infants has yet to be realised. The peripheral sites confirmed the use of extremities in the process of heat dissipation, especially the head. There were no differences in temperature measures at any of the peripheral sites, between babies in the warm or cooler environments.

The Abnormal Thermal Environment.

The fifth objective required babies to be monitored under different thermal conditions to those chosen by the parents. Parents who participated in a repeat monitoring under constrained conditions required trust in the researcher who prescribed the level of insulation and room temperature for the infants day and night sleep. For many parents the loss of control to choose for their infant was so uncomfortable that they could not participate in this part of the study. The number who came forward for analysis was less than anticipated. There were further losses when those who willingly accepted the safe change in insulation or room temperature for their babies manipulated a reversal of environmental conditions at monitoring. Often parents had appeared relaxed about the change only later, during the night to remove blankets or clothes, turn off the heater, or open windows. Where only the room temperature was to be increased parents were asked to dress their infant as under free choice conditions, but chose clothing of a smaller tog unit. As seen in the methodology there were also experimental difficulties in achieving the expected increase in room temperature. Variability between homes meant that the effectiveness of the experimenter to bring about any real change was limited. Parental control was found to be a strong factor, and the reluctance of parents to let go could be seen as a powerful drive.

Despite a real change in the thermal environment, no significant temperature changes were observed with night time sleep. The experimental change was anticipated to test the rigidity of babies thermal response at this age. The result revealed an immediate adaptation to the new set of circumstances into which each baby was placed. This implies the direct mature functioning of the thermoregulatory responses of babies aged 3 to 4 months.

To expect parents to change without knowledge or experience would be greatly questioned by the psychologists who have studied the personal conflict brought about by change (Festinger L. 1957; Festinger L Carlsmith J.M 1959).

"The innovator makes enemies of all those who prosper under the old order, and only lukewarm support is forthcoming from those who would prosper under the new......partly because men are generally incredulous, never really trusting new things unless they have tested them by experience"

Machiavelli, THE PRINCE.

The loss of control for a parent with no knowledge of, or experience of, other methods of thermal care would be fearful. It is surprising that so many co-operated rather than that so many refused.

Recent government advice asks parents to reduce the risk of cot death by positioning the baby in the lateral or supine position to sleep, keeping baby cool, with emphasis against exposing the fetus or baby to cigarette smoking. The fear of cot death among parents is high so it is of no surprise that parents are changing their behaviours with this advice. This study took place prior to these recent Government directives and it could be presumed that even fewer parents would have been willing to see an increase in thermal measures to add warmth as occurred here. The data base of babies being studied in Leicester shows a recent change in parental behaviours from prone to lateral or supine and a clustering of parents choosing cool environments as opposed to warm.

SUMMARY

Experimental control of the thermal environment was achieved and revealed that parental behaviour is resistant to change with the absence of experience or knowledge. The physiological response of deep body temperature in babies who experienced warmer conditions to those normally chosen by their parents, revealed no difference in the pattern of deep body temperature control.

Observed Feeding Changes From Birth to Monitoring

The fourth objective of observations of parental feeding practices was achieved by following the pattern of behaviour in a larger sample of parents from birth to 4 months post–delivery. The information used in the analysis of feeding patterns was taken from diaries kept prospectively by parents. The diaries were designed to be user friendly and were fully explained to parents. The reliability of diaries for producing accurate data on parental behaviour has been called into question. Parent's feeding choice could be verified by the researchers own observations, leaving only reports of illness that occurred after initial contact and prior to the monitoring period not directly observed by the researcher. Many episodes of illness could be verified by the family Health Visitor, but often there was no need to report these to members of their local Primary Health Team. Concerns of parental reporting in diaries focuses on parental over and under reporting. These criticisms emerged from studies where diaries were used by parents at home to assess neonatal behaviours such as crying (Brazelton TB, 1962). However useable data were obtained in 91% of a mixed socioeconomic group whose home diaries of infant crying times were verified by a tape recorder (Barr RG, Kramer MS, Boisjoiy C, McVey–White L, Piess IB 1988). In this study the diaries were well accepted, often validated and used a large sample for reduction of error.

In this study of 209 parents, 65% breast fed at birth and 32% bottle fed, which reflects the OPCS study, where 64% of infants were breast fed in 1985. The value of knowing the number of babies who were breast fed once, remains a poor indicator of feeding intentions, as reports continue to show a decline in breast feeding during the first few days and weeks postnatally. By 12 to 22 weeks post–gestational age, in this study the figures for breast fed babies were 33.7% and bottle fed 66.2%. This reflects the same trend as documented in 1988.

> "At four weeks the majority are at best only partly breast fed; by six weeks the position at birth has practically reversed, with 61% exclusively bottle fed; and by four months, this figure has risen to 74%. At nine months only 12% of mothers continue to breast feed". (DHSS 1988)

Reasons given for a UK mother who is likely to succeed in continually breast feeding reflect some of the findings in this study and include, first baby, maternal age over 25 years, higher educational attainment (over the age of 18 years), higher social class and lives in the South East of England (DHSS 1988). Maternal educational achievement was not assessed in this study, but maternal age and social class factors were evident in this population. As we noted in the introduction the clear socioeconomic factors do not in themselves have a direct effect, but they reflect the complexity of life style factors in the mothers background and environment.

Babies who were continually breast fed In the study population appear to be at less risk of upper respiratory tract infection during these early months, although surprisingly the babies who were changed, from breast to bottle feeding, have the highest reporting of illness. The effectiveness of IgA (immunoglobulin), especially in colostrum, protects babies from rhinitis, bronchitis, gastrointestinal, and respiratory illness, asthma, otitis media, and eczema (Cockburn F 1983). One study found that cot deaths were less likely in breast fed infants who were felt to be less liable to infection (Barrett AM 1961). In New Zealand breast feeding has recently been identified as one of three factors that in some way protect against cot death (Mitchell EA, Becroft DMO, Barry DMJ, 1991). Other work fails to draw clear conclusions as to the advantage of breast feeding and the incidence of infective illness especially for upper respiratory tract infections (Taylor B, Wadsworth J, Golding J, Butte N 1982: Ruben DH et al 1990). The reasons for a change from breast to bottle feeding, were not recorded in this study therefore clear conclusions as to the role of illness appear confused. It could be claimed that illness was not the cause of the change but the effect. That Illness was apparent in the changers who received some immunity from breast milk, suggests that it may not be the type of feed which protects against illness, but some other factor. This other factor may be closely associated with the commitment of the mother to the pregnancy and her mothering ability, associated with social factors pertaining to the environment, which culminate in the total ingredients of what takes place within a home and influences the baby. As we noted in the introduction, social class and health choices have more to do with cultural/behaviourial and materialist consequences working within individual's lives.

Although it is accepted that establishing breast feeding is not easy and requires good early nursing and medical care in the obstetric unit with continued domiciliary support, the established evidence in support of the benefits of breast feeding often fail to discuss the costs. In the study population one of the benefits of bottle feeding was clearly prolonged nights sleep. That,

"many parents of young infants yearn for an uninterrupted night's sleep"

(Beal V.A. 1969)

possibly goes without saying. Other studies have identified frequent night waking with breast feeding (Eaton-Evans J, Dugdale AE 1988), and have sought explanations in the known physiological effects of breast milk. In particular breast milk leaves the stomach more rapidly than formula feeds resulting in shorter periods of satisfaction (Barness NA 1979). Other work, recognising the predominance of breast fed babies in night waking, points to the intricate pattern of responses elicited by the bottle feeding parent which are different to that of the breast feeding parent. This work identifies different attitudes of parents, in that the bottle feeding parent seeks to quickly identify and seek solutions to the problems, in order to suppress the night waking, whereas the breast feeding mother is more able to tolerate night waking for longer before trying to solve the dilemma (Wright P, Macleod HA, Cooper MJ, 1983).

The parental choice of feeding, appeared to be independent of the choices concerning the thermal environment of their infant. The total thermal scores for babies who remained breast feeders, babies who changed to bottle feeding and bottle feeders were all very similar. Babies who had been breast fed and changed to bottle feeding, had the highest thermal score (32.2), and also the highest reporting of illness, suggesting that parents may chose more layers of insulation or warmer rooms after a period of illness. We have previously identified evidence that supports a large amount of ignorance for the need to keep baby cool during fevers. Viral illness, and the tendency to heavily insulate infants have recently been reinforced as possible risks of SIDS (Gilbert R, et al 1992).

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SUMMARY

The fourth objective was fully achieved with the observations of parental feeding choices from birth to age 3 to 4 months. Feeding preferences were consistent with other studies and highlight the decline in breast feeding in the first few weeks of life. Factors associated with this reveal strong socioeconomic overtones. Child morbidity was higher in the bottle feeding groups although the reasons for termination of feeding were not obtained. One of the benefits of the choice to bottle feeding, could have been a prolonged night's sleep. In terms of thermal care it appears that parents may not fully understand the principle of keeping baby cool.

CONCLUSIONS

The aim of this thesis, to establish the pattern of body temperature in babies between 3 and 4 months of age at home, has been achieved.

This work forms part of the link towards a fuller understanding of how home thermal care affects the physiological mechanisms of the developing baby. Only when we complete this understanding can the final objective of this study, "to produce a formula of optimum thermal care" for the developing baby, be achieved.

This work could find no evidence to question the practice of the majority of parents. The identified temperature patterns found during the day and night proved to be remarkably replicable despite differences in infant thermal care and appear to be independent of the thermal environment. There is therefore no evidence from temperature data that current parental practices, as observed in this study, concerning choice of room temperature, clothing and wrapping, alter core or peripheral body temperature patterns from the norm. The majority of parents who chose average thermal care resulting in a thermal score of 30, suggest a sensible model for others to follow.

Further knowledge is required if we are to arrive at a scientific prescription for parental thermal care. We need to understand if certain groups of babies are experiencing any physiological stress from the conditions in which they are nurtured. In this study we have identified some babies who were in warmer, and cooler conditions than the average. As hyperthermia has been so closely associated with infant deaths the warm group require special attention. Are babies in warmer conditions experiencing physiological stress?

Studies of heart rate and oxygen saturation obtained with temperature data during night time sleep, prospectively achieved on babies from birth to the arrival of a mature temperature rhythm, have now been undertaken (Lodemore MR, PhD thesis 1993). This study found that heart rate follows the same pattern as rectal temperature with

night time sleep, so that heart rate falls at bedtime in babies with mature temperature rhythms. There was no evidence of differing heart rate patterns in babies kept in warmer environments that had mature temperature patterns. However, babies who develop temperature rhythms later then the average are experiencing higher heart rate patterns for longer. More work is required to identify if these babies face any physiological risk from achieving late temperature rhythms, especially where they experience warm thermal care.

The study also identified that babies who develop late temperature rhythms share the same characteristics with babies identified to be at risk of post-neonatal mortality, especially SIDS. These include environmental and constitutional factors of bottle feeding, younger maternal age (both factors associated with the manual classes), lower economic status, male infants, birth trauma and second or subsequent children. Further physiological measures on babies with identifiable risk factors for SIDS are required, to include bottle fed second and subsequent children born to younger mothers from the manual social classes. Longitudinal studies continue in Leicester in which physiological measurements on babies are collected from birth, in which selection criteria incorporates the above risk factors. Physiological measurements now also include 24 hour urine collection for identification of hormonal corticosteriods associated with stress.

The findings of this study were made on healthy infants, and lend the question what happens during febrile illness. Are the rules applied in health incorrect in ill health? Further study of physiological measures on babies incubating infection continue in Leicester, and will provide further evidence. More information of the heat balance issue is also under study from measurements of sweating.

As recently stated,

" It is vital that these issues are clarified, because if overheating is indeed a contributory factor to some cases of death or damaging illness it would be entirely preventable by soundly based advice to mothers"

(Bacon CJ, et al 1991).

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APPENDICES

APPENDIX A1

POST-NEONATAL NUMBER RATES PER 1,000 LIVE BIRTHS AS DEFINED BY FATHERS' OCCUPATION AT DEATH REGISTRATION OPCS 1989

CAUSE OF DEATH	SOCIAL CLASS						
	1	2	3	4	5	6	7
Respiratory	0.2	0.2	0.2	0.3	0.3	0.4	0.4
Congenital Anomalies	0.4	0.5	0.8	0.5	0.9	0.8	1.0
Sudden Infant Death Syndrome	0.9	0.8	0.9	1.0	1.8	2.3	2.4
External cause of injury and poisoning	0.0	0.0	0.1	0.1	0.1	0.1	0.4

APPENDIX A2

EXAMPLE OF LETTER GIVEN TO PARENTS

Dear Parent,

I am a health visitor working within the Department of Child Health, University of Leicester, based at the Leicester Royal Infirmary. Our research group is currently looking to establish how babies temperatures vary in a home environment. This information is needed so that we can know the best temperature ranges for healthy babies at home.

We are recruiting babies aged 3 to 4 months, and would like to invite you to help with this work. Participation would involve the monitoring of your baby's temperature in your home, with the use of a small harmless device. The study would interfere as little as possible with your daily life.

If you are able to help, please return the enclosed response form.

Yours sincerely,

Mrs Elizabeth Anderson
Research Health Visitor

RESPONSE FORM

1. I am/We are willing to participate in this research, which involves the monitoring of our baby's temperature at home.

2. I am/We are interested in participating in this work, but would like to ask more questions.

3. I am/We are not able to take part in this study.

To enable me to arrange a convenient time to meet you at home, please complete:

Name ....

Address .... Tel. No. ....

APPENDIX A3 DIARY OF CHILD HEALTH

| Name: |
| Date of Birth: |
| Please record if your baby appears unwell, including visits to GP, and medicines prescribed. |
| Week 1 |
| Week 2 |
| Week 3 |
| Week 4 |
| Week 5 |
| Week 6 etc |

APPENDIX A4 QUESTIONNAIRE COMPLETED WITH PARENTS

BASIC DETAILS

Baby's Name: Male/Female
Date of Birth:

Mother's Name:
Date of Birth:
Occupation:

Father's Name:
Date of Birth:
Occupation:

Siblings/Date of Birth:

Family Address:

Type of housing:

Data regarding baby to be monitored

Birth details

     Gestational age:

     Type of delivery:

     Labour length:

     Labour complications:

     Apgar score:

     Birth weight:

     Head circumference:

     Feeding established at:

     Feeding choice:

Conditions after birth

     Cyanosis:

     Jaundice:

     Vomiting:

     Minor infections:

     Other:

After discharge

     Health visitor/GP:

     Local clinic:

     Immunisation:

Family Health

Parents

     General Health:

     Smoking:

Siblings

     General Health:

<u>Home Conditions</u>

Heating

    Central heating   – gas

                                            – oil

                                            – solid fuel

    Storage heaters:

    Gas fires:

    Electric fires:

    Open fire:

    Other:

    Hours in use:

Baby's Room

    Radiator:

    Electric fire:

    Portable heater:

    Other:

APPENDIX A5 MONITORING DETAILS

Current health of baby

       Illness   – respiratory
                       – gastro–intestinal
                       – other

Features of Interest of baby

Is your baby well today?   YES / NO

Any changes in the following:
      Crying:
      Sweating:
      Restlessness:
      Passive:
      Wakeful:
      Other:

Measurements
      Weight:

Current feeding
      Details:

Details of clothing worn during monitoring

Day time / Night time

Garment	Description	Tog
Napkin		
Vest		
Socks		
Babygro		
Shirt		
Trousers		
Knitted suit		
Dress		
Cardigan		
Bonnett		
Mittens		
Sleepsuit		
Other		
Bedding		
Blanket		
Sheet		
Duvet		
Other		

Type of cot/bed

Description

Position in room

Relationship to heater

Sleeping position

Prone

Supine

Lateral

APPENDIX 6 TOG VALUES

Standard tog values used to quantify the insulation on sleeping babies. Data supplied by the Shirley Institute, Manchester (Clulow, personal communication).

GARMENT	Fabric Insulation 'TOG'
Clothing:	
Nappy	2.0
Vest	0.2
T–Shirt	0.3
Babygro	1.0
Velour babygro	1.5
Sleepsuit	4.0
Nightgown	0.6
Pyjamas	2.0
Cardigan	2.0
Jumper	2.0
Trousers	2.0
Tights	0.2
Socks	0.2
Mittens	0.2

GARMENT	Fabric Insulation `TOG'
Bedding:	
Cotton sheet	0.2
Flannelette sheet	0.5
Old blanket	1.5
New blanket	2.0
Thin quilt	2.5
Medium quilt	4.0
Cot quilt (standard)	9.0
Thick quilt	12.0
Baby nest	4.0

PHOTOGRAPH OF BABY ATTACHED TO MONITOR

Baby aged 3 months, awaiting surgery for cleft lip and palate at LRI, whose parents gave permission for a photograph to be taken to demonstrate the position of the thermistor probes, on a partially dressed infant.

APPENDIX A8 ACTIVITY SHEET

Please indicate the timing of events while your baby is attached to the monitor, to include feeds, changing, sleeps, activity times ie play etc.	
TIME	**EVENTS**

APPENDIX A9 ACKNOWLEDGEMENT

THANK YOU LETTER

Dear

Thank you very much for allowing me to come into your home and monitor your baby's temperature. We hope that with your help and that of other parents, this information will develop a better understanding of how to care for babies at home.

Yours sincerely,

Ms Elizabeth Anderson
Research Health Visitor

APPENDIX A10

THE ABDOMINAL PROBE-FURTHER ANALYSIS

Mathematical formula for calculating thermal resistance:

T core– T skin= Heat flow x Body Resistance
And
T skin–T abdominal= Heat Flow x Tog

Therefore,

$$\frac{T\ core-\ T\ skin}{R} = HF \qquad \frac{T\ skin-T\ abdominal}{R} = HF$$

$$\frac{T\ core-\ T\ skin}{R} = \frac{T\ skin - T\ abdominal}{R}$$

$$R = \frac{T\ core-\ T\ skin}{T\ skin-T\ abdominal} \quad x \quad Tog$$

Results of applying the above formula to 23 babies in this study:

MEAN SCORE OF RESISTANCE AS A MEASURE OF EFFECTIVENESS OF THE ABDOMINAL PROBE

time	−1hr	bedtime	1hr	2hr	3hr
measure	0.53	1.37	0.97	0.61	0.51

APPENDIX A11 CASE REPORTS

1) SUBJECT IN AVERAGE THERMAL CONDITIONS AT NIGHT
    Thermal Score 31.   (Subject No. 18)

A male infant born at 41 weeks gestation by normal spontaneous delivery, weighing
7lbs 9oz (3340g), with an apgar score of 9 at one minute. He was breast fed at birth.

The mother was aged 31 years, a full-time house wife, and the father was 33 years,
in business as a potato merchant. They had two other children. The family lived in
their own home some 5 miles outside the city centre, in a large old detached house.

The baby's health diary reported a skin infection at 2 weeks of age treated by
antibiotics, and a cough and cold at 4 weeks treated by antibiotics. He developed a
mild form of baby eczema at 6 weeks and at 10 weeks was discovered to have a
small umbilical hernia. At 15 weeks he received his first triple vaccination. Age 16
weeks he received antibiotics for a sticky eye.

He took part in monitoring at 17 weeks of age, in early March, when he was reported
to be well. He was breast fed and did not receive any solids.

PARENTAL CHOICES

At night he slept in his parent's room in a cot. He was placed on either his left side
or supine. He was reported to sometimes move from his side onto his back. He was
clothed in 3.2 tog units, covered by a further 10 togs. The home was gas centrally
heated, on a times basis, off at 8pm and on at 4am. The room temperature reached
a maximum of 22.5°C and a minimum of 17.8°C during the night. His total nights
sleep was 13 hours, the longest duration being 7.25 hours after which he woke for a
feed before returning to sleep.

The rectal and ambient temperature patterns for the night, can be seen in Figure A1
and A2.

2) SUBJECT IN WARM THERMAL CONDITIONS DURING THE NIGHT

Thermal Score 36.6   (Subject No. 55)

A male infant born at 42 weeks gestation, by normal spontaneous delivery, weighing 8 Lbs 9oz (3890g), with an apgar score of 9 at one minute. He was breast fed at birth, but bottle fed on his second day post–delivery.

He was the second child of a young couple. The mother was 18 years of age, and the father 24 years, reported to be at sea in the navy. They lived in a council–owned maisonette situated on an estate adjacent to the city centre.

The infants health diary was dominated by early problems of vomiting, from birth to age 4 weeks. This was monitored by the GP and Health Visitor, and subsided on its own. He received antibiotics at 4 weeks for a cold and cough.

He was monitored at 17 weeks of age, during October. At monitoring he was taking four bottles daily with two solids given during the day.

PARENTAL CHOICES

He slept in a cot in a bedroom shared with his sibling. He was placed to sleep in the prone position. He was dressed in 3.5 tog units, with an extra 9.2 units of bed coverings. The parents had very little control over their own heating supply as they had difficulty with their thermostat. The homes were heated from a central boiler on the estate. The maximum room temperature was 24.5°C the minimum 23.9°C. During the night he slept for 9.5 hours without disturbing his parents.

The rectal and ambient temperature patterns for the night, can be seen in Figures A1 and A2.

3) SUBJECT IN COOL THERMAL CONDITIONS DURING THE NIGHT
Thermal Score 24.35   (Subject No. 6)

A female infant born at term by normal spontaneous delivery weighing 5lbs 15½oz (2.41g), with apgar score of 8 at one minute. She was breast fed at birth.

She was the first child of parents who lived in a owner occupied house some 6 miles outside the City centre. The house was a post war semi–detached property. The mother was 30 years of age and a librarian, but planned to become a full–time mother. The father was 31 years of age, a research fellow at Leicester University.

The health diary sheet included snuffles at 6 weeks of age, with no other episodes of illness or concern. At 12 weeks of age she received her first triple vaccine.

She was successfully monitored at 18 weeks post delivery in January, earlier monitorings at 14 weeks were lost when the data logger crashed during monitoring. She continued to be breast fed and was reported to be well.

PARENTAL CHOICES
She slept in her own room in a cot, and was always placed supine. She was dressed in clothing of 5.2 tog units, with a further 7.0 tog units added at bedtime.

The home was gas centrally heated controlled by thermostat at 19°C. At midnight the heating went off and came on again at 3am. The room maximum temperature was 20.8°C falling to a minimum of 12.15°C during the night. She slept for a total of 10.5 hours waking after 7.5 hours for a breast feed.

The rectal and ambient temperature patterns for the night, can be seen in Figures A1 and A2.
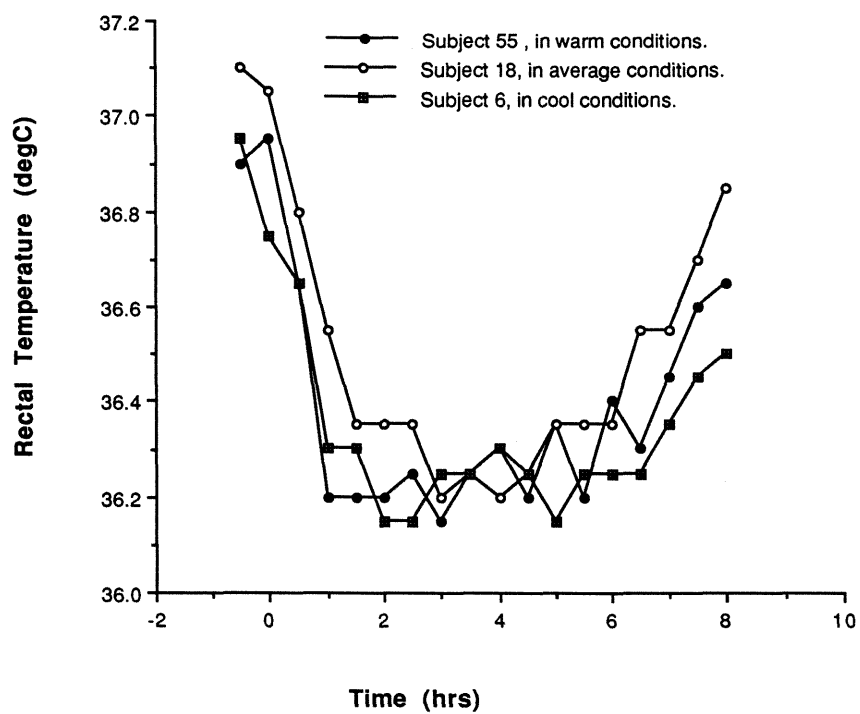
Fig. A1 The pattern of rectal temperature during 8 hours night sleep, in three subjects.
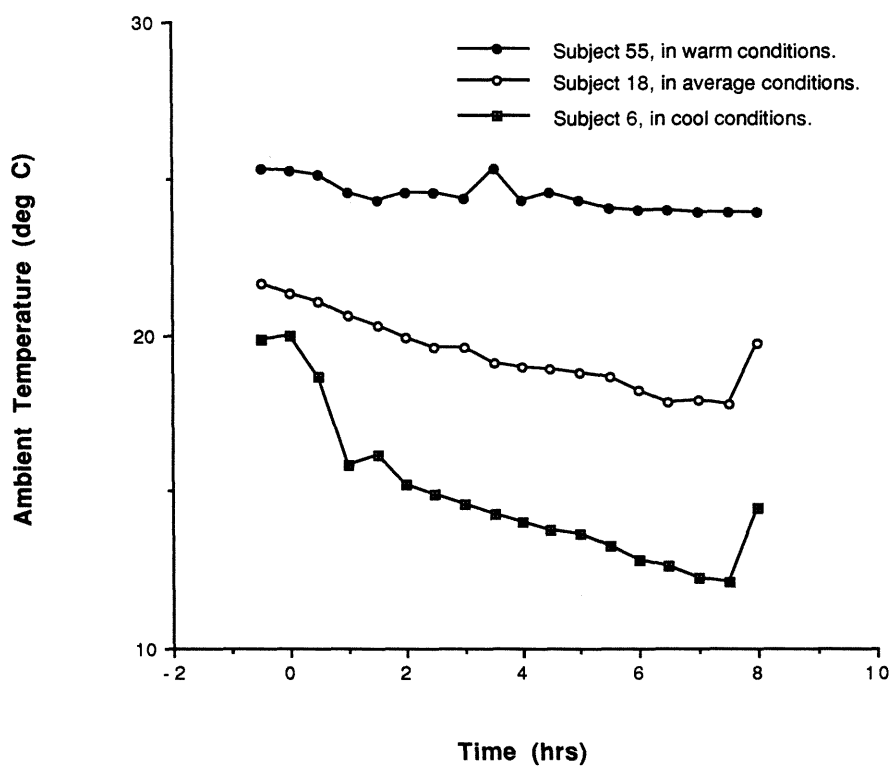
Fig A2. The pattern of room temperature during 8 hours night sleep,
in three subjects.