A longitudinal study of growth and nutritional status of Glasgow infants from birth to 2 years

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SUMMARY

Introduction

A longitudinal study was undertaken in Glasgow to assess the growth and nutritional status of a representative sample of 127 healthy infants, born in 1992-3, from birth-2 years. Weight, length, triceps and subscapular skinfold, head, mid-upper arm (MUAC), calf and thigh circumference were measured monthly till 6 months then at 9, 12, 18 and 24 months. Body mass index, sum of skinfolds and mid-arm muscle circumference (MAMC) were obtained from the above measurements.

Aims

1. To assess and describe growth and nutritional status of Glasgow infants and to compare with other data sets.

2. To identify factors which influence growth and nutritional status.

3. To assess feeding and weaning practice, compare with other UK data sets, and to identify factors influencing feeding and weaning practice.

Comparison with reference values

For weight in the first 4-5 months both boys and girls had values which were substantially greater than 'Tanner and Whitehouse' standards (Tanner et al, 1966). At 2 months distributions of Glasgow infants were substantially positively shifted when compared with 'Tanner and Whitehouse' data for both boys and girls. Weight was more similar to the 'UK 1990' reference values (Freeman et al, 1995) and the 'Revised UK 1990' references (Freeman et al, 1996). Growth in the second six months of life was more similar for Glasgow infants and the other data sets. By 2 years, however, Glasgow

boys were heavier than 'Tanner and Whitehouse' and the 'UK 1990' and 'Revised UK 1990' references (Savage et al, 1996a; Savage et al, 1998b).

For length, differences between Glasgow infants and 'Tanner and Whitehouse' and 'UK 1990' references were much less marked. The most noticeable difference was for Glasgow girls at 3 months who had a lower mean value when compared with 'UK 1990' both initial and revised data. Length of Glasgow girls was negatively shifted compared with 'UK 1990' references for girls. However, at two years both boys and girls from the Glasgow sample were longer than 'Tanner and Whitehouse' and 'UK 1990' references (Savage et al, 1998b; Savage et al, 1996a).

Triceps and subscapular skinfolds were compared with the older 'Tanner and Whitehouse' (Tanner and Whitehouse, 1975) and more recent data from Cambridge (T.J. Cole personal communication). For both triceps and subscapular skinfolds Glasgow infants had substantially lower values when compared with 'Tanner and Whitehouse' but were much closer to the Cambridge values although slightly higher. This difference is probably due to differences in feeding and weaning practice between samples. The 'Tanner and Whitehouse' data were collected in the late 1960s when breastfeeding rates were low and introduction of solids extremely early. The formulas used were less modified and more energy dense than to-day. The Cambridge sample had high breast feeding rates and fairly late introduction of solid food when compared with Glasgow infants.

Factors influencing growth and nutritional status

We tested the influence of gender, feeding practice, timing of weaning, social class and mothers' smoking habit during pregnancy on growth and nutritional status.

There was a clear gender difference: boys at one year had greater measurements than girls except for thigh circumference and skinfolds. Boys gained more weight, length and head circumference in the first year than girls but no other differences in velocity were found for any other measurements.

There were few differences between breast and formula-fed infants. The only difference in boys was for head circumference with breast-fed infants having greater head circumference at 12 and 24 months. Body mass index (BMI) at 12 months and gain in BMI over the first year were greater in the formula fed girls when compared with breast-fed girls.

No significant differences were found in boys between those weaned early and those weaned later. For weight, length, head circumference, MAMC and thigh circumference early weaned girls had greater measurements at some if not all ages than those weaned later (Chapter 3; Savage et al, 1996b).

There were some differences in growth and nutritional status between social classes. This applied mainly to girls in the second year of life. Girls from social classes I and II had greater head circumference, calf circumference and sum of skinfolds at 24 months and greater gain in weight, head circumference, MUAC, calf circumference, sum of skinfolds and triceps skinfold over the second year of life compared with those from lower social classes.

Mothers who smoked during pregnancy had infants with smaller anthropometric measurements at one month but these differences had disappeared by the end of the first year.

Feeding and weaning practice

Feeding and weaning practice were similar to that found for Scotland by the OPCS 1990 Infant Feeding Report but also fairly similar to that found for the rest of the UK (White et al, 1992). Timing of introduction of solid food was similar in three data sets. At 3 and 4 months Glasgow had more infants weaned than either Scotland or the rest of the UK. By 6 months nearly all infants from all three data sets had been weaned. Factors found to influence feeding and weaning practice included maternal age, social class, educational attainment and birth order (Savage et al, 1994; Savage et al, 1998a).

Conclusions

In summary, the present study represents a detailed investigation of growth and nutritional status in a representative sample of Glasgow infants which was well characterised. Such studies are rare and there is a great necessity for them (Dept of Health, 1994). The study allowed us to (1) confirm the need for newer anthropometric reference data, (2) identify some of the factors which influence infant growth and nutritional status in a representative sample not characterised by abnormal feeding practices and (3) confirm the non-compliance with the guidelines for feeding and weaning practice and identify factors associated with compliance.

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ABBREVIATIONS

ADI - average daily intake

BMI - body mass index

DARLING - Davis Area Research on Lactation Infant Nutrition and Growth

GGHB - Greater Glasgow Health Board

HUMAG - Human Measurements Anthropometry and Growth

IHD - ischaemic heart disease

LDL - low density lipids

LRNI - lower reference nutrient intake

MAFF - Ministry of Agriculture Fisheries and Food

MAMC - mid arm muscle circumference

MUAC - mid-upper arm circumference

NCHS - National Centre for Health Statistics

NHANES - National Health and Nutrition Examination Surveys

NSHG - National Study of Health and Growth

OPCS - Office of Population Censuses and Surveys

RNI - reference nutrient intake

SD-score - standard deviation score

WHO - World Health Organisation

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Introduction

1.1 Basic biology of growth and nutritional status

1.1.1 Introduction

Growth during the first year of life is critical in determining health and disease in later life. There has been much discussion since the work by Barker on the importance of growth and nutrition in early life and its effect on later health and disease.

Growth is very rapid in early infancy, with infants typically doubling their weight in the first four months and trebling it by one year. With high rates of growth and low nutrient reserves infancy and early childhood are periods of particular risk for growth failure and undernutrition (Kings Fund, 1992). Monitoring growth is the most useful assessment of nutritional well-being and an essential part of child health screening (Reilly, 1997).

Nutritional assessment is the evaluation of nutritional status of an individual. There are five approaches to nutritional assessment, anthropometry; dietary; biochemical; clinical and functional. By carrying out a nutritional assessment undernourished or overnourished children can be identified; the nutritional effects of any intervention or therapy can be monitored; the prevalence of under or over nutrition in a group can be determined (Reilly, 1997).

In the UK, and especially in Scotland many infants are not fed as recommended (White et al, 1992). Normal growth of infants must be described, and may serve as reference values against which growth can be assessed. Until recently the standards used to assess growth and nutritional status in infants in the UK were very old (Tanner et al, 1966). These standards have recently been replaced by new UK reference data (Freeman et al, 1995) which should be more applicable although they are as yet largely untried in clinical practice. Since these new data were published in 1995 they have already been revised (Preece et al, 1996).

Changes in rate or pattern of growth due to secular trends and/or differences in feeding practice, should also be assessed in order to determine the adequacy of growth references. Studies previously carried out in the UK have compared growth of infants today with that when the 'Tanner and Whitehouse' data were collected and have found marked differences in early infancy (Wright et al, 1993; Whitehead et al, 1989). Although the new references were much better, differences were found between them and the first version published in 1995 (Wright et al, 1996).

Glasgow has been thought for many years to have a very bad nutritional record with many people not following 'healthy eating' guidelines. There is also a perception that infant feeding in Glasgow is different from that of the rest of the UK or perhaps even to the rest of Scotland. If the feeding and weaning practice is different then perhaps the growth also differs. On the other hand it may be that infants in Glasgow are not being fed that differently from other infants in Scotland and the UK. Only a limited number of longitudinal studies where diet and growth are described are available anywhere in the world and the present Glasgow study is valuable in giving a clearer description of growth and nutritional status of infants and of the relationships between feeding and weaning practice and growth and nutritional status.

The present study, although a separate study in its own right, was also part of a larger European study (Euronut) where growth and nutritional status were examined in 23 European countries. Glasgow was the only UK cohort from this study although there was another cohort from Eire. Other countries involved in the study include France, Germany, Holland, Sweden, Spain and Greece.

1.1.2 Malnutrition

Poor growth in infancy or childhood is the first clinical sign of a condition needing treatment such as malnutrition. Ratios of weight and height with age have been used for many years to describe degrees of malnutrition (Waterlow, 1976). These degrees of malnutrition are called "wasting" and "stunting". Wasting is defined as a deficit in weight for height (using National Centre for Health Statistics (NCHS) references), where the individual or group is 80% or less of expected weight for height. Stunting is defined as a slowing of skeletal growth and is where the individual or group is 90% or less of expected height for age. A variety of other indices, all of which attempt to adjust weight for height, have also been used to define malnutrition (Wright et al, 1994a; Reilly, 1997).

1.1.3 Measurement of total body fat

Defining nutritional status using weight adjusted for height is rather crude (Reilly, 1998). An alternative is to define over or undernutrition on the basis of body fatness (Lohman, 1993). When estimating nutritional status it is sometimes desirable to estimate total body fat. Under water weighing is usually used as the reference method in adults and older children for assessing body fat (Durnin and Womersley, 1974), however, this is an impossible measure to make in infancy. Measurement of skinfold thickness is a simple and widely used method of predicting body-fat in adults (Durnin and Womersley, 1974). However, its use in infancy and childhood to predict percentage body fat has not been validated. There is increasing recognition that the extrapolation of skinfold thickness to percentage body fat makes a number of assumptions and is fraught with problems (Davies and Lucas, 1989). However, skinfold thickness can be used as an indicator of nutritional status even if percentage body fat cannot be obtained. Other methods used to predict total body fat in infancy include total body water by dilution (Davies and Lucas, 1989) and impedance (total body electrical conductivity) measurements (De Bruin et al, 1996). However, these methods of assessment are complicated and expensive and not suitable for routine assessment in large samples of infants (Reilly, 1998).

For this reason, the studies in this thesis focused on anthropometric proxies for body composition rather than measurements of body composition.

1.1.4 Low birthweight infants

There has been a decline in the amount of stillbirths and infant mortality since the 1960s but the incidence of infants born with a low birthweight (<2500g) has remained relatively constant, around 7% in the UK. This is a greater proportion than is found in most other European countries .

There are several disadvantages of infants being born with a low birthweight which include a greater prevalence of neurological and developmental handicap. Poor fetal growth is also associated with decreased intellectual achievement (Pharoah et al, 1994) and impaired health in later life (Ravelli, 1976; Barker et al, 1993).

Infants born with a low birth weight (LBW) are usually grouped depending on their gestational age. Some infants are born full-term but are small, usually referred to as small for gestational age infants (SGA) and some infants are born prematurely and this is the reason for their deficit in weight (pre-term). Low birthweight infants have been found to grow differently to normal weight infants but, more importantly, among the LBW infants growth differs depending on whether the infants are SGA or preterm (Cruise, 1973). The growth velocity of preterm infants is greater than SGA infants and at one, two and three years the SGA (37-42 weeks gestation) infants had smaller mean measurements than preterm infants (both 28-32 and 33-36 weeks gestation) (Cruise et al, 1973).

1.1.5 Fetal and infant origins of disease in later life

Studies have been carried out by Barker and colleagues in Southampton (Barker, 1992) to assess the long term effects of nutrition in early life. Before these studies were carried out there was very little information on this subject, probably due to the complexity of these issues and long term time scale involved.

Studies have been carried out in animals which showed the effect of nutrition in early life (Winick and Noble, 1989). These have shown that early life is an important time for organ development and this is vulnerable to long term programming by environmental factors, one of which is nutrition. Organs and tissues in the body mature during periods of rapid cell division before birth and during infancy and different organs mature at different rates. During periods of undernutrition the organs under rapid cell division will be most vulnerable. In the Barker studies, lower weight at birth and at one year has been taken to indicate that a baby was subject to a sub-optimal environment in utero and/or in infancy.

Strong links have been found between poor growth in early life and the incidence and risk factors of ischaemic heart disease (IHD). Data from Hertfordshire on 5000 men born between 1911 and 1930 showed that cause of death in these men was related to birthweight and weight at one year (Barker et al, 1989a). Men with the smallest weight at one year had greater IHD mortality. A similar pattern was also found for mortality due to stroke and obstructive lung disease.

Another study traced men born from 1920-1930 in Hertfordshire who were still living in the area and measured risk factors for IHD such as blood pressure, body mass index (BMI), waist/hip ratio, serum lipid, fibrinogen, factor VII and glucose tolerance. All of the above factors were found to have a relationship with birthweight, weight at one year or both (Hales, et al, 1991; Barker et al, 1992a; Fall et al, 1992; Law et al, 1992). Those infants with the lowest birthweight were found to have the highest blood pressure. This relationship has also been found in other studies of men and women of different ages (Barker et al, 1990; Barker et al, 1989b) and also in children (Law et al, 1991).

This has been investigated further with not only weight being examined but also length and head circumference. Men and women born in Preston and Sheffield maternity hospitals before the mid 1940s were examined. Abnormalities in their metabolism were found to be associated with specific patterns of uneven growth. Thinness and stunting at birth was found to be a predictor for high blood pressure in later life (Barker et al, 1992b). Thin babies identified by being below mean weight and head circumference at birth (thin babies) and short babies, above mean for weight and head circumference but below mean for length (short babies) were found to have higher blood pressure in later life. The mechanisms of these infants developing high blood pressure probably differ due to different times when the fetus was subject to adverse conditions. For thin babies this is thought to be during mid-gestation and for short babies near the end of gestation. It is postulated that thin babies have a different physiology and metabolism in later life than short babies. Thin babies are more likely to develop insulin resistance and syndrome X whereas short babies have raised levels of plasma fibrinogen (Barker et al, 1993). For thin babies this may be due to the fact that they lack muscle which is the main site where insulin works. There is then a deficit of the normal response to insulin which may lead to some problem with insulin later in life, for example onset of diabetes.

The ratio of placental weight to birthweight is another predictor of high blood pressure in later life (Barker et al, 1990). The highest blood pressures were found in men and women who had a high placental weight to birthweight ratio. A study in Oxford has shown that high placental weight was found to be associated with maternal anaemia and a fall in mean cell volume in pregnancy (Godfrey et al, 1991).

Glucose tolerance in later life was also found to be related to early growth (Hales et al, 1991). Men who had the lowest birthweights and weight at one year were found to have the lowest glucose tolerance. When BMI in later life was examined it was found that men who were small at one year but who had a high body mass index in later life were found to have the lowest glucose tolerance (Hales et al, 1991).

It has been suggested that all these effects may be confounded by other factors, however, these conclusions were not affected when adjusted for smoking, obesity and social class.

For the study in Hertfordshire (Fall et al, 1992) infant feeding practices were recorded. Breast or formula feeding was recorded and the age when breast-fed infants were weaned from the breast. The mortality of IHD related to infant feeding was examined (Fall, et al, 1992). Men who were bottle-fed from birth and those who had been breast-fed longer than one year had higher IHD mortality rates and serum levels of total cholesterol, low density lipids (LDL) cholesterol and apolipoprotein B than those men who had been weaned from the breast before one year and who had been breast and bottle-fed. No information was given on introduction of solid food, probably because this information was not collected.

These studies are important in showing that growth and nutritional status in early life has long term consequences. This provides an additional argument for improved means of assessing growth and nutritional status in early life. It is also important to establish which factors affect growth and nutritional status in infancy and early childhood.

1.1.6 Growth

Weight faltering can occur at any time but is more common during and after weaning. Poor weight gain or growth has many causes, for example, genetic or emotional factors or nutritional factors (not getting enough of the correct food, difficulties in suckling or swallowing, vomiting, malabsorption or an inability to utilise food because of infection or metabolic disease).

The regulation of growth during infancy is different from the regulation during childhood. It is not well understood but nutrition seems to play a major role during infancy (Karlberg et al, 1994). The role of growth hormone becomes more important after infancy which is then modified by sex hormones during puberty. It is for this reason that Karlberg has suggested a growth model, the ICP model, which divides growth into three components, **infancy**; **childhood** and **puberty** (Karlberg et al, 1994). Therefore, growth can be limited by nutrition in early life.

1.1.7 Growth charts

Reference data are central to nutritional assessment, but reference data for infancy used until recently have been limited. Secular trends in growth, and changes in infant feeding practice (Chinn et al, 1989; Whitehead and Paul, 1984; Wright et al, 1993; Tanner et al, 1966) have led to the need for new reference data sets. Reference data are often used as growth 'charts', based on measurements in apparently healthy children.

A growth standard or reference is defined as "a dataset representing the distribution of a given anthropometric measurement as it changes with a co-variant (usually age) in the two sexes, based on a specific reference sample of children" (Cole, 1993). The distribution is usually summarised by centiles including the median (50th centile). The mean and standard deviation are sometimes also given. Conventionally seven centiles are given which are symmetrical about the mean (e.g. 3rd, 10th, 25th, 50th, 75th, 90th, 97th) including extreme values (3rd/97th or 5th/95th). The most recent UK charts (Freeman et al, 1995) however use 9 centiles (0.4th, 2nd, 9th, 25th 50th, 75th, 91st, 98th, 99.6th).

The term 'growth standard' is ambiguous. Does it represent ideal growth or is it reference growth. For example, if a growth standard based on children from a developed country was used to assess growth of children from a developing country then this might be unhelpful as most children will fail to meet the measurements. Growth standards are better not used as a norm as this implies that they represent optimal growth which is a wrong assumption. A larger child is not necessarily a healthier child. For height, differences are found between different populations. Men from the Netherlands are on average 5 cm taller than those from the USA (Hamill et al, 1977, Tanner and Davies, 1985; Van Wieringen, 1985). For the above reasons the term reference data is usually preferred.

This leads into the discussion of whether international or local reference values should be used. An international standard is useful for comparing the growth of different populations and for use where national reference values are not available. International standards will however be inappropriate for growth in some regions of the world.

The National Centre for Health Statistics (NCHS) (Hamill et al 1977) has been adopted by the World Health Organisation (WHO) as an international standard (WHO, 1983). However, the data used in the construction of these standards is over 30 years old and has been found to be inappropriate for growth of infants in the UK (Wright et al, 1993). Local reference charts are needed to provide appropriate reference data for infants and young children.

There are two main ways of collecting data on growth: cross-sectional or longitudinal studies (Gibson, 1990; Reilly et al, 1997). Cross-sectional studies are fairly easy to carry out and can produce data quickly. Individuals are measured once and mean and median values of the measurements are calculated at various ages. Cross-sectional data does not provide any information on the velocity of measurement over time. The samples used to construct any growth chart should be reasonably large and representative of the population they are to assess. They provide useful information on the average measurement attained at various ages over time.

A longitudinal study, as well as providing information on the attained measurement at each age, can also provide information on the change of measurement over time. As growth during infancy is extremely rapid, especially in the first six months of life, measurements taken to construct growth charts should be monthly over this period. In the second six months of life growth velocity has slowed a little and the measurements can be less frequent. In the second year of life six monthly measurements should be adequate (Gibson, 1990).

When assessing velocity of growth in an individual infant or child from growth charts longer periods are most useful. Measurement of growth velocity over, for example one month, is too short a time period because the velocity will be subject to greater measurement error as two measurements errors are included whenever growth increments are measured (Gibson, 1990). The greater the time between the two points the greater the velocity and hence the measurement error will be a smaller proportion of this measurement.

Comparison of a measurement with reference data can be done in three ways:-

1. Centiles

The centile position of the measurement can be given.

2. The SD-score of the measurement can be worked out using the following equation.

$$\text{SD-Score} = \frac{\text{measurement - median of the reference population}}{\text{SD of the reference population}}$$

3. Percentage of reference median.

The measurement can be given as a percentage of the reference median.

One aim of the present study was to provide longitudinal data on the growth and nutritional status of a representative sample of normal, healthy infants in a well-conducted study where extensive information on the parents and infants was also collected. The study will allow us to examine growth charts currently in use and examine whether they are adequate for use in clinical practice.

1.1.8 Conditional reference charts

It is recognised now that the old style of centile charts are of limited use for assessing growth. Growth charts can only identify infants at a low centile or who are falling across centiles. Cole has provided conditional reference charts (Cole, 1995) which will compare an infants current weight with that expected from their previous recorded weight accounting for the phenomenon of "regression to the mean" (that is that on average light infants tend to grow faster than heavier infants). This a statistical phenomenon and states that children at the extremes of the distribution will move towards the average. These conditional references were constructed from the 'UK 1990' weight references (Freeman et al 1995). The data were supplemented with data from 223 infants from the Cambridge Infant Growth Study who were measured between four weeks and two years. This reference was also validated using data on 727 infants from the Newcastle Regional Health Authority database.

Another method, similar to this, was set up in Newcastle to identify failure to thrive in infancy and early childhood (Wright et al, 1994). The index used here, the "thrive index", is based on conditional references and also corrects for "regression to the mean". The thrive index is the discrepancy between the child's predicted and expected growth based on previous data.

1.1.9 Secular trend in growth

Now that the new reference values for growth and nutritional status are available (Freeman et al, 1995; Cole et al, 1995) the differences between these and the 'Tanner and Whitehouse' charts were examined (Freeman et al, 1995). There was an overall increase in stature between the time of data collection by 'Tanner and Whitehouse' (Tanner et al, 1966) and the 'UK 1990' reference values. This reflects a trend towards earlier maturity and greater adult stature and weight compared with earlier generations. Previous studies were carried out to investigate this secular trend. Voss and co-workers examined the weight and height of children starting school in Southampton and Winchester health districts (Voss et al, 1987). The proportion of children falling below the 3rd centile for stature of 'Tanner and Whitehouse' was examined and it was found to be only 1.4% suggesting that children from this area were taller than the 1950s when the 'Tanner and Whitehouse' data were collected.

Two other studies did not find any secular trend when compared with the 'Tanner and Whitehouse' data. The first was carried out by Rona and Altman (Rona and Altman,

1977) and compared the 1972 National Centre for Health and Growth (NSHG) data with 'Tanner and Whitehouse'. The other study was conducted in Leeds and like Voss et al assessed children starting school (Buckler, 1985). They found that children of this age were similar in growth to 'Tanner and Whitehouse' data. Both studies, however, made the conclusion that this may be catch up growth of these populations with the wealthier 'Tanner and Whitehouse' sample from South East England, primarily London. It may be that Glasgow is in a similar situation to Leeds. The present study is important in that it will allow us to examine growth and nutritional status of Glasgow infants and compare it with that of the older and most recent reference values.

One common misconception found in most of these studies comparing the data of 'Tanner and Whitehouse' was that data were collected in 1966. This, however, was when the data were published and not when they were collected which was from 1952-54 (Tanner et al, 1966).

The secular trend from 1972 to the present day has also been examined (Rona and Altman, 1977) using the National Study of Health and Growth data of growth in primary school children. The differences found from this comparison ranged from 0.5 cm in the youngest girls (4.5 years) to over a centimetre in the oldest boys (12 years). This study also found differences in different regions and for different ethnic groups.

Studies from America have shown that over the years there has been a trend towards increased infant and childhood obesity (Dietz et al, 1986; Gortmaker et al, 1987). This may also be the case in the UK and, therefore, UK studies which examine growth and nutritional status will allow us to observe this.

1.1.10 Anthropometry

The assessment of growth and nutritional status by objective anthropometric methods (e.g. weight, length, head circumference, body mass index, skinfolds, mid-upper arm circumference) is central to the identification of growth failure and undernutrition (Cross et al, 1995), but surveys (Moy et al, 1990; Hendrickse et al, 1997) have shown that these measurements are rarely carried out. This reflects failings in medical education (Moran and Jackson, 1995) and the common assumption that simple anthropometric measurements cannot be made by the non specialist with accuracy and precision in infants: this assumption is incorrect (Doull et al, 1995; Betts et al 1992).

Weight, length and head circumference are the three measurements most routinely made on infants in the UK and these are usually carried out at a baby clinic. At birth all infants are weighed, with some but not all infants having length and head circumference taken. After birth, measurements are made at key ages throughout infancy and childhood usually limited to weight and length (before 2 years) or height. Other measurements which are sometimes made are limb circumferences and skinfolds although these are usually only measured in research studies of growth.

Length (or stature), often referred to as linear growth, is an index of skeletal development of the child. Weight, skinfolds and limb circumferences are more difficult to interpret. They are indices of growth, but also give some indication of nutritional status. Weight on its own is a poor indicator of nutritional status, however, when combined with length is much more useful (Gibson, 1988). Weight for length and/or body mass index, BMI, (weight/length^2) are indices of whether the child's weight is appropriate for its length and in the case of BMI, age is also taken into account. Slight differences in the timing of the rise in BMI can lead to centile crossing, therefore it may be difficult to interpret BMI in infancy (Cole et al, 1995).

Head circumference is also an important measurement of growth as it is closely related to brain size. The brain triples in size during infancy and reaches more than 90% of its adult size by two years of age (Dobbing and Sands, 1973).

1.2 Growth standards/references for weight, length and head circumference

In this section the reference studies for growth will be described and discussed.

1.2.1 International standards

National Centre for Health Statistics (NCHS)

The United States Standards from the National Centre for Health Statistics (NCHS) are recommended by the World Health Organisation (WHO) as an international standard (Hamill, 1977 and Hamill et al, 1979). For children up to 3 years of age the data used to construct these standards were from the Fels Institute for Research (Roche and Hiimes, 1980), collected between 1929 and 1975. This is a wide time period covering children who were born more than 40 years apart. Even the most recent measurements collected are now over 20 years old. In the Fels study 867 children were followed longitudinally but like most studies at this time did not pay enough attention to early infancy where growth is extremely rapid. Measurements were made only every three months in the first year and 6 month intervals in the second year.

Roche and colleagues published reference data for the first year of life based on NCHS data (Roche et al, 1989). One month increments were constructed by extrapolation from the three monthly measures for weight and recumbent length using serial data from 504 infants from the Fels study.

1.2.2 National standards - UK

'Tanner and Whitehouse' Standards

The growth standards which were most commonly used in the UK until recently were those of 'Tanner and Whitehouse' (Tanner et al, 1966). The data for the 'Tanner and Whitehouse' standards were collected between 1952 and 1954, over 40 years ago, and were based on the data of Moore, Hindley and Falkner (Moore et al, 1954). As with the NCHS study this was also longitudinal and followed 160 infants (80 male, 80 female) again with measurements made only at three month intervals. Head circumference data are only available from age two years and upwards.

Gairdner and Pearson Paediatric Standards

The paediatric standards of Gairdner and Pearson for weight and length (Gairdner and Pearson, 1971) were based on the same data as 'Tanner and Whitehouse' standards between 0-24 months. Head circumference data for 0-2 years did not come from 'Tanner and Whitehouse' but from Harvard data (Nelson, 1964). The preterm data came from two other sources; weight 32-40 weeks gestation from Tanner and Thomson, 1970 data from Aberdeen infants, weight at 28 weeks gestation from Babson, 1970 and length and head circumference 28-40 weeks gestation also from Babson, 1970.

British Ministry of Health Standards

The British Ministry of Health Standards (Ministry of Health, 1959) enrolled 17,308 infants in a longitudinal study and the data were collected between 1949-1950. The infants were weighed every month and allowing for drop-outs as many as 10,039 were still participating at 12 months. Infants attending welfare clinic from eleven areas from England and Wales were selected (Birmingham, Bristol, Cardiff, Kent, Leeds, Liverpool, London, Northumberland, Middlesex (Finchley), Norwich and Glamorgan (Rhondda)). This was an enormous number of infants and rarely did this study receive the credit or attention it deserved. The one disadvantage of this study is that only weight was measured in these infants.

New 'UK 1990' reference values

New UK Reference values are now available which are based on more frequent measurements in early infancy and these are given for weight, length (Freeman et al, 1995), BMI (see later) and head circumference. The new charts cover the age range 0-20 years and new centile positions are used in these charts giving nine centiles (0.4th, 2nd, 9th, 25th, 50th, 75th, 91st, 98th, 99.6th). Only 8 out of 1000 children will lie outside the nine centile range and it is recommended in clinical practice that these children should be referred immediately (Cole, 1994).

Construction of stature reference curves are relatively easy as the distribution of the data is Gaussian (Van't Hoff et al, 1985). For other anthropometric measurements this is not the case. In order to take this into account centile curves can be estimated using Cole's LMS method which adjusts for skewness and allows measurements for each individual to be described as an SD-score or an exact centile (Cole, 1988; Cole and Green, 1992). This method normalises the data at each age using a Box-Cox power transformation. The centiles at each age are then given as the Box-Cox power needed to make the distribution normal (L), the median (M) and the coefficient of variation (S) of the distribution. The fitting process ensures that the LMS values change smoothly with age and that the centile curves are smooth. Centiles constructed by the LMS method allow data to be converted directly to SD-Scores using the following equation:-

$$\textbf{SD-Score} = \frac{(\textbf{Measurement}/\textbf{M})^{\textbf{L}}-1}{\textbf{LS}}$$

These new charts were constructed from seven different sources of data within the UK:-

1. Human Measurements Anthropometry and Growth (HUMAG) Children's' growth studies

2. HUMAG Adults Anthropometric Measurements Study

3. National Study of Health and Growth (NSHG)

4. Statures and Weights of Adults in Great Britain

5. Tayside Growth Study

6. Cambridge Infant Growth Study

7. Whittington Birth Data Study.

Three of the above studies were used to construct the charts for the first two years of life:-

1. HUMAG Children's Growth Study

2. Cambridge Infant Growth Study

3. Whittington Birth Data Study.

HUMAG Infant Growth Study

This study was conducted by the HUMAG Research Group at Loughborough University (British Standards Institution, 1990) and was sponsored by a syndicate of British retailers and garment manufacturers. The samples for the infants and toddlers were recruited in 1987. One sample included 0-1.99 year old infants and the second 2-4.99 year olds. Sixteen areas in England and Wales, of approximately equal size, were chosen and the mothers were selected from social service departments, nursery schools, the National Childbirth Trust and mothers and toddlers groups. Other information (age, sex, area of residence and ethnic group) were also collected although no socio-economic data were available. Infants were measured in nappies and older children in minimal clothing. No adjustments to weight were made for clothing.

Cambridge Infant Growth Study

The Cambridge Infant Growth Study began in 1984 at the Medical Research Council's Dunn Nutrition Unit, Cambridge. The study was set up to study the effects of different feeding practices on infant growth (Whitehead and Paul, 1984). The infants were from four cohorts recruited from 1984-88 giving a total of 252 infants and were studied to between 2-7 years of age. Only the first two years of data were included in the new reference values. Gestational age, other anthropometry and socio-economic data were also collected. Infants were measured in light clothing to the nearest 10g with the clothing weight deducted. All measurements for this study were carried out by a single observer. The Cambridge Infant Growth Study can also be considered as a separate growth reference.

Whittington Birth Data Study

This was a fetal growth study which was carried out at Whittington hospital in London over a six month period in 1987-88. Infants at 32 weeks gestation and above were recruited, although only the 756 white infants were used for the reference values (9 sets of twins and one set of triplets were included in these). The measurements made were birthweight and day two length. Gestational age, age of the mother and parity were also collected. Infants were weighed naked to the nearest 10g and all measurements were carried out by a single observer.

Differences were observed between the data sets used to make up the 'UK 1990' references probably because not all the studies were carried out on representative samples. Cambridge is one example of this with a higher incidence of breast-feeding and later introduction of solid food than mothers in most other parts of the UK (White et al, 1992; Whitehead and Paul, 1986). For this reason the most recent study NSHG was chosen as a reference data set. Comparability between the data sets was obtained by adding or subtracting the differences relative to NSHG data set. The estimates of differences between data sets, assumed to be constant, were produced by a linear modelling procedure using multiple regression.

Newcastle Failure to Thrive Study

Routine weight data were collected on a complete annual cohort of Newcastle children (3418) aged 18-30 months (Wright et al, 1993). The birthweight and up to six other weights between birth and 18 months were collected. The cohort was a representative sample of full-term infants born in Newcastle. The data from these children were compared with the standards of 'Tanner and Whitehouse', National Centre of Health

Statistics (NCHS) and also to the more recent growth study of Cambridge infants (Wright et al, 1993).

When compared with 'Tanner and Whitehouse' the Newcastle children had a mean weight SD-score of around 0.5 at 6 weeks which then fell 0.7 SD between 6 weeks and 18 months. When compared with the NCHS the same pattern was observed. When compared with the more modern standards from Cambridge a much closer match was observed. However, Newcastle children tended to be slightly heavier from 6-18 months (Wright et al, 1993).

Differences for length and more markedly for weight and head circumference were found between the older charts ('Tanner and Whitehouse', 'Gairdner and Pearson' and NCHS) and the most recent ('UK 1990' References and Newcastle data) suggesting there were secular changes in these measurements over time. This may be due to differences in feeding and weaning practice at the times when the data were collected.

Iowa and Harvard Growth Studies

Other standards available include the Iowa and Harvard standards from America. The Iowa study used cross-sectional data from 550 subjects collected between 1926 and 1940. This study consisted of mothers from higher socio-economic classes attending a university well-infant laboratory (Jackson and Kelly, 1945). The Harvard study, however, was longitudinal and followed 228 Boston children (111 boys, 117 girls) between 1929 and 1939 (Stuart and Stevenson, 1959 and Stuart and Reed, 1959). The children from this study were low to middle socio-economic status.

Dutch Growth Standards

The Dutch standards were based on cross-sectional data of 5,800 subjects collected between 1964 and 1966 (Van Wieringen, 1971). However, it must be noted that, as with the UK, the majority of mothers at this time formula-fed rather than breast-fed and the formulas available were the older ones.

More recent data of growth in length and weight from birth-2 years of age are available for a representative sample of Dutch infants born in 1988-89. Growth of this cohort was examined with reference to socio-economic status and other characteristics (Herngreen et al, 1994).

Swedish Growth Standards

There are two sets of Swedish standards available. The data for the older set (Karlberg, 1976) was collected in 1955 on 122 boys and 90 girls followed longitudinally and recruited from a maternity clinic in Solna, a suburban area of Stockholm. The other Swedish standards are more recent and were constructed from a very large representative sample of 2471 children (1264 boys and 1207 girls) followed longitudinally. Standards for weight, height and head circumference are available from 1 month to six years of age (Lindgren et al, 1994).

1.3 Nutritional status standards

1.3.1 Body mass index (BMI) standards

Body mass index (BMI) or Quetelet index relates weight to height and is a useful and simple index of nutritional status. It is calculated as weight/height^2 with weight in kg and height in metres.

Table 1.1 Growth studies in infants and young children.

Study	Years of Study	Type of Study	Sample Size	Measurements	Location
NCHS/Fels	1929-75	Longitudinal	867	weight, length and head circumference.	Ohio (Middle class white children)
'Tanner and Whitehouse'	1952-54	Longitudinal	160	weight, length, head circumference	London (Random sample, central London
Gairdner and Pearson	1952-54	Longitudinal	160	weight and length	London (Random sample, central London)
Gairdner and Pearson	1929-39	Longitudinal	228	head circumference (from 40 weeks gestation)	Harvard (Low to middle socio-economic status)
British Ministry of Health	1949-50	Longitudinal	17308	weight	17 areas of England+Wales
New Reference Values-Cambridge	1984-90	Longitudinal	252	weight, length, head circumference, mid-upper arm circumference, triceps and subscapular skinfolds	Cambridge (Higher socio-economic status)
-HUMAG Infant Growth Study	1978-87	Cross-sectional	9282	weight and length	England+Wales
-Whittington Birth data Study	1987-88	Cross-sectional	756	weight and length	Whittington
Iowa	1926-40	Cross-sectional	550	weight and length	Iowa (higher socio-economic group)
Harvard	1929-39	Longitudinal	228	weight, length and head circumference	Boston (Low to middle socio-economic status)
Dutch	1964-66	Cross-sectional	5,800	weight and length	National Dutch sample
Swedish	1955	Longitudinal	212	weight, length and head circumference	Solna (Suburban area of Stockholm)
	1980	Longitudinal	2471	weight, length and head circumference	Stockholm (National sample)

French BMI standards

The only BMI standards which were available until recently were from France (Rolland-Cachera et al, 1991). Four different samples were used to construct these data:-

1. The first sample, at birth, was from the Paris Area Health Data Centre and was collected between 1980 and 1985. Children were invited to have free health checks at the age of 10 months, 2 years and 4 years. Measurement at birth was obtained from birth records. Any infants who were born at less than 36 weeks gestation were excluded.

2. The second sample, from 1 month till 15 years, was the French sample of the International Longitudinal Study of Growth which was carried out in 7 countries and co-ordinated by the Centre International de L' Enfance (Falkner et al, 1961). Subjects were recruited between 1953-60 and 171 were followed until the end of growth with the last measurements made in 1979. Length was measured until the children were 2.5 years and then height from then on. This sample did not provide any of the birth data.

When sample 1 and 2 were compared for BMI at 10 months, 2 and 4 years no significant differences were found.

3. The third sample was cross-sectional and included 16-21 year old subjects. It was carried out by the Regional Health Institute (IRSA) on behalf of the French national health insurance scheme for wage earners. Data from this sample were recorded from 1976-77 during medical interviews.

4. There were two samples which could have been used to construct the 21 year and older charts, the IRSA (21569 males, 23284 females) and the health survey 1980 made by the National Institute Health Survey for Statistics and Economic Studies (INSEE, 1987). Although the INSEE study was on a representative sample, the weight and height was provided by the subjects themselves. However, when compared to the IRSA data no significant difference was found. The INSEE data was used as it provided information on adults up until at least 85 years old. These charts were constructed using the Cole LMS method which adjusts for skewness and allows the BMI for each individual to be described as an SD-score or an exact centile (Cole and Green, 1992).

New 'UK 1990' reference values

New 'UK 1990' reference values are available for 0-23 years (Freeman et al, 1995) which should be more appropriate for assessing nutritional status of UK children. The BMI references were constructed from the same data as the weight, length and head circumference. These charts were also constructed using the Cole LMS method which adjusts for skewness (Cole and Green, 1992). When compared with the French data the British values were slightly higher.

Tayside Growth Study

BMI charts are available based on the growth of children from Tayside, however, the measurements did not begin on the children until they were 3 years old (White et al, 1995). The Tayside growth study was started in 1989 to assess the incidence and prevalence of short stature in this area of Scotland. Heights and weights of children aged 3, 5, 7, 9, 11 and 14 were obtained by health care workers as part of the routine health checks between 1989-91 (n=34,533).

When BMI from the Tayside study was compared with the French data, Dundee children appeared to be "fatter" than the French children. Two reasons were suggested for this difference. Firstly, it may be that Scottish children are heavier for their height than French children or perhaps it reflects a secular upward trend from 1956-79 when the French standards were collected. More studies should be carried out in the UK to examine if this trend is only confined to Tayside. It has also been suggested that the earlier the adiposity rebound the greater the risk of adult obesity (Rolland-Cachera et al, 1984). Charting BMI during infancy and childhood as well as weight and height may enable us to identify at an early age children who are likely to become obese adults.

National Health and Nutrition Examination Study (NHANES I)

This was the first NHANES study which was carried out in 1971-74 and was part of the NCHS data (Hammer et al, 1991). The data were collected cross-sectionally on 5679 of 1-19 years white individuals. Social class data were collected on the individuals by way of a deprivation index based on family's income and size. However, no significant differences were found between social classes and hence no adjustments were needed.

1.3.2 Skinfold and mid-upper arm circumference standards

'Tanner and Whitehouse' triceps and subscapular skinfold standards

'Tanner and Whitehouse' (Tanner and Whitehouse, 1975) is the standard for triceps and subscapular skinfold used in this country even although the measurements were carried out in the late sixties. However, these measurements were not made on the same sample of children as the sample recruited for weight and length. The data for the skinfold thicknesses from 1 month to 1 year were that collected by Hutchison-Smith in 1966-67

(Huthchison-Smith, 1973). This study was carried out in Bakewell, Derbyshire in the Midland Infant Welfare Clinic where 200 infants were followed longitudinally. For 1 to 5 years the data were from the London Institute of Child Health group of the International Children's Centre Longitudinal Growth Study. About 50-100 children of each age were seen each year by one of three observers and were thought to be a representative sample of children born in the West Central area of London, though there was no formal attempt to confirm this.

Cambridge Infant Growth Study

Studies carried out more recently have found great differences in the skinfold measurements they have taken and those measured for the 'Tanner and Whitehouse' standards. The Cambridge Infant Growth Study measured growth longitudinally and measured both triceps and subscapular skinfolds. From about 6-18 months, the average triceps skinfold in boys for the 'Tanner and Whitehouse' data was 11.5-12.0 mm. The average Cambridge value lay around the 10th centile of the Tanner chart with a value around 8 mm. Other studies have also found similar discrepancies with the 'Tanner and Whitehouse' data (Schulater et al, 1976; Boulton, 1981; Yueng, 1983).

The explanation of these differences either has to be methodological, or lie in real differences in skinfold thicknesses. In the 1960's when data were collected for 'Tanner and Whitehouse' charts breast-feeding was at its lowest in the UK and introduction of infants onto solid food was very early. Formula milks used were not as modified as they are now and in some cases mothers were making the formula too concentrated. In Cambridge, however, feeding practices at the time of collection of data were very different to this and indeed to the rest of the UK. Cambridge has a high prevalence of breast-feeding and late introduction of solid food (Whitehead and Paul, 1986). However, it must be noted that the formula-fed infants from the Cambridge study had skinfolds very similar to those breast-fed. The difference seems then to be linked either to the differences in the formula milks available or the very early introduction of solid food to infants in the 'Tanner and Whitehouse' cohort.

National Health and Nutrition Examination Study (HANES I+II)

Triceps and subscapular skinfold data were collected cross-sectionally on around 14,000 children 1-17 years old. The HANES I survey was conducted in 1971-75 (Miller, 1977) and the HANES II from 1976-80 (McDowell et al, 1981). As stated before these surveys were carried out by the NCHS.

United States Ten States Nutrition Survey

This was a cross-sectional study of 12,396 white United States children and adults aged 0-44 years old carried out in 1968-70. Percentiles for right triceps skinfold and upper arm muscle size are given. The first thing to note from the values for triceps skinfold is that they are very similar to those of 'Tanner and Whitehouse'. This suggests that the difference between 'Tanner and Whitehouse' and the Cambridge standards is not methodological but a real difference of skinfold measurement with time i.e. there has been a secular trend towards lower skinfolds in infancy.

1.4 Biology of infant feeding

1.4.1 Breast and formula feeding

There is no doubt that breastfeeding provides the best nourishment for the infant in the first few months of life (Dept of Health, 1994). Formula milk can not exactly mimic breast milk, as not all components of breast milk have been identified and the purpose of many factors in breast milk which have been identified are unknown. It would also not be economical to include minor factors such as lactoferrin in formula milk as would greatly increase the cost. Advice from the recent COMA report Weaning and the Weaning Diet (Dept of Health, 1994) states that *"breast milk provides the best nourishment during the early months of life. Mothers should be encouraged and supported in breastfeeding for at least four months and may choose to continue to breastfeed as the weaning diet becomes increasingly varied."*. Below are some of the main differences which have been found between breast and formula milk.

Composition of breast milk and formula milk

The composition of breast milk can vary from person to person from month to month, day to day, during the day and also during a single feed. This variation is presumably functional. Formula milks do not have this advantage as they are based on the average composition of mature breast milk.

Protein content

Human breast milk contains less protein than the milk of any other mammal including cow's milk (Akre, 1989). Cow's milk has a whey/casein protein ratio of 20/80 compared with human milk which has a ratio 60/40.

Infant formulas are of two types depending on their ratio of whey/casein:-:

1. *casein dominant* - based on cow's milk protein and have a whey/casein ratio 20/80.

2. *whey dominant* - has modified cow's milk protein to give a whey/casein ratio 60/40 like that of breast milk.

As the whey dominant formulas have a protein ratio most similar to that of breast milk then these are recommended from birth for those infants who are not to be breast-fed at all (Dept of Health, 1994). Even though breast milk and whey dominant formula-milk contain the same ratio of proteins the proteins in each group differ i.e. the human and bovine casein exhibit different structures. β-Casein is the predominant casein in human milk whereas cow's milk has a large proportion of α-caseins (Kunze and Lonnerdal, 1990).

The whey proteins which are found in breast milk include alpha-lactalbumin, secretory IgA (SIgA), lysozyme and lactoferrin. SIgA comprises 90% of the immunoglobulins in human milk compared with cow's milk where IgG is predominant. The purpose of lysozyme in breast milk is to catalyse the hydrolysis of specific molecular bonds in bacterial cell walls and hence it acts as a bactericidal agent by potentiating the effects of immunoglobulins (Adinolfi et al 1966). Lactoferrin is a milk specific iron-binding glycoprotein which aids intestinal iron absorption. It also limits iron availability to potentially pathogenic enteric flora by competing with the bacterial demands for iron (Riordan, 1993).

Amino-acid content

Although the whey dominant formulas have a 60/40 whey/casein ratio similar to breast milk they do not have amino acid levels which are identical. Breast milk has higher levels of cysteine and lower levels of methionine than cow's milk (Jelliffe and Jelliffe, 1978).

Fat content

About half of the energy from human milk is provided by fat. Cow's milk fat is harder to digest than human milk fat. This is due to fatty-acid composition, tri-glyceride positional specificity (Filer et al, 1969) and complementary enzymatic activities that originate in the milk and infants gastro-intestinal tract. Breast milk also has a higher cholesterol concentration than does cow's milk or formula milk (Mellies et al, 1979).

Fatty acid content

Breast milk provides a supply of the long chain polyunsaturated fatty acids (LCPUFA) docosahexanoic acid (DHA) and arachadonic acid (AA) as well as their precursors the essential fatty acids α-linolenic and linoleic acid needed for the developing brain and retinal membranes. Many infant formulas have little or no DHA and AA and some do not even contain the precursor for DHA α-linolenic acid. Formula-fed infants, particularly if premature may be unable to convert the essential fatty acids to the active LCPUFA. In these circumstances other fatty acids are used as substitutes giving different concentrations of LCPUFA in the brain and retinal tissue (Farquharson et al, 1992).

LCPUFA have now been added to some formula milks. A recent study (Willatts et al, 1998) has found that infants fed a formula supplemented with LCPUFA were better at problem solving at 10 months than those fed an unsupplemented formula. The study concluded that term infants may benefit from these supplemented formulas and that the effects persist beyond the period of supplementation.

Carbohydrate content

Lactose is the main carbohydrate in breast milk providing about 40% of the energy content of milk. Cow's milk has much lower concentrations of lactose. Breast milk also contains oligosaccharides. In colostrum (the milk produced in the first few days after birth) these oligosaccharides comprise 27% of the total carbohydrate content falling to 15-16% by 2 months (Coppa et al, 1993).

Micronutrient content

Iron content of breast milk is much lower than that of formula-milk. However, breast-fed infants rarely deplete all of their iron stores before the age of 4 months (Saarinen et al, 1977; Calvo et al, 1992). This is probably due to the efficiency of iron absorption from breast milk (Saarinen et al, 1977; Fomon et al, 1993) with about 50-70 % being absorbed. The absorption of iron from breast milk is enhanced by lactoferrin. Lactoferrin binds two molecules of ferric iron and may facilitate absorption via intestinal receptors. Bovine lactoferrin is not effective in this way and, therefore, iron absorption from formula milk is much less efficient (Saarinen and Siimes, 1977; Fomon et al 1993). A higher concentration of iron is added to formula to combat this problem. Iron in formula milk is in the form of an inorganic salt, usually ferric ammonium citrate only around 10% of which is absorbed (Akre, 1989).

Levels of calcium and phosphorus are lower in breast milk than they are in formula. Calcium is efficiently absorbed from human milk probably due to its high lactose content, composition and structure of fat and low buffering capacity (Scaafsma and deWaard, 1978). Zinc is present in breast milk in small quantities but like iron it has high availability. Zinc levels in formula milks are generally higher than those of breast milk. However, high amounts of zinc will disturb the absorption of copper and iron. Copper, cobalt and selenium are found in greater quantities in breast milk than they are in cow's milk.

Energy content

The average density of mature human milk is generally used as the basis of assessing infants energy requirements. The energy density of human milk was traditionally assessed by analysis of macronutrient content of expressed milk. The mean value of this measurement was found to be 700 kcal/l (Department of Health and Social Security, 1977). This was probably the best estimation at the time, however, it was subject to error. Expressed milk is now thought to have a greater fat content than normal and, therefore, gave an over estimation of fat content and hence energy density than breast milk suckled by a baby (Lucas et al, 1990).

Using the doubly labelled water method for determining energy expenditure it has been possible to determine the energy content of suckled milk. Using this method Lucas and colleagues found that the energy content of human milk to be 530 kcal/l at six weeks and 580 kcal/l at three months. In contrast formula milk had an energy content of 600 kcal/l at six weeks and 660 kcal/l at three months, higher than those values for breast milk. As we now believe that the energy requirements in infancy are 25-30% lower than older estimates (Prentice et al, 1988; Prentice et al, 1990), the energy density of formula milks should be lowered. These findings may explain why some studies find that formula-fed infants are heavier than those breast-fed (Whitehead and Paul, 1984; Dewey et al, 1992). However, it has also been found that breast-fed babies have lower total energy expenditure than formula-fed infants (Butte et al 1990 and Heinig et al, 1993) but this was not replicated in a study in Cambridge where no differences were found between energy expenditure of breast and formula-fed infants (Wells et al, 1995a).

Feeding method and infections

Breastfeeding has been found to protect against many infections and a brief outline of the evidence is given below.

Gastrointestinal infection

There is much evidence that breastfeeding protects against gastro-intestinal infection in developing countries (Habicht et al, 1986). This is probably due to the fact that clean drinking water and facilities for boiling water are not available for making up formula. However, it is less clear whether there is less gastro-intestinal disease among breast-fed infants in developed countries. There has been some concern about the methodology of studies carried out to address this question (Bauchner et al, 1986) and this may be the reason for conflicting views. A more recent study carried out in Dundee (Howie et al, 1990) met these methodological criteria (avoidance of detection bias, adjustment for confounding variable, definition of outcome events and a definition of infant feeding) and found that breast-feeding did confer some protection from gastro-intestinal infection. They found that infants who were breast-fed for at least 13 weeks had a reduced risk of gastro-intestinal disease when compared with those infants who were fed infant formulas. The benefits were seen throughout the first year of life even though breastfeeding had ceased.

Respiratory infection

These studies, like the studies of gastro-intestinal infections can be subject to methodological flaws. The Dundee study (Howie et al 1990) found a protective effect of breastfeeding on respiratory infections, however, this was not marked as with the gastro-intestinal infection. Other studies have found some protection of breastfeeding if not against the occurrence then at least against the severity of the respiratory infection (Cunnigham et al, 1991; Frank et al, 1982; Rubin et al, 1990).

Otitis media

There is conflicting evidence on whether breastfeeding protects against otitis media (middle ear infection). Again the problem here is whether all confounding variables have been taken into account and whether the sample was large enough to observe an effect. Some studies have found a protection of breastfeeding against otitis media (Teele et al, 1989; Sipila et al, 1989; Saarinen, 1982; Duncan et al, 1993) whereas others have not (Harsten et al, 1989; Tanoi et al, 1988; Rubin et al, 1990).

The most recent study of these which was carried out by Duncan et al and published in 1993 involved over 1,000 infants from Arizona (20% Hispanic, 80% Caucasian). It was found that exclusive breastfeeding for at least 4 months decreased the incidence of otitis media in the first year of life. As well as having a large sample this study also corrected for many confounding variables and had clear cut groups where duration of exclusive breastfeeding was clearly defined.

It is not known what it is about breastfeeding that protects against otitis media, although it may be in part due to the mechanisms of breastfeeding compared with that of bottle-feeding. The bottle-teat occupies only the oral cavity whereas the teat formed from the breast and the nipple is sucked up into the babies palate encouraging the Eustachian tube to open properly (Hall, 1994).

Other advantages of breastfeeding

Protection against allergies

There may be a protection of breastfeeding against developing allergic disease. However, the extent of this protection and the mechanisms involved remain unclear although breastfeeding is still recommended for those infants where there is a family history of allergy (Lucas et al, 1990; Burr et al, 1993). It may be that being breast-fed minimises contact with possible allergens in cow's milk, which being from another species could be considered foreign to the infant.

Diabetes

There is an increased risk of bottle-fed infants developing insulin-dependent diabetes mellitus (Virtanen et al, 1991). It is now thought that this may be due to the bovine whey protein bovine serum albumin present in formula milk triggering diabetes in genetically susceptible infants (Monte et al 1994).

Microflora

The faecal flora of breast-fed infants, which reflects the colonic microflora, is different to that of formula-fed infants. Breast-fed infants have predominantly bifidobacteria in their faeces whereas formula-fed have larger numbers of potential pathogens such as

Escherichia coli (Balmer et al, 1989). The bovine lactoferrin, the whey/casein ratio and iron content of formula may cause this difference. This difference between breast and formula-fed infants may in part explain why there is a greater incidence of gastrointestinal infection in formula-fed infants.

Developmental status

Breastfeeding is thought perhaps to have a favourable effect on the developmental status of infants. However, most studies which have addressed this question have been confounded by the social and demographic differences between mothers who breast and those who formula feed.

Lucas and colleagues (Lucas et al, 1992) examined the influence of post-natal feeding in pre-term infants on subsequent IQ. Infants who received breast milk for one month post-partum were found to have higher IQ scores at 8 years of age even when socio-economic status and mother's education level were accounted for. These results have not as yet been confirmed in term infants.

Intake control

Breast-fed infants control their own intake of milk whereas mothers control the intake of formula-fed infants. Breast-fed infants consume a fairly constant intake of volume of milk from 1-4 months unlike formula-fed infants who have been found to increase the quantity over this period (Montandon, 1986).

Expense

There is no doubt that breastfeeding is cheaper than formula-feeding. This is perhaps why a large proportion of mothers in developing countries breastfeed. In the UK mothers on low income are provided with "milk tokens" to purchase formula milk if they are bottle-feeding and therefore have less incentive to breastfeed.

Maternal/infant bonding

Breastfeeding is believed to help establish a close relationship between mother and child. However, there is no strong evidence that, in the long term, breastfeeding is superior to formula-feeding for the establishment of a loving relationship between mother and her child.

Contraceptive effect

Breastfeeding is known to have a contraceptive effect. Women who breastfeed six times or more per day are highly unlikely to menstruate or ovulate during this time (Short, 1984). This contraceptive effect of breastfeeding is very important, however, in developing countries where other forms of contraception are not available (Thapa et al, 1988).

Elimination of manufacture and preparation errors in formula feeding

Errors could occur during the manufacture of formula milk. Wrong amounts of ingredients may be added. Contamination may also occur. The other problem with formula milks is in the preparation. Some mothers may make up the formula to the wrong concentration. If the formula is too dilute then the infant will receive inadequate nutrients and energy whereas if it is too concentrated then this may lead to dehydration or obesity.

Other benefits to infant or mother

Breast-fed infants have a lower incidence of Sudden Infant Death Syndrome (Carpenter et al, 1983; Ford et al, 1993), multiple sclerosis (Piscane, et al 1994) and perhaps less gastrointestinal diseases such as Crohn's and coeliac disease in later life (Wharton and Edwards, 1991). There are also benefits to breastfeeding mothers who will have reduced risk of hip fracture, osteoporosis, ovarian cancer and pre-menopausal cancer, more rapid weight loss after pregnancy (Dewey, 1993) and faster return of the uterus to normal size.

1.4.2 Introduction of solid food (weaning)

The next important period is when infants are weaned onto solid food. Weaning in this thesis is defined as the first time an infant has been given any non-milk foods other than breast milk or formula.

Recommendations for weaning

The recommendations on timing of weaning from the COMA, 1994 report Weaning and the Weaning Diet (Dept of Health 1994) are :-

"The majority of infants should not be given solid foods before the age of four months, and a mixed diet should be offered by the age of six months."

Weaning is not recommended before the age of four months because it is thought that the physiology and development of the infant are not mature enough to cope with non milk food i.e.

1. neuromuscular co-ordination is not well developed

(i) young infants have poor head control

(ii) the extrusion reflex prevents spoon feeding

(iii) they are unable to swallow properly

2. the gastro-intestinal and renal systems are not sufficiently mature

(i) gastro-intestinal and pancreatic enzymes are not sufficiently produced

(ii) the gut has increased permeability to large molecules such as food proteins and the "closure" of the gut to these proteins does not occur until 3-4 months (Walker, 1984)

(iii) the renal capacity of young infants is unable to cope with a high solute load

Disadvantages of early weaning

There are disadvantages in both weaning an infant too early and too late. It may be that introducing infants to solid food too early predisposes them to obesity, however, the evidence is not convincing. It was thought that infancy was an important critical period for determination of the total adipocyte number in the body (Brook et al, 1972), however, more recent studies have shown that this is not the case. In man, infancy does not appear to be a period of rapid adipocyte multiplication (Dauncey et al, 1975; Knittle et al, 1979). The massive storage of fat which takes place during this time is achieved by increase in fat cell size rather than an increase in fat cell number (Dauncey et al, 1975).

Early introduction of solids in developing countries gives an increased risk of gastro-intestinal infection probably related to poor quality weaning foods, inadequate sanitation and poor nutritional status. If the infection is severe then it may lead to failure to thrive (Popkin et al, 1990). However, this has not shown to be the case in developed countries.

A study from Dundee (Forsyth et al, 1993) which observed the effect of weaning on growth also observed its effect on illness on three groups of infants, those weaned before 8 weeks, between 8 and 12 weeks and after 12 weeks. Gastrointestinal illness, wheeze and nappy dermatitis were not found to be related to early introduction of solids. A significant increase was found for respiratory illness at 14-26 weeks and persistent cough at 14-26 and 27-39 weeks among those infants who were given solid food early. The incidence of eczema was only greater in those infants who introduced solids between 8-12 weeks of age.

Foods such as cereals and legumes contains factors such as phytate which inhibit iron absorption and decrease its anti-infection properties (Oski and Landaw, 1980). Introduction of solid food to breast-fed infants will decrease the provision of the protective factors in the milk and perhaps decrease the frequency of breastfeeding. It is also thought that later introduction of solids decreases the incidence of coeliac disease during infancy (Kelly et al, 1989).

Disadvantages of late weaning

There are disadvantages of infants being introduced to solids later than 6 months. Around this time breast milk will no longer meet the need of the infant for energy, protein, iron, zinc and vitamins A and D. Formula milk will probably meet this micro-nutrient requirement after 6 months but it will not meet energy requirements.

Feeding skills such as chewing should be learned at this age as learning these skills later can be very difficult (Stephenson and Allaire, 1991). By six months infants should be starting to drink from a cup and bottle feeding should be stopped by around one year. If children are still drinking from a bottle after one year then they may not learn the necessary feeding skills. The recommendation from the Coma report (Dept. of Health, 1994) is: *"Infants should be supervised during meal times. Semi-solid food should be given from a spoon and not mixed with milk or other drink in a bottle. From six months of age they should be introduced to drinking from a cup and from one year feeding from a bottle should be discouraged".*

Nutritional composition of the weaning diet

Energy and Macronutrients

"The provision of adequate dietary energy to ensure normal growth and development should be a principle determinant of the diets of children under five years of age." is the advice on energy from the Weaning and the Weaning Diet Report (Dept. of Health, 1994).

During the first six months of life the growth rate of infants is faster than at any other time during their life. During the second half of their first year the growth rate although slower is still greater than at any other stage in childhood. Therefore, it is important that throughout the weaning process adequate food energy is provided for the infant.

When infants are exclusively breast-fed around half of their energy is provided from fat. Formula has been designed also to give a value which is close to this (30-57% of energy from fat is a statutory requirement). As the infant is weaned, carbohydrate begins to provide the major dietary energy although fat still contributes a large proportion. Protein provides a much smaller proportion. As the infant progresses to a more diverse diet energy rich foods should still be given. Low fat products should not be offered until at least two years of age. Giving low energy products will lead to a low energy intake which could lead to slower growth velocity and eventually failure to thrive (Stordy et al, 1995).

Supplementary vitamins

The present day practice in infant feeding: third report (DHSS, 1988) recommends that *"vitamin supplementation should be given to infants and young children aged from six months up to at least two years and preferably five years".*

Of the mothers in the OPCS 1990 Infant Feeding survey (White et al, 1992), 12% at 6 weeks, 19% at 4 months and only 30% at 9 months were giving supplementary vitamins. The low percentage at 6 weeks is not a matter for concern as most infants are breast-fed or receiving infant formula and are unlikely to become vitamin deficient. However, at 9 months when most infants are receiving a mixed diet and cow's milk rather than formula, they are more likely to become deficient.

The weaning report (Dept of Health, 1994) gives a more detailed description of vitamin supplementation. It suggests that for a breast-feeding mother who had adequate vitamin status during pregnancy that vitamin supplements are not required before six months. If after six months breast milk is still their main drink then supplements should be given. Formula-fed infants are only recommended to receive vitamins if they consume less than 500 ml per day of formula or follow-on milk. Infants on less than this or whose main drink is cow's milk should receive vitamins. Supplements were recommended for all infants from 1-5 years where adequate vitamin status can not be assured from food.

Nutrient intakes

The Ministry of Agriculture Fisheries and Food (MAFF) survey also assessed the nutrient intakes of 6-12 month old infants. Nutrient and energy intakes were compared with the UK Dietary reference values. With the exception of zinc (90% of the Reference Nutrient Intake {RNI}) and vitamin D (50% of the RNI) average intakes of nutrients from food were well above the RNIs. Supplements, however, provided 43% of the sample with additional vitamin D and allowed them to reach the RNI (sunlight will also provide further vitamin D). Although the average daily intake for iron met the RNI, the median was only 7 mg which corresponds to 90% of the RNI.

Zinc

The average daily intake (ADI) of 6-12 month old infants was 4.5 mg (median 4.4 mg) which is below the RNI (5 mg). When 6-9 and 9-12 month old infants were considered separately, intakes were greater in 9-12 month old infants (ADI 4.8 mg median 4.6 mg) compared with 6-9 month old infants (ADI 4.3 mg median 4.3 mg). Seventy one percent of all infants were below the RNI with 6% below the Lower Reference Nutrient Intake (LRNI).

Vitamin D

The average daily intake (ADI) of vitamin D for all infants was 3.49 μg (median 1.21 μ g). ADI is only 50% of the RNI of 7.0 μg. When 6-9 months and 9-12 months were considered separately, those aged 6-9 months had markedly greater intakes (ADI 4.7 μg median 2.2 μg) than infants 9-12 months (ADI 2.14 μg median 0.95 μg).

Infant formulas were by far the major source of vitamin D. Infants in Scotland and Northern England had significantly greater vitamin D intakes than those from the South East, East Anglia and London, probably due to the higher consumption of formulas in the north of the UK. For the 43% of the sample that took supplements all intakes met the RNI.

Iron

The average daily intake (ADI) for iron of all infants was 8.1 mg (median 7 mg). The ADI was above the RNI of 7.8 mg but the median was below. Infants aged 6-9 months (ADI 9.3 mg median 8.8 mg) had intakes greater than infants 9-12 months (ADI 6.7 mg median 5.8 mg).

The higher ADI in the younger infants is probably due to their high intakes of fortified formulas and commercial infant food. Seventy-three percent of 9-12 month old infants had intakes below RNI with 21% below the LRNI.

Infants in Scotland and Northern England had significantly higher iron intakes than those from the South East, East Anglia and London again presumably due to their greater consumption of commercial infant foods and infant formulas.

Iron intakes were higher in those infants who were fed solely on commercial infant foods when compared with those fed predominantly "family foods". Infants whose main source of milk was cow's milk, breast milk or low fat milks had significantly lower iron intakes than those fed infant formulas.

In conclusion the MAFF (Mills and Tyler, 1992) survey suggests that *"on average the diet of British infants aged 6-12 months are nutritionally adequate. However, iron intakes may be marginal particularly in older infants, in those infants fed largely on "family foods" and in those who consumed cow's milk, breast milk or low fat milk as there main milk. Zinc intakes also tended to be lower than the RNI."*

1.5 Infant feeding practice (Scotland and the UK)

1.5.1 Milk feeding practice and factors influencing feeding practice

Breastfeeding

Breastfeeding declined around the middle of the century perhaps due in part to the introduction of National Dried Milk. However, National Dried Milk was thought to be linked to hypertonic dehydration which led to increased death of infants at this time (Simpson and O'Duffy, 1967). A slight increase was then observed in the breast-feeding rate. After this small increase the breastfeeding rate fell steadily till it reached its lowest point around 1970 probably due to the availability of infant formulas. The breastfeeding rate then started increasing again until 1980 where it has remained almost static until the present day (Martin, 1978; Martin and Monk, 1982; Martin and White, 1988; White et al, 1992).

Two major surveys were carried out which assessed breastfeeding rates in the UK. The OPCS, 1990 Infant Feeding Survey (White et al, 1992) and the MAFF 1986 Survey on Food and Nutrient Intakes of British Infants 6-12 Months of Age (Mills and Tyler, 1992). The OPCS 1990 Infant Feeding Survey is one of a series of reports produced every five years since 1975.

The overall breastfeeding rate for the UK was reported as 63% (OPCS) and 64% (MAFF). For first births the breastfeeding rate was greater (69%-OPCS, 71%-MAFF) than those for higher birth orders e.g. second births (59%-OPCS, 66%-MAFF). Social class was also found to influence breastfeeding rate. For the UK, 86% of mothers from social class I elected to breastfeed compared with only 41% for social class V. These values were even lower for Scotland with 84% of mothers in social class I breastfeeding initially and as little as 28% from social class V (White et al, 1992).

The tendency for breastfeeding to decline at higher latitude was examined by both surveys. London and South East England were found to have the highest incidence of breastfeeding (74%-OPCS, 77%-MAFF) with Scotland having the lowest (50%-OPCS, 55%-MAFF). In the OPCS survey, Northern Ireland was included for the first time in 1990 with even lower incidence of breastfeeding than Scotland at 36%. It should be noted however that these are raw data and are not adjusted for confounding variables such as social class.

Other factors which influenced breastfeeding reported in the OPCS were maternal age, smoking, previous experience of breastfeeding and age at completion of full time education. Older women were more likely to breastfeed. For the UK, those who were 30 years or over were most likely to breastfeed with an incidence of 86% falling to 39% of mothers under 20. Educational level of mothers had a strong influence on breastfeeding. Those mothers who completed full-time education after the age of 18 were most likely to breastfeed (91%) with those who left school at 16 or under being least likely (50%). Mothers who smoked were less likely to breastfeed than non-smokers, 47% compared with 69%. Previous breastfeeding experience tended to influence how mothers fed subsequent babies. Almost all (94%) of women who had breast-fed a child for longer than 3 months chose to breastfeed their latest child compared with 23% of women who had not breast-fed before.

Duration of breastfeeding was found, like incidence of breastfeeding, to be longer in women who had previously breast-fed a child, in higher social classes, were educated beyond 18 years of age, living in the South of the country and who were non-smokers. The OPCS survey indicated that there had been no marked change in the incidence or duration of breastfeeding in the UK since 1980.

Glasgow and the West of Scotland are renowned for an "unhealthy diet" and its health consequences (The Scottish Diet, 1993) and therefore may be less likely to follow the recommendation that it is best to breastfeed their infants. The present study, in a representative sample from the West of Scotland, will allow us to observe breastfeeding rates and the factors which influence breastfeeding and compare these with those found from the above two surveys.

Formula feeding

Even though the OPCS Infant Feeding Survey (White et al, 1992) found no change in the incidence or duration of breastfeeding between 1985 and 1990 there has been a trend towards formula-feeding with more mothers supplementing breastfeeding with formula. Thirty percent of mothers gave infant formula from birth and by six weeks, 38% of mothers who had initially breast-fed were formula-feeding with some of those mothers who continued breastfeeding supplementing with formula. At 6-7 weeks half of the infants were receiving casein dominant formula and by 4-5 months this had rose to 61%.

At 6 weeks and 4-5 months breast-fed babies who received supplementary bottles were more likely to be on a whey dominant formula (73%) than those who were exclusively formula-fed (42%).

Cow's milk feeding

The age at which infants should be first given cow's milk is controversial. The COMA report suggests that infants can be given cow's milk from 6 months of age but not as a main drink until one year. However, other recommendations have been made which suggest that no cow's milk should be given before one year (Wharton, 1990).

Forty-two percent of mothers from the OPCS Infant Feeding Survey who were bottle-feeding were giving cow's milk as a main milk (at 9-10 months) compared with 67% in 1985 (White et al, 1992). As many as 76% in 1990 and 88% in 1985 were giving cow's milk in some way. Breast-fed infants were more likely to be given cow's milk at 9-10 months than those who were exclusively bottle-fed.

1.5.2 Weaning practice

Like breastfeeding rate, the timing of introduction of solid food varies. In the UK from the middle of the century the age of weaning became earlier coinciding with the decrease in the incidence of breastfeeding. Weaning was at its earliest around 1970 where it was usual for an infant to receive solid food at 3-4 weeks after birth (Whitehead and Paul, 1987). After this the timing of weaning became later coinciding again with the breastfeeding rate which was increasing. In developing countries the introduction of solid food can be late or early depending on the circumstances. In some countries it is not unusual to find infants being exclusively breast-fed at one year. On the other hand some infants are weaned as early as one month.

However, it appears from both the OPCS and the MAFF surveys that many mothers in the UK are not following guidelines for infant feeding and weaning (i.e. breastfeeding and weaning onto solid food at 4 months). In both the above surveys some mothers had introduced solid food as early as 3 weeks and by the time the infants were 8 weeks old 16% in the MAFF and 19% in the OPCS had received some solid food. Both surveys found that the majority of mothers give solid food at 3 months and by 6 months almost all do.

The weaning report recognises that much more work is needed in this area to observe when weaning is occurring and factors influencing weaning (Dept of Health 1994).
"Research should be directed to understanding normal weaning and to establishing guidance on the rate at which the liquid diet of early infancy should change to a diet where solid foods provide the major part of energy and nutrient needs. The factors which predispose to weaning should be defined".

1.5.3 Factors affecting weaning practice

Region

Solid food was introduced to infants in the north of the UK earlier than to those in the south (White et al, 1992; Mills and Tyler, 1992). The MAFF survey (Mills and Tyler, 1992) found mothers in Scotland and North England introducing solids earlier than those in the south of the country (Table 1.2).

Table 1.2. Mean age at introduction of solid food by region.

Region	Mean age of introduction of solids
Scotland	13.0
Northern England	12.0
Midlands and E.Anglia	13.5
Wales and S.W.England	13.9
South East and London	14.3

These results were not adjusted for social class and were based on raw data therefore this difference may reflect the higher incidence of breast-feeding in the south or may be a social class difference.

The OPCS Infant Feeding Survey (White et al, 1992) reported similar results to the MAFF survey (Mills and Tyler, 1992). Within England and Wales the further north one goes the earlier the introduction of solids. Table 1.3 shows the proportions of mothers introducing solids at each age in the whole of the UK and in Scotland alone from the OPCS survey.

Table 1.3. Percentage of infants in the UK and Scotland who had introduced solid food at each age.

Age at introduction of solid food	UK	Scotland
4 weeks	3	3
6 weeks	7	10
8 weeks	13	19
3 months	53	58
4 months	83	83
6 months	96	96
9 months	100	100

Feeding method

There have been many studies which have found that formula-fed infants were introduced to solid food earlier than breast fed infants (White et al, 1992; Mills and Tyler, 1992; Whitehead et al, 1986; Wilkinson and Davies, 1978). For the OPCS survey 12% of women who had formula-fed had introduced solids by 6 weeks compared with only 2% of breastfeeders. The MAFF survey indicated that infants who were initially exclusively breast fed were on average given solid food later than those who received either both breast and bottle or bottle milk only (Table 1.4).

Table 1.4 Mean age of introduction onto solid food by feeding method.

	Mean age of introduction of solids (wks)
Entire sample	13.3
Males	13.2
- Breast	13.6
- Bottle	12.8
- Breast + Bottle	12.0
Females	13.5
- Breast	14.5
- Bottle	12.0
- Breast + Bottle	13.0

Social class

The age of introduction of solid food was found to be strongly related to social class (defined by the current or last occupation of the husband/partner, Registrar General, 1980) in the OPCS survey. The groups were social class I-V, no partner and unclassified. Mothers with no partner were most likely (76%) to have introduced solid food by three months compared with only 57% in social class I (Table 1.5). This effect was still seen when breast and formula-fed infants were considered separately within each social class group.

Table 1.5. Age at introduction onto solid food by social class.

Age at introduction of solid food	Social Class							
	I	II	IIInm	IIIm	IV	V	No partner	Unclass
4 weeks	1	1	2	3	2	6	4	4
6 weeks	2	5	8	10	10	15	14	10
8 weeks	9	13	17	20	22	24	28	20
3 months	57	61	70	69	73	72	76	68
4 months	91	92	96	94	96	95	95	94
6 months	100	99	99	99	100	99	99	99
9 months	100	100	100	100	100	100	100	100

Birthweight

The study carried out in Dundee (Forsyth et al, 1993) found that infants who were weaned earlier tended to be heavier than those infants at the same age who had not been weaned. The OPCS survey (White et al, 1992) also tried to address this question. However, the only measurement available to them was the birthweight and so this was used as an indicator of later weight. At three months it was found that a greater percentage of infants that had a birthweight 3500g or more had been weaned compared with lighter infants- 72% compared with 66%.

Smoking

The OPCS survey found that mothers who smoked during pregnancy were more likely to introduce solids early compared with mothers who did not smoke. By three months 75% of mothers who smoked during pregnancy had introduced solid food compared with 66% of mothers who did not smoke during pregnancy.

1.5.4 First type of solid food given

Cereals and rusks were found to be the most common first foods given to infants in both the OPCS and the MAFF survey. Percentages of first food given to infants who had been weaned by 6 weeks in the OPCS survey are given in Table 1.6.

Table 1.6. Percentage of first foods given to those infants in the OPCS survey who had received solid food by six weeks.

First solid food	% OPCS
Cereals	95
-Baby rice	42
-Rusks	51
-Other cereals	2
Dried/tinned/jar of food	4
Fresh/home-made	1
Other	0

The OPCS survey found that rusks were the most common food given whereas the MAFF survey found that baby rice was by far the most popular. However, the OPCS survey was only observing the first food given to infants weaned before 6 weeks whereas the MAFF survey identified the first food given to each infant (Table 1.7). The Weaning Report (Dept of Health, 1994) recommends that first weaning foods should be fruit and vegetable purees and non-wheat cereals and, therefore, most mothers in the above surveys were following these guidelines.

Table 1.7. First solid foods given to infants in the MAFF survey.

First solid food	% MAFF
Cereals	88
-Baby rice	56
-Rusks	24
-Other cereals	8
Fruit / veg purees	5

By four months, when most babies were receiving solid food, commercial baby food was most commonly given to infants in the OPCS. General nutrition was the factor mothers considered when deciding what solid food to give. Sugar was the most frequently avoided ingredient with salt and additives next. Mothers in the MAFF survey also tended to avoid adding salt and sugar to weaning foods.

The MAFF survey suggested that infants aged 6-12 months of age consumed a wide range of food with an increase in variety with increasing age. Commercial infant foods formed an important part of the diets of these infants with few relying on "family foods" alone. The commercial infant food became less important as the babies became older.

1.5.5 Additional drinks

The MAFF survey investigated the first alternative drink to milk or water (Table 1.8). Baby syrups were the most common alternative drink given to infants. However, these have since been withdrawn from the market and been replaced by concentrated fruit juice drinks.

Table 1.8. First alternative drinks given to infants.

1st alternative drink	%
Baby syrups	44
Herbal drinks	20
Baby fruit juice	20
Other pure fruit juice	7
Fruit squash	4
Other	5

The OPCS reported the percentage of infants receiving additional drinks at 6 weeks. Breast fed babies were less likely to be having additional drinks at 6 weeks than bottle fed babies (58% compared with 89%, overall 79%). The majority of mothers (59%) gave plain water with 45% giving a herbal baby drink containing sugar. Mothers in the 1990 survey were less likely to be giving sweetened drinks than those in the 1985 survey (50% compared with 74%).

1.6 Factors affecting growth and nutritional status

1.6.1 Breast vs formula feeding

Growth and nutritional status of infants may differ depending on whether they are breast or formula-fed. Many studies have been carried out to examine the growth of exclusively breast-fed infants. Weight and length gain between birth and 3-4 months of age have been found to be similar in exclusively breast and formula-fed infants (Butte et al, 1990). However, many studies have found that differences in growth emerge around

3-6 months and continue to be seen even after breast-feeding has ceased. Exclusively breast-fed infants tend to be lighter and shorter than infants formula-fed or those breast-fed for a short period and weaned onto formula and solid food (Whitehead and Paul, 1984; Fomon, 1974; Roche et al, 1989; Salmenpera et al, 1985; Whitehead et al, 1986; Whitehead and Paul, 1981; Dewey et al, 1992).

Many studies have shown that in the first 3 months of life exclusively breast-fed infants have a greater (Owen et al, 1984; Salmenpera et al, 1985; Whitehead et al, 1986 and Whitehead and Paul, 1984) or similar (Butte et al, 1990) weight gain compared with the 50th centile of the NCHS standards (Hamill, 1977). However, weight gain between 3-6 and 6-12 months was much less than that for the NCHS giving lower mean weight centiles than the NCHS at 6 months (Owen et al, 1984) and at 9 and 12 months (Salmenpera et al, 1985; Whitehead et al, 1986; Whitehead and Paul, 1984; Dewey et al, 1992; Saarinen and Siimes, 1979).

It was also reported in some studies that length gain was lower in breast-fed babies. Owen et al (1984) carried out a study in Albuqurque (USA) to compare exclusively breast-fed (n=64) and formula-fed (n=164) infants who did not receive solid food before 6 months. From birth to 6 months the formula-fed infants, of the same sex, gained significantly more length than the breast-fed. Mean length for age centiles for formula-fed infants were higher at 6 and 9 months of age. Other studies with smaller sample sizes have confirmed Owens findings (Salmenpera et al, 1985; Whitehead and Paul, 1984; Whitehead et al, 1986; Whitehead and Paul, 1981; Hitchcock et al, 1985; Duncan et al 1984).

However, it must be noted that for some of these studies exclusive breast-feeding was compared with formula feeding plus solids. The studies endeavoured only to observe the effects of exclusive breast-feeding and whether this might be appropriate and not to observe differences in growth between breast and formula-fed infants. However, exclusive breastfeeding for longer than 3-4 months is not relevant to most industrialised countries and especially the UK. The effect of feeding practice on growth should be examined in studies of more 'normal' situations where feeding practice is representative of the UK. The present study will allow us to test the effects of breast and formula-feeding in a typical sample where infants are not exclusively breast-fed for long periods.

One aspect of the DARLING (Davis Area Research on Lactation Infant Nutrition and Growth) study in California, was to observe whether there were different growth patterns between breast-fed (n=46) and formula-fed (n=41) infants (Dewey et al, 1992). The two groups were well matched for maternal age, education, pre pregnancy percentage of ideal weight, pregnancy weight gain, parental height, parity, ethnicity, socio-economic status and infant sex and birthweight. However, there was a high average educational level of women in both the feeding groups.

For this study the introduction of solid food to the infants was not before 4 months. Breast-fed infants were defined as those who were breast-fed for at least 12 months and formula-fed infants were those formula-fed from birth or who were not breast-fed for longer than 3 months and then given formula. The formula was given until at least the end of the first year. Infants who had been given breast milk for three months were therefore, surprisingly, considered to be formula-fed (Dewey et al, 1992). Differences were found between the weight of breast-fed when compared with formula-fed infants.

This difference was significant between 6 and 18 months. No difference was observed for length or head circumference between the groups. It should be noted that the ambiguity of the groups study makes a clear conclusion difficult.

In the last ten years a similar study by the Cambridge group compared growth of breast-fed infants introduced to solid food before 4 months and after 4 months and also of formula-fed infants (Whitehead and Paul, 1986). In this study formula-fed infants were introduced to solid food significantly earlier than the breast-fed infants and exhibited growth patterns which were similar to those of the of breast-fed infants introduced to solid food before 4 months. Weight gains were similar between breast-fed infants introduced to solids before and those introduced after 4 months in the first 3 months of life but higher between 3-12 months for those breast-fed who received solid food before 4 months. Length gain was also greater for those infants who had received solid foods by 4 months. This study seems to suggest that introduction of solid food may have a greater effect on growth of length and weight than does feeding method (breast vs formula).

In developing countries it has been found that exclusively breast-fed infants grow better than formula-fed infants. This is not surprising due to the infection that can be caused due to lack of clean water supplies which will cause diarrhoea and hence growth faltering and it is not possible to conclude that these differences are due to type of feeding per se.

A study from Finland carried out in the late 1970s (Saarinen and Siimes, 1979) found that there were no differences in growth between infants breast-fed and those who were fed a modern formula milk. The introduction of solid food in this study was set at three and a half months. Infants fed a home prepared cow's milk formula had greater measurements than the breast-fed group. This suggests that the home-prepared formula may be more energy dense than modern formula which supports the idea that the older formulas used when 'Tanner and Whitehouse' skinfold data were collected were more energy dense causing greater deposition of fat. This study also further emphasises the point that differences in growth are more likely to be due to age at weaning rather than whether the infant is breast-fed or fed modern formula.

1.6.2 Age at introduction of solid food (weaning)

Infants who are introduced to solid food early may have different anthropometry than those infants weaned later. There has been conflicting evidence on this. The DARLING Study (Heinig et al, 1993) described the differences in growth between breast-fed infants who were introduced to solid food before 6 months (n=41) and on or after 6 months (n=19) and also infants who were formula-fed (n=45). The mean age of introduction of solid food was earlier in the formula-fed infants compared with the breast-fed, and as only 5 formula-fed infants were introduced to solid food after 6 months they were assessed as one group. Using SD-scores no difference was found for weight, length and weight for length of breast-fed infants introduced to solid food before 6 months and after 6 months. This was probably due to the fact that breast-fed infants introduced to solid food before 6 months decreased their intake of breast milk and hence, the total energy intakes were equal in the two groups. Breast-fed infants introduced to solid food early were, however, found to gain more weight between 6-9 months but not between 0-6 or 9-12 months than breast-fed infants who were introduced later. Formula-fed infants gained more weight than breast-fed from 4-9 months.

However, within the formula-fed group there was no relationship between the timing of introduction of solids and growth velocity. There was no difference in length within the groups (Heinig et al, 1993).

An interesting result from this study (Heinig et al, 1993) was that although formula-fed infants decreased food frequency when introduced to solid food they still maintained their intake of formula and hence, the intake from solid food appeared to be additive to that from formula. They concluded then that solid food given before six months of age in general replaces the milk source in breast-fed infants but not in the formula-fed infants. This greater energy intake from the formula-fed infants probably accounts for the greater weight gain in the second six months of life. This study was not carried out in a representative or random sample, and both mothers who breast and formula-fed had high educational and socio-economic status.

This study did not observe affects of early weaning as none of the infants were introduced to solid food before 4 months. The study was set up initially to observe breast and formula feeding and mothers were only recruited if they did not intend to introduce solid food before 4 months.

An earlier study carried out in Wales (Davies et al, 1977) examined the effect of solid food on the growth of infants formula-fed from birth during the first three months of life. A large number of infants were recruited (821) and were split into 3 groups, those who introduced solids before 6 weeks (657 infants), between 6 weeks and 3 months (124 infants) and after 3 months (40 infants). Mean weekly rates of weight and length were calculated but no significant difference was found between the three groups.

However, three months is a very short time period and it is possible that an effect would not be observed until after this time.

In contrast, a recent study in Dundee (Forsyth et al, 1993) found differences in growth depending on when infants were introduced to solid food. Again a large number of infants were followed (671 initially with 455 still available for measurement at 2 years). Infants introduced to solid food early (<8 (n=65) or 8-12 weeks (n=332)) were heavier than those who were introduced to solids later (>12 weeks (n=274)) at 4, 8, 13 and 26 weeks of age. This difference in weight was not observed at the end of the first or the second year of life. At their first solid feed those infants who were introduced to solids were heavier than infants the same age who had not received solids. The study concluded that perhaps early introduction of solid food to infants is less harmful than has been previously reported.

In the last ten years a small study in Cambridge compared growth of breast-fed infants introduced to solid food before 4 months (n=19) and after 4 months (n=18) and also of formula-fed (n=14) infants (Whitehead and Paul, 1986). The incidence of breast-feeding was high and solid food was introduced relatively late in this sample of infants. As with the DARLING Study formula-fed infants were found to be introduced to solid food significantly earlier than the breast-fed infants and not surprisingly exhibited growth patterns which were similar to those of the breast-fed infants introduced to solid food before 4 months. Weight gains were similar between breast-fed infants introduced to solids before and those introduced after 4 months in the first 3 months of life but higher between 3-12 months for those breast-fed who received solid food before 4 months.

Length gain was also greater for those infants who had received solid foods by 4 months.

Skinfold data from the infants who were formula-fed from birth or from less than 2 weeks of age were not substantially different from the breast-fed infants. The mean values of these formula-fed infants again occupied a position which was close to the breast-fed infants given solids before 4 months. In conclusion, any difference between infants who are breast and formula-fed appears to relate more to the age at which solids are introduced and how quickly they replace milk as the major source of sustenance rather than the milk type which the infant receives.

The evidence above is not conclusive and it would seem that more work has to be carried out to determine the effects of timing of weaning on growth. To date the Dundee study (Forsyth et al, 1993; Wilson et al, 1998) is the only study which has been carried out in a representative sample in the UK.

1.6.3 Other factors affecting growth and nutritional status

Other factors which might affect the growth of infants include sex, social class, mothers' smoking habit during pregnancy and the anthropometry of the infant at birth.

It is well established that boys grow faster than girls and that they have greater anthropometric measurements at each age. The fact that separate growth charts are constructed for each sex is evidence of this. Also the majority of studies analyse boys and girls separately. Differences in weight, length and head circumference measurements in early infancy might lead to boys being fed differently from girls.

Growth in length and weight from birth-2 years of age was examined in a representative sample of children in the Netherlands born in 1988-89 and was related to socio-economic status and other factors thought to affect growth (Herngreen et al, 1994). It was found that at one and two years of age that differences in attained weight and length and weight and length gain were small and not significantly different according to socio-economic status. The only exception to this was that children born to Mediterranean parents with low socio-economic status were heavier than the other children and were found to gain more weight than children of Dutch parents with the same socio-economic status. Other factors which were found to be associated with differences in attained weight and height were parental height, birthweight, parity and ethnic descent (Herngreen et al, 1994).

An assessment of the National Health and Nutritional Status Study (HANES I+II) data looking at poverty found that lower mean values for growth were found for children living below the poverty threshold compared with those living above (Jones et al, 1985). The difference was found to be less between HANES I (1971-75) and HANES II (1976-80). The interesting result from this study was that the growth differences shown were not consistently associated with differences in energy intake.

Studies have found that mothers who smoked during pregnancy had infants with lower birth measurements including a study by Roquer et al, 1995. This study was carried out in Spain and measured 129 new-borns of 37-41 weeks gestation. Reduced weight, length, cranial and thoracic parameters at birth were found when infants were exposed to active or passive smoking. The OPCS Infant Feeding Survey (White et al, 1992) found infants of mothers who smoked during pregnancy to have lower birthweight. Catch-up growth was observed after birth for infants of those mothers who smoked during pregnancy in the Dutch study (Herngreen et al, 1994) which mainly observed effects of social class.

As noted above, very few longitudinal growth studies of infants have been carried out in the UK and more specifically in Scotland. The data collected in this study has enabled growth and factors which influence growth to be assessed in a representative sample of Glasgow infants and which may also throw some light on what is happening in the rest of the UK.

Therefore, the present study represents a detailed investigation of growth and nutritional status in a representative sample of Glasgow infants which were well characterised. These studies are rare and there is a great necessity for them (Dept of Health, 1994). The study will allow us to (1) test the adequacy of anthropometric reference data for growth and nutritional status in infancy and early childhood, (2) identify the factors which influence infant growth and nutritional status in a representative sample not characterised by abnormal feeding practice and (3) to assess the feeding and weaning practice of these infants and the factors associated with this practice.

Chapter 2

Methods

2.1 The sample and the sampling frame

2.1.1 Sampling frame

When carrying out a study to describe any aspect of a population the sample selected should ideally be representative of that population. In order to obtain a fairly representative sample of births from all social classes in Glasgow a stratified sample based on postal code and "neighbourhood type" was used. Neighbourhood type is a proxy for social class which is now widely used in public health medicine in the West of Scotland. Each postal code in the Greater Glasgow Health Board (GGHB) area has been subdivided into Neighbourhood types (1-8, where 1 represents the highest and 8 represents the lowest socio-economic status) based on socio-demographic data obtained by census surveys (Appendix 1). These neighbourhood types were combined with postal code information on each mother from labour ward records in order to select a sample which reflected the socio-demographic nature of the GGHB area. In order to limit the time spent travelling, the sample was selected from a relatively restricted geographical area, i.e. North and West Glasgow. This restricted area made measurement easier from a practical point of view and meant that recruitment could be restricted to a single maternity hospital. North and West Glasgow contains a mix of social classes which were similar to that of the whole GGHB area.

A few options were explored in order to obtain the socio-economic information and to identify a suitable sampling frame needed to recruit mothers into the study:-

(i) Greater Glasgow Health Board Health Information Unit

(ii) Greater Glasgow Health Board Community/Primary Care Unit at Belvidere House.

In both these cases the relevant data which included the mothers address, postal code, social class, gestational age, birthweight and age of mother was only available when the infants were three months old, which was too late from the point of view of the study.

Eventually it was decided that the only feasible method of recruitment was from a maternity hospital. The Queen Mother's Hospital seemed to be the most appropriate for this, as the catchment of this hospital included all the postal codes from the sampling frame. Ethical approval for the study was obtained from Yorkhill NHS Trust. Suitable mothers and infants were selected from the hospital records and were recruited to the study while still in hospital. Mothers of all infants who participated gave written informed consent (Appendix 2).

Postal codes which were used to recruit the sample were as follows:-

G3, G11, G12, G13, G14, G15, G20, G61, G62 and G81

Using the postal code above including the first digit from the second part of the postcode (e.g. G3 8 or G62 7) each mother was assigned a neighbourhood type. The postal codes above give a whole range of neighbourhood types from 1 through to 8 (Table 2.1).

Table 2.1. Postcodes from the sample in each neighbourhood type

Neighbourhood Type	Postal code
1	G61.1, G61.2, G61.3, G61.4, G62.6, G62.7, G62.8
2	G81.6
3	G11.5, G11.7, G12.0, G13.1
4	G13.2, G13.3, G13.4, G14.9, G15.6, G20.0, G81.3, C
5	G81.1, G81.2, G81.5
6	G3.6, G3.7, G12.8, G12.9, G20.6
7	G15.7, G15.8
8	G3.8, G11.6, G14.0, G20.7, G20.8, G20.9

2.1.2 Sample size

It was decided that 120 mother and infant pairs should be recruited into the study. This number was comparable to previous longitudinal studies. For example, 'Tanner and Whitehouse', the reference for growth used in the UK until recently, followed 80 infants of each sex longitudinally in the first two years of life (Tanner et al, 1966). From a practical point of view a sample of around 120 was the maximum number that could be recruited given the frequency of measurements and the fact that all measurements were to be made by only one observer. It was ideal to have one observer as this gave less scope for measurement error.

Drop-outs and missing data points

Altogether 229 mothers were invited to take part in the study. Of these, 82 mothers refused while still in hospital and 20 originally agreed and then opted out. Of those who opted out some mothers changed their minds after leaving hospital and others were not at home on several occasions when visited to make the measurements. These 102 mother and infant pairs were defined as non-participants. This leaves 127 mother/infant pairs who were defined as participants (69 boys; 58 girls). Another 11 mothers dropped out and by the end of the study, which meant that 116 mother/infant pairs participated to the end of two years. Although 116 infants were still participating by the end of the second year only 112 were actually measured (Table 2.2).

Of the eleven mothers who dropped out, seven mothers moved out-with travelling distance and four mothers decided not to continue in the study for other reasons (Table 2.2).

In total there were 12 missing data points not due to participant drop-out:- five were due to observer illness, three due to the mother/infant being on holiday at the time of the measurement, one due to infant illness and three could not be measured within two weeks of the actual measurement date. There were also six occasions where the infant could not be measured due to total non-compliance of the infant (Table 2.2).

Table 2.2. Information on missing data and drop-outs

Age (months)	Missing points	Unable to measure	Cumulative drop-outs moved	Cumulative drop-outs non-compliance	Total missing sets of measurements	Numbers measured
0	0	0	0	0	0	127
1	1	0	0	0	1	126
2	3	0	0	0	3	124
3	3	0	0	0	3	124
4	0	0	0	0	0	127
5	3	0	0	0	3	124
6	0	0	0	0	0	127
9	0	0	0	0	0	127
12	1	1	1	2	5	122
18	0	2	5	4	11	116
24	1	3	7	4	15	112
Total	12	6	13	10	41	1356

np = classed as non-participants
drop-outs moved = mothers who moved out of the area and were not within travelling distance
drop-outs non-compliance = mothers who decided they did not want to continue in the study

In total 97% of potential measurements were made (1356 sets of measurements out of a potential 1397, 127 times 11 sets of measurements on each infant).

2.1.3 Stages of recruitment

Recruitment was carried out in two stages. The reason for recruitment in this way was that the first six months of the study for each infant was intensive, with monthly measurements. It was therefore decided that the second period of recruitment should begin as monthly measurements on the first half was ending. The first half were recruited between August and October 1992 and the second half from January to May 1993 (Table 2.3).

Table 2.3. Number of participants, non-participants and dropouts

	Numbers Recruited				By the end of the study			
	Recruited	Boys	Girls	Non-Participants	Still Participating	Boys	Girls	Drop-outs
Aug-Oct 1992	61	34	27	50	55	33	22	6
Jan-May 1993	66	35	31	52	61	34	27	5
Total	127	69	58	102	116	67	49	11

2.1.4 Exclusion criteria

The study was set up to examine the growth and nutritional status of normal infants, therefore there were exclusion criteria for both the infant and the mother. These are given below.

Infant

(a) Gestational age < 37 weeks

Normal gestational age was considered to be 37-42 weeks. Any infant born before 37 weeks was considered to be premature and therefore excluded.

(b) Gestational age unknown

Gestational age had to be known so that we knew the infants were not premature. For all mothers and infants considered for the study the gestational age was known.

(c) Birthweight < 2500g

Infants below 2500g are considered to be low birthweight infants. Very few infants were excluded for this reason as most infants below this weight were born before 37 weeks gestation.

(d) Congenital malformations, inherited metabolic disease, neo-natal disease which requires hospitalisation for more than 7 days, chronic disease

The above four categories may have had some effect on the growth of the infants and therefore any infants falling into these categories were excluded. Two infants recruited in the study were later diagnosed with cerebral palsy and both were excluded from the analyses.

(e) Twins

Twins are usually born before 37 weeks gestation, have lower birthweight and may grow differently from singletons. All sets of twins born during recruitment were not approached to participate.

Mother

Diabetes and epilepsy

Mothers had to be well and those with diabetes and epilepsy were excluded. However, only one mother was excluded because of epilepsy and of all the mothers who were approached none were diabetic.

The mothers or infants who were omitted from the study because of the exclusion criteria were not considered as non-participants.

2.1.5 Description of the sample

Information was obtained from the GGHB to determine the percentage in the GGHB area in each neighbourhood type and to compare this with the mothers who were recruited. The percentages of neighbourhood types were similar between our sample and the GGHB area (Table 2.5). There appeared to be a greater number of mothers from neighbourhood type 1 and less from 2 in our sample compared with the GGHB area. However, if we consider these two neighbourhood types together we have the same percentage from neighbourhood 1/2 in both samples. The GGHB area contained more mothers from neighbourhood type 8 than our sample. However, on the whole neighbourhood types between the two samples were similar (Table 2.4).

Table 2.4. Percentage neighbourhood type from our sample and from the GGHB area.

Neighbourhood type	No.	%	% GGHB
1	28	22	13
2	2	2	9
3	18	14	10
4	29	22	17
5	17	13	20
6	14	11	5
7	12	9	10
8	9	7	17

It has to be recognised that this type of system gives us only an approximation of social class. For this reason, we collected information on employment of both parents in order to assign a social class. This was carried out by using the Registrar Generals Classification (1980) which uses the occupation, or if unemployed the last occupation, of the head of the household. This is an old classification and depends on the occupation of the father. This classification did not take into account the occupation of the mother even if her occupation gave a higher social class than the father. The mothers occupation was, however, used when she was living alone or living with parents. Other unclassified people were those where the head of the household was a student or had never been employed. Table 2.5 shows the numbers from each social class in the sample.

Table 2.5. Numbers of mothers from each social class.

Social Class	No.
I	27
II	16
IIINM	15
IIIM	35
IV	18
V	9
Unclassified	8

Percentages from each social class have been compared with information from the GGHB on social class distribution of the whole of the GGHB area and also from the geographical areas (postal sectors) that we recruited from (Table 2.6).

Table 2.6. Percentage from each social class compared with the area recruited from and whole of the GGHB area for total households and females in couples.

	Total Households			Females in Couples		
Social Class	Whole GGHB Area	Area Recruited From	Our Sample	Whole GGHB Area	Area Recruited From	Our Sample
I	8	11	21	9	12	21
II	29	32	13	29	30	13
IIInm	15	15	12	12	11	12
IIIm	25	22	28	30	27	28
IV	14	12	14	13	12	14
V	7	5	7	5	5	7

First the social class distribution for all households in the GGHB area and the area we recruited from were compared with the sample. From this information it can first be observed that the area selected to recruit from was representative of the whole of the GGHB area. Second the sample that we selected from this area for the study was reasonably representative of the GGHB area in terms of social class. This comparison included all households but it was thought that comparing females in couples would be more appropriate. This comparison can be seen in the second half of Table 2.6. Although this comparison was more appropriate the percentages in each social class were very similar to those observed for all households. Again the area recruited from was representative of the GGHB area and the sample we recruited was representative in terms of social class apart from perhaps social class I and II. Social class I and II showed most difference with our sample containing more from social class I and less from social class II. However, if these two social classes were considered together, like neighbourhood type 1 and 2, the proportions of all social classes were very close.

Participants vs non-participants

Another method of assessing how representative the sample was of Glasgow was by comparing the participating mothers with those who decided not to participate. This was possible as mothers who were invited to participate but decided not to were asked if they would answer a short questionnaire (Appendix 3).

Using a two-sample t-test birthweight and age of mother were examined between the two groups. A Chi-square test was used to compare the proportions of mothers with higher or further education, living with father, having their first child and having a boy (Table 2.7).

Table 2.7. Participants versus non-participants means of birthweight and age of the mother and proportions of mothers with 1st child, further or higher education, living with father and having a boy.

Variable	Participants	Non-participants	P-value
Birthweight (mean) kg	3.46	3.48	0.70
Age of mother (mean) years	28.7	26.3	0.0006
1st child	51/127	49/102	0.12
Further/higher education	62/127	40/102	0.15
Mothers with father	117/127	88/102	0.15
Boys	69/127	49/102	0.34

No significant differences were found between the groups except for age of the mother. The mothers who participated were older than those who decided not to participate (mean age 28.7 years for participants and 26.3 years for non-participants). This result was slightly unfortunate but not entirely unexpected. It seemed reasonable that older mothers were more likely to take part than younger mothers. This difference, however did not appear to be of any practical significance and might have had only a small effect on the analysis presented.

2.2 The measurements

One observer, the author made all the anthropometric measurements on the infants except for some of the birth measurements. Birthweight of infants were taken from hospital records. Length and head circumference were measured by the observer within three days of birth. Often this was not possible and we attempted to retrieve these from medical records. However, more often than not they were not recorded and when they were the accuracy of the measurement could not be assured.

2.2.1 Frequency of measurement

Infants were measured monthly for six months and then 9, 12, 18 and 24 months. These times were chosen because they were convenient and were easy to calculate from the birth date. The actual timing in days for each measurement was as follows :-

30, 60, 91, 122, 153, 183, 274, 365, 548 and 730 days

As far as possible measurements were made +/- three days of the actual date of measurement. This was more important in the first six months of measuring because infants were being seen every month and their rate of growth was relatively fast. Sometimes it was impossible to see the infants within this time in which case they were seen as soon as possible rather than missing the visit altogether. However, if the measurement was more than two weeks late for any of the first 6 measurements they were not carried out. As noted above other sources of missing data were illness of the observer, the infants or the parents. Sometimes the infant was extremely uncooperative and the measurement had to be abandoned. This happened on only a few occasions and all between 12 and 24 months of age. Before this age no measurements were abandoned for this reason (Table 2.1). The total number of infants included in the analysis was 127 although due to drop-outs and missing points each time point does not include 127 infants (Table 2.3).

2.2.2 Anthropometry

The measurements taken were:-

Infant	***Parents***
Weight	Weight
Recumbent length	Height
Head circumference	
Mid-arm circumference	
Calf circumference	
Thigh circumference	
Triceps skinfold	
Subscapular skinfold	

Anthropometry is a good indicator of health and development of infants. All of the above measurements were reasonably easy to carry out and were not invasive to the infant or the mother. All measurements were carried out using the methods described by Lohman et al (Lohman et al, 1988). If any of the measurements caused undue distress to the infants then they were abandoned. For all of these measurements the participation of another person (usually the mother) was necessary in order to make the measurements accurately.

Weight

Weight was recorded on electronically "damped" scales (Seca, UK) which have an accuracy of 10g up to ten kilograms and 50g thereafter. A towel was placed on the scales before weighing for the comfort of the infant as the scale can be cold. The scales were zeroed before weighing the infant. The infant was almost always weighed naked and the weight was recorded in grams. On a few occasions infants were measured with nappy usually because the infant was ill and having the child naked for a longer period than necessary was thought to be unnecessary. In these cases a nappy from the same child was weighed and this subtracted. However, if the nappy was wet it was always removed as the weight of it could not be assessed. Measurement was taken when the weight from the scales was flashing which indicated that a stable weight had been reached.

From age 0-6 months the infant was usually weighed lying on the scale. From about 6 months onwards some infants could place their feet on the ground and, therefore, it was better to have them seated on the scale. From about 12 months onwards the infant was able to stand on the scale if they did not like to sit. This was possible by removing the top from the scale and zeroing the scale again. The infants were usually measured twice, once in kilograms and once in pounds and ounces for the mother. Occasionally in the older infants it was extremely difficult to make this measurement and then the measurement was carried out only once, in kilograms.

Recumbent length

Recumbent length was measured using a Castlemead Infant Measuring Table (London). The participation of the mother was necessary in this measurement. The mother was asked to hold the infant's head firmly but gently with the crown in contact with the top end of the measuring board. The infant's legs were kept straight by pressing firmly on the knees until the measurement was completed. The whole procedure was repeated and the mean value of the two readings taken. If the infant was restless during this measurement it was carried out by positioning only the left leg. The recumbent length was measured to the nearest millimetre.

This measurement was extremely difficult when the infant became restless which meant that the infant had to be held very firmly down on the board to get the measurement. Sometimes this would upset the infant and we would not try and make a repeat measurement.

Head circumference

With the infant recumbent sitting on the mothers knee, the paper measuring tape (Eskland, England), was slipped under the infant's head and placed over the centre of the occipital bone at the back of the head and the centre of the frontal bone. The head circumference was measured to the nearest millimetre and was carried out in duplicate with the mean value of the two readings taken. Sometimes the infant tried to pull the tape of their head. We had to ensure, therefore, that the infant's hand was not inside the tape when the measurement was made.

Mid-upper arm circumference

The arm was marked at the mid-point between the tip of the acromion process and the olecranon. The circumference was then taken at this mark using the measuring tape. This was carried out in duplicate and the mean of the two measurements recorded to the nearest millimetre. When making this measurement the arm of the infant must be as relaxed as possible or this affected the measurement.

Calf circumference

This was taken as the maximal circumference around the calf using the measuring tape. Several readings are taken and the maximum used. The calf circumference as with all the circumferences was measured to the nearest millimetre. This was an easy measurement to make and did not present any problems.

Thigh circumference

This measurement was made around the upper thigh at the level of the gluteal fold using the measuring tape. The gluteal fold was usually quite distinctive especially in the fatter infants. The thinner infants had less of a fold, so this was more difficult to identify. The thigh circumference was measured in millimetres and was carried out in duplicate with the mean value of the two readings taken.

Care had to be taken when doing the circumference measurements to ensure that too much pressure was not exerted on the arm or leg by pulling the tape too firmly and thus squeezing the tissues. The thigh circumference was the circumference where most care had to be taken.

Triceps skinfold

A fold of skin was picked up over the posterior surface of the triceps muscle on a vertical line passing upwards from the olecranon. Care was taken to pick up the skinfold away from the underlying muscle, without taking up any of the muscle tissue itself. The callipers (Holtain Ltd, Dyfed, UK) were applied vertically at the marked level (the mark made for the MUAC), the fingers removed from the skinfold and the reading taken. The whole procedure only took 2-3 seconds, and it was important not to allow the callipers to squeeze the skinfold for more than 1 or 2 seconds, or a false reading would be obtained as a result of excess compression. The triceps skinfold was measured in millimetres to the nearest 0.2 mm and was done in triplicate with the mean value of the three recordings taken. Sometimes this measurement was really difficult and more than three measurements were taken in order to obtain a true reading.

Subscapular skinfold

The procedure was the same as for the triceps skinfold, with similar care used in picking up and measuring the skinfold. This skinfold was picked up just below the angle of the left scapula with the fold slightly inclined in the natural line of subcutaneous fascia. The subscapular skinfold was also measured in millimetres to the nearest 0.2 mm and was carried out in triplicate with the mean value of the three readings taken.

All limb and skinfold measurements are taken on the left hand side of the body. Very occasionally this was not possible and the measurement was then made on the right hand side.

In young infants it was easier to have them lying face down across the mothers lap in order to make the subscapular and the triceps skinfolds. This position was easier as the infant had less freedom of movement than in other positions tried. As the infants became older this was not appropriate and the measurement was usually carried out with the infant sitting on their mother's knee.

Sometimes more than two measurements (three for the skinfolds) were made on the infants because they became restless and hence, more measurements were needed to achieve two that were satisfactory.

Parental measurement

Height and weight of the mother and where possible the father were measured.

Weight was measured in kilograms to the nearest 0.5 kg using electronic scales (Salter, UK).

Height was measured in centimetres to the nearest 0.1 cm using a portable stadiometer.

All mothers were measured for height and weighed when possible at every visit. Fathers height and weight were taken if they were in at any point during the visits. Otherwise mothers were asked to find out the fathers weight and height. For height this was straight forward as most people know their own height. Where the fathers did not know their own weight and were not available to be measured this usually involved them weighing themselves and the mothers conveying the information to me. This was not ideal as it relied on the measurements being made accurately and then the correct weight and height given.

2.2.3 Precision of measurements

Measurements which were used in the study were practised on infants and young children many times before the study commenced. Several trained examiners described and demonstrated the measurements and results were compared until adequate agreement in measurements was made.

All the measurements carried out on the infants recruited in the study were made only by one single observer, the author. Measurements were carried out on 20 infants twice in order to assess the intra-observer difference for each measurement. The time between the measurement was usually one or two days so that the second measurement was carried out blind but no difference would be seen in the measurement due to growth.

The degree of precision found for the measurements in this study were acceptable and similar to those found for other studies (Lohman, 1988; Alsop-Shield et al, 1994; Voss et al, 1990; Doull et al, 1995).

Two different equations were used to assess intra-observer differences:-

Percentage error of the measurement

The difference between the two measurements was divided by the mean of the two measurements and then multiplied by one hundred giving a measurement of agreement (Bland, 1987).

$$\% \text{ error} = \frac{m1-m2}{(m1+m2)/2} \times 100$$

The average percentage error of measurement can be calculated for each measurement (Table 2.8).

Table 2.8 Percentage error of each measurement

Measurement	% error
Weight	1.5
Length	0.8
Head Circ.	0.4
MUAC	1.5
Calf Circ.	1.4
Thigh Circ.	1.3
Triceps Skf.	7.4
Subscapular Skf.	5.4

Technical error of measurement

This measure was used in other studies to assess the intra-observer difference (Mueller and Martorell, 1988; Bland, 1987). Two-thirds of the time the repeat measurement should come within ± the value of the technical error of measurement i.e. for MUAC the technical error of measurement was 0.2 cm, therefore, two-thirds of the time the repeated measurement will be within ± 0.2 cm of the first measurement (Table 2.9).

Table 2.9. Technical error of measurement for each measurement

Measurement	Technical error of measurement
Weight	0.1 kg
Length	0.6 cm
Head Circ.	0.2 cm
MUAC	0.2 cm
Calf Circ.	0.4 cm
Thigh Circ.	0.2 cm
Triceps Skf.	0.6 mm
Subscapular Skf.	0.3 mm

$$\textbf{technical error of measurement} = \sqrt{1/2n \sum (x_i - y_i)^2}$$

where
n = no. of infants measured
x_i = first measurement
y_i = second measurement

Differences between left or right side

As noted above all measurements were carried out on the left hand side where possible as most of the reference data from which they were to be compared were carried out on the left hand side. To test whether it would have made any difference measuring on the right hand side 5 infants were measured on the left hand side three times and then the right hand side once. As only five infants were examined the numbers were very small and nothing could be concluded statistically. However, examining the data suggests that the differences between sides were no greater than the differences on the same side and the differences were not consistently in the same direction.

Errors at different ages

At different ages the measurements of infants were more difficult and hence the precision of the measurement may be less. In order to assess whether the error of measurement was related to the size of the measurement and hence age of the infant the 20 infants who were measured twice were used. For each separate measurement the difference between the two measurements was plotted against the mean of the two measurements for the twenty infants. No relationship was found for any of the measurements i.e. the size of the error did not depend on the size of the measurement.

2.2.4 Questionnaires

Data were collected using:-

EC "Euronut" questionnaires

These questionnaires were designed for the study for use by all participating centres in the European Study. These were the main questionnaires used and information on environment, employment, feeding and weaning practice, illnesses and allergic reactions were assessed from these questionnaires.

(i) Initial questionnaire given to mothers while still in hospital. Includes questions about the pregnancy as well as the infants birth measurements and gestational age (Appendix 4).

(ii) 1-6, 9 and 12 month questionnaire given to the mothers during the visits to them in the first year (Appendix 5).

(iii) 18 and 24 month questionnaire given to mothers in the 2 visits during the second year of study. Included more questions on feeding than the first year questionnaire (Appendix 6).

Office of Population Censuses and Surveys Infant Feeding questionnaire

The OPCS questionnaire on infant feeding practice was that used in the most recent OPCS survey (White et al, 1992). This provided better dietetic data than Euronut Questionnaire and permitted comparison of dietary data in our sample with that of a large representative sample of infants from the UK. It included a 24 hour recall on the infants feeding, allowed us to assess the exact age of introduction of solid food, gave information on inoculation, mother and fathers occupations, whether they were working and in the case of the mother whether she was on maternity leave and any other problems that the infant may have had (Appendix 7).

Weaning questionnaire

An additional questionnaire was given to 98 mothers to assess weaning practice. This was in order to assess further the factors which influenced weaning and whether any formal advice on weaning was received (Appendix 8).

EC "Euronut" non-participant questionnaire

This was the questionnaire given to those mothers who decided not to participate by all centres in the European Study. This included information such as age of the mother, whether this was her first child, whether she was living with the baby's father and the birthweight and sex of the baby (Appendix 3).

2.3 Statistical analyses

2.3.1 Two-sample t-test

A two-sample t-test was carried out where two groups which were normally distributed were to be compared.

2.3.2 Mann-Whitney t-test

For two group comparisons where the distribution was not normal a Mann-Whitney non-parametric test was carried out.

2.3.3 Chi-square test

Where proportions in two samples were to be compared a Chi-square test was carried out. When there were more than two categories, i.e. for percentages between centiles, a Chi-square goodness of fit test was used.

2.3.4 Multiple regression analysis

As growth is known to be influenced by many factors which are closely related to each other, multiple regression analyses were carried out to assess which factors influenced growth even when other factors were taken into account.

All statistical analyses were carried out using minitab and advice was sought on statistical methods from a statistician.

Chapter 3

Infant growth and nutritional status in Glasgow compared with reference data

3.1 Introduction

Infancy and childhood are critical periods of growth (an increase in size over time) as growth in infancy is very rapid. Growth failure is often the first sign of underlying disease. The most appropriate method of assessing growth and nutritional status is anthropometry (Cross et al, 1995). If anthropometry is not used to assess growth status and undernutrition then growth failure and undernutrition are often missed. Interpretation of anthropometric measurements relies heavily on comparison with reference data. Therefore, the main aim of this chapter is to compare Glasgow data with that from other UK and international data sets. These UK data sets are the older references 'Tanner and Whitehouse' (Tanner et al, 1966) and 'Gairdner and Pearson' (Gairdner and Pearson, 1971) used until recently, the new UK references and the Cambridge data, one of the data sets used in construction of the new references. The international data set recommended by The World Health Organisation (WHO) is the National Centre for Health Statistics (Hamill, 1977; Hamill et al, 1979).

Until recently 'Tanner and Whitehouse' (Tanner et al, 1966) were the references used to assess weight and length of infants. For age 0-2 years the data were based on 160 infants from a fairly well-educated sample of parents in London, born 1952-54 and followed longitudinally (80 boys, 80 girls). These charts have now been found to be inadequate to assess growth in infants especially for weight in the first 6 months of life (Wright et al, 1993; Whitehead et al, 1989).

New reference data, 'UK 1990' references (Freeman et al, 1995; Cole et al, 1995), have now been constructed for weight, length, BMI and head circumference based on seven data sets throughout the UK, three for age 0-2 years (Cambridge, Human Measurements

Anthropometry and Growth (HUMAG) and Whittington birth data study). These new references were mainly based on 252 infants from a well educated and affluent population in Cambridge, characterised by high rates of breastfeeding and relatively late introduction of solids. The Cambridge data were adjusted to the growth of the HUMAG Study, a representative sample of English and Welsh children from 1970's and 1980's. No Scottish data were used to construct these charts for the 0-2 year age range. New centile positions were used in these charts giving 9 centiles (0.4, 2, 9, 25, 50, 75, 91, 98, 99.6) and, therefore, only 8 out of 1000 children will lie outside the nine centile range and it is recommended that these children should be referred immediately for further investigation (Cole, 1994).

These references were found to be unsuitable for assessment of weight in infancy (Wright et al, 1996). When weights of Newcastle children (n=3418) in the first year of life were compared with the new 'UK 1990' references (Freeman et al, 1995) and older 'Tanner and Whitehouse' (Tanner et al, 1966) references, substantial sex differences were found. Boys were found to have a mean SD-scores higher than girls (around 0.42 SD higher than girls from 3 months). These references may also be unsuitable for length and, therefore, BMI (Savage et al, 1998b). The references for weight, length and BMI have now been re-examined because of these large differences and have been revised in computerised form (Cole et al, 1996). The nature of these revisions are unclear.

The adequacy of these new reference data, initial and revised, for weight, length, BMI and head circumference of Glasgow infants must be examined, as the sample used to construct them was not truly representative of infants in the UK, and because of the problems identified above. The Glasgow infants being a sample of normal, healthy infants and representative for feeding and weaning practice of the UK (Chapter 6), may be used to test the validity of the references being used.

Gairdner and Pearson charts are also available for weight and length in infancy (Gairdner and Pearson, 1971). These were also constructed from the 'Tanner and Whitehouse' data from 0-24 months.

After weight and length the most frequently made measurement on infants is head circumference. Head circumference is an important measurement which should be made more often as it provides an index of brain growth which is very important during infancy. Until recently, 'Gairdner and Pearson' (Gairdner and Pearson, 1971) was the reference recommended for head circumference. It should be noted that for ages 0-2 years these were constructed from American data from the Harvard growth study.

The Cambridge Infant Growth Study (Whitehead et al, 1989) found that head circumference in Cambridge infants was greater than that found from the older American National Centre for Health Statistics (NCHS) references (Hamill, 1977; Hamill et al 1979). This difference may be due to a secular trend over time or may be due to real differences between populations. The other possible explanation for this discrepancy is differences in measuring technique e.g. measuring round a different part of the head.

New head circumference data are now available for the UK as part of the 'UK 1990' references (Child Growth Foundation, 1995). Although these new data are available many health visitors and hospitals still use the older data. Therefore, it must be investigated whether these new UK data or the old 'Gairdner and Pearson' data are appropriate for head circumference of UK infants.

Weight is an indicator of growth but may also give an indication of nutritional status. However, there are other measurements and indices which give a more useful indication of nutritional status e.g. BMI, skinfolds and limb circumferences (mid-upper arm, calf and thigh circumference). Glasgow data must also be compared with references for these to determine whether the nutritional status of Glasgow infants was similar to that of the samples used for the references.

Until recently only French data (Rolland-Cachera, 1991) were available for BMI from birth to two years. There were UK data for early childhood from the Tayside Growth study but these started at age three years (White et al, 1995). Now, however, the 'UK 1990' references, initial and revised for BMI, are available. BMI is also available for the Cambridge study separately as for weight, length and head circumference and are used as another comparison in this chapter.

Mid-upper arm circumference (MUAC) is another measurement which is sometimes made on infants to give an indication of nutritional status ('protein-energy' status), however, there are very few data sets available for this measurement especially in the UK. The Cambridge Infant Growth Study did measure this and is used as a comparison for the Glasgow data.

The other main anthropometric measurements made on children are skinfold thicknesses. There are reference data available for these in the UK (Tanner and

Whitehouse, 1975) but the data for these were collected in the late 1960s and have been reported to be inadequate for assessing infant skinfolds today (Whitehead et al, 1989). It must be noted that the sample used to construct the skinfolds was an entirely different sample to that used for the weight and length charts. The data for the skinfold thicknesses from one month to one year was collected by Hutchison-Smith in 1966-67. This study was carried out in Bakewell, Derbyshire in the Midland Infant Welfare Clinic where 200 infants were followed longitudinally. One to five years data were collected from the London Institute of Child Health group of the International Children's Centre Longitudinal Growth Study. About 50-100 children of each age were seen each year by one of three measurers and these were thought to be a representative sample of children born in the West Central area of London.

Very large differences were found between the skinfolds of the Cambridge infants (Whitehead et al, 1989) and those of the 'Tanner and Whitehouse' (Tanner and Whitehouse, 1975) infants (who had much larger skinfolds). This difference may have arisen due to a methodological difference, but is more likely to be due to a real biological difference, as feeding practice has changed between the late 1960s and today. In the late 1960s breastfeeding was at its lowest with the vast majority of mothers formula-feeding and introducing their infants onto solid food extremely early. In the Cambridge study the majority of mothers were breastfeeding and weaning onto solid food relatively late (mean timing of introduction of solids: formula-fed boys 10.6 weeks; formula-fed girls 13.9 weeks; breast-fed boys 14.9 weeks; breast-fed girls 17.4 weeks, Whitehead et al, 1986). However, even the formula-fed infants from their study had similar values to the breast-fed suggesting that it was the formula milks which were composed differently. Older infant formulas were more energy dense than the more modern formulas available now and may also have been too concentrated when made up (Arneil and Chinn, 1979).

An additional concern is that Cambridge infants are not representative of infants in the rest of the UK (Whitehead et al, 1989). The majority of the Cambridge infants selected in these studies were from a well-educated and affluent sample whose feeding and weaning practice were not typical of the rest of the UK (Dept of Health, 1988; White et al, 1992). Therefore, there is great need for other samples, more representative of the UK, to examine these skinfold references and their adequacy for assessing nutritional status in infancy.

As discussed in the introductory chapter there are very few data sets for anthropometric measurements on representative samples in the UK and especially in Scotland. The main aim of the present study was to assess the adequacy of growth references (both the older and most recent, as both are still being used in clinical practice) by using a representative sample of Glasgow infants from a well-conducted, longitudinal study with a single trained observer. The results from this chapter have now been published (Savage et al, 1998b) and a copy is given in communications.

3.2 Methods

3.2.1 Comparisons with reference data

Comparisons were made in two ways:-

(1) Weights, lengths, and BMIs were expressed as standard deviation scores (SD-scores) relative to 'UK 1990' and 'Revised UK 1990' references and the mean SD-scores for boys and girls compared at each age. Weights, lengths and triceps and subscapular

skinfolds of Glasgow infants were compared with the 'Tanner and Whitehouse' references (Tanner et al, 1966; Tanner and Whitehouse 1975) and head circumference compared with 'UK 1990' and 'Gairdner and Pearson' references (Gairdner and Pearson, 1971) using the same method. The Cambridge data for weight. length, BMI, head circumference, MUAC and triceps and subscapular skinfold were compared by the same method (Table 3.1).

For weight, length and head circumference data were compared with National Centre for Health Statistics (NCHS) reference data and BMI was compared with French data (Rolland-Cachera, 1991) but only the means were examined.

Table 3.1. Measurements and the references/standards used as comparisons.

Measurement	Standards/References Compared
Weight and Length	'UK 1990' References Tanner and Whitehouse Standards Cambridge National Centre for Health Statistics 'Revised UK 1990' References
Body Mass Index	'UK 1990' References French Rolland-Cachera Cambridge 'Revised UK 1990' References
Head Circumference	'UK 1990' References Gairdner and Pearson Cambridge National Centre for Health Statistics
Triceps and Subscapular Skinfold	Tanner and Whitehouse standards Cambridge
Mid-Upper Arm Circumference	Cambridge

(2) The percentage of infants falling above and below the 90th and 10th centile of 'UK 1990', 'Revised UK 1990' references, 'Tanner and Whitehouse', 'Gairdner and Pearson' and Cambridge data was examined at 1, 3, 12 and 24 months (18 months for head circumference comparison with 'Gairdner and Pearson') for all 7 measurements. Chi-square goodness of fit tests were used to determine whether the percentage above

the 90th and below the 10th centiles was significantly different than that from the references.

These two methods of comparison were made as this allowed us to test for differences in the means, at the centre of the distribution and also allowed us to test for differences between the Glasgow study and reference data at the extremes of the distribution. It is more usual for percentages above and below the 97th and 3rd to be used for this purpose but owing to the smaller sample size in this study the 90th and 10th centiles were used.

3.3 Results

3.3.1 Weight (Tables 3.2 and 3.3)

'Tanner and Whitehouse' Standards

When Glasgow infants were compared with 'Tanner and Whitehouse' standards large differences in weight were observed in both sexes, but especially in boys (Table 3.2/3.3). The greatest differences were seen in the first 6 months. At two months boys had a mean SD-Score of +1.05 SD and girls +0.51 (Fig 3.1/Appendix 9 Table 1). From six months to two years there were smaller differences. Boys had slightly greater mean SD-score and girls slightly lower mean SD-score (e.g. at one year boys had an SD-Score of +0.13 SD and girls -0.07 SD).

These differences were further emphasised when the percentages below and above the 10th and 90th centile were examined. At one month, only 1.5% of boys were below the 'Tanner and Whitehouse' 10th centile with 29.4% above the 90th centile. This was also the case in girls but the differences were less marked: 5.2% below the 10th centile and 25.9% above the 90th centile at one month. These differences were statistically significant. At one and two years the percentages of boys and girls above the 90th centile and below the 10th centile were closer to the expected 10% (Appendix 10 Table 1).

A sex difference, when compared with the 'Tanner and Whitehouse' references, was observed over the two years. At all ages in the first 2 years, boys had greater mean SD-score than girls, ranging from 0.20 to 0.51 SD-score (Appendix 9 Table 1/Fig 3.1). The percentage of boys above the 90th centile was greater than girls and the percentage of girls below the 10th was greater than boys. At three months, 30.3% of boys and 19.0% of girls lay above the 90th with 3.0% of boys and 6.9% of girls below the 10th centile. This difference between expected and observed at three months in boys but not in girls was statistically significant (Appendix 10 Table 1).

'UK 1990' References

When infants were compared with the initial 'UK 1990' references smaller differences were found than for 'Tanner and Whitehouse' (Table 3.2/3.3). However, a sex difference was still observed when compared with these new references.

Girls had a mean SD-score ranging from -0.41 to -0.14 SD between one month and two years. Boys, however, had a mean SD-Score greater than the references (0.04-0.51 SD over the 2 years) the difference being greatest at two years. Boys had greater mean weight SD-scores compared with girls in the first year of life. From one month to one year mean sex differences between 0.36-0.63 SD-scores were found. This difference was also observed in the second year of life. For example, the mean weight SD-score for boys was 0.69 SD higher than girls at two years (Appendix 9 Table 2/Fig 3.2).

At all 4 ages examined, a greater percentage of boys than girls lay above the 90th centile and a greater percentage of girls than boys lay below the 10th centile. The greatest difference was at three months where nearly four times as many girls as boys, 19.0% compared with 4.5%, lay below the 10th centile and twice as many boys as girls lay above the 90th centile, 12.1% compared with 6.9%. However the differences between observed and expected at this age were not statistically significant (Appendix 10 Table 2).

'Revised UK 1990' References

When Glasgow infants were compared with the 'Revised UK 1990' data differences were still observed although the difference was less marked than for comparison with the initial data (Table 3.2 and 3.3/Fig 3.3).

The difference in boys ranged from 0.04 to 0.39 SD-Score (initial 'UK 1990 data: 0.04 to 0.49 SD-Score) and in girls from -0.30 to 0.13 (initial 'UK 1990' data: -0.41 to 0.06 SD-Score, Fig 3.20). The greatest sex difference of the revised data was at two months with a difference between boys and girls of 0.47 SD-Score compared with the initial 'UK 1990' data where the greatest difference at 24 months was 0.67 SD-Score (Appendix 9 Table 3).

When the percentages at the extremes of the distribution were examined there were no significant differences in the percentages observed and expected above the 90th and below the 10th centiles (Appendix 10 Table 3).

National Centre for Health Statistics (NCHS)

When Glasgow infants were compared with the NCHS standards (Hamill, 1977, Hamill et al, 1979) similar differences to those found between Glasgow and 'Tanner and Whitehouse' standards were observed.

At all ages Glasgow boys and girls had greater mean weight than that of the NCHS data, especially over the first six months of life (Table 3.2 and 3.3).

Cambridge Infant Growth Study

When the infants were compared with Cambridge data (Whitehead et al, 1989, Whitehead and Paul, 1986) the mean SD-score of Glasgow infants lay above the 50th centile (0.24 to 0.63 SD) at all ages in boys and all but one to three months (-0.13 to 0.27 SD) in girls (Appendix 9 Table 4/Fig 3.4). A sex difference was also observed at most ages, boys had a mean SD-score greater than girls ranging from 0.05 to 0.51 SD over the two years.

As with the other references there was a greater percentage of boys above the 90th centile and a smaller percentage below the 10th centile than girls at each of the four ages examined. The largest sex difference was observed at two years with almost twice as many boys above the Cambridge 90th centile than girls (23.1% compared with 12.8%) and almost three times as many girls below the 10th centile than boys (8.5% of girls compared with 3.1% of boys). This difference in boys between the percentages observed and expected was statistically significant (Appendix 10 Table 4).

Table 3.2. Mean weight of Glasgow boys compared with 'Tanner and Whitehouse', NCHS, Cambridge, 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	'Tanner and Whitehouse'	NCHS	Cambridge	'UK 1990'	'Revised UK 1990'
0	3.59	3.50	3.3	ND	3.55	3.55
1	4.52	ND	4.3	4.27	4.48	4.49
2	5.60	ND	5.2	5.19	5.41	5.43
3	6.44	5.93	6.0	5.97	6.25	6.26
4	7.11	ND	6.7	6.63	6.95	6.97
5	7.77	ND	7.3	7.19	7.53	7.55
6	8.27	7.90	7.8	7.68	8.03	8.05
9	9.47	9.20	9.2	9.10	9.19	9.22
12	10.42	10.20	10.2	9.85	10.06	10.10
18	11.93	11.60	11.5	11.10	11.36	11.44
24	13.14	12.70	12.6	12.17	12.37	12.51

ND=no data

Table 3.3. Mean weight of Glasgow girls compared with 'Tanner and Whitehouse', NCHS, Cambridge, 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	'Tanner and Whitehouse'	NCHS	Cambridge	'UK 1990'	'Revised UK 1990'
0	3.34	3.40	3.2	ND	3.41	3.40
1	4.07	ND	4.0	4.06	4.26	4.23
2	4.91	ND	4.7	4.85	5.14	5.05
3	5.76	5.56	5.4	5.52	5.93	5.80
4	6.45	ND	6.0	6.11	6.60	6.45
5	7.09	ND	6.7	6.62	7.17	7.01
6	7.62	7.39	7.2	7.07	7.65	7.49
9	8.74	8.72	8.6	8.44	8.78	8.60
12	9.54	9.70	9.5	9.19	9.63	9.46
18	10.89	11.10	10.8	10.48	10.98	10.82
24	12.01	12.20	11.9	11.59	12.12	11.97

ND=no data

3.3.2 Length (Tables 3.4 and 3.5)

'Tanner and Whitehouse' Standards

When compared with 'Tanner and Whitehouse' standards, Glasgow boys had a difference for length of between 0.10 and 0.44 SD and girls between -0.01 to 0.29 SD from one month to two years. These were smaller differences than those found for weight. The differences compared with the standard for both boys and girls were observed from 3-4 months and then few differences were seen until 18 and 24 months (Table 3.4/3.5; Fig 3.5; Appendix 9 Table 1).

The percentages below the 10th centile and above the 90th centile also show these differences. At one month both boys and girls had less than 10% below the 10th centile (2.9% for boys; 5.2% for girls) and more than 10% above the 90th (14.7% for boys; 13.8% for girls). However, these differences were not statistically significant. Girls showed little difference at 3, 12 and 24 months whereas only around 3% boys at 3 and 24 months lay below the 10th centile and 12.1% and 21.5% at 3 and 24 months respectively, lay above the 90th centile. Only the difference at 24 months was statistically significant (Appendix 10 Table 5).

There were sex differences for length but these were smaller than those found for weight. These differences were not always in the same direction. At some ages boys had a greater mean SD-score than girls and at other ages it was girls who had the greater mean SD-score although these differences were fairly small. The greatest was at five months where girls had a mean SD-score 0.23 SD greater than boys (Appendix 9 Table 1).

When the percentages below the 10th and above the 90th centile were observed at 1, 3, 12 and 24 months the greatest sex difference was at 24 months where there was twice as many girls as boys below the 10th centile (3.1% of boys; 6.4% of girls) and twice as many boys as girls above the 90th centile (21.5% of boys; 10.6% of girls). This difference at 24 months in boys was statistically significant (Appendix 10 Table 5).

'UK 1990' References

When Glasgow infants were compared with the new UK references for length, differences were also found. Mean SD-score for boys and girls were below the 50th centile at one to five months. Between nine months and two years mean SD-scores for both sexes were above the 50th centile (Appendix 9 Table 2/Fig 3.6).

Sex differences were also observed although these differences were not as marked as for weight. The greatest difference was at 3 months for length where there was a difference between sexes of 0.39 SD-scores (Appendix 9 Table 2 /Fig 3.1).

The percentage above the 90th and below the 10th centiles also show these differences although again there was less difference than for weight. At one month around 14.7% of Glasgow boys and 15.5% of girls fell below the 10th centile with 7.4% boys and 5.2% girls above the 90th, however these were not statistically different than expected. At three months there was a greater percentage of girls below the 10th centile than boys and at 12 months a greater percentage of boys above the 90th centile. The difference between observed and expected was statistically different at 3 months in girls but not for boys at 12 months. At two years the greatest sex difference was observed with 4.6% of boys and 8.5% of girls below the 10th and 21.5% of boys and 12.8% of girls above 90th centile. This difference in boys was statistically significant (Appendix 10 Table 6).

'Revised UK 1990' References

For length there was a difference of between -0.07 and 0.49 SD-Score (initial 'UK 1990' data: -0.15 to 0.43 SD-Score) and girls between -0.32 and 0.46 SD-Score (initial 'UK 1990' data: -0.41 to 0.47 SD-Score, Fig 3.21). The greatest sex difference of the revised data was at 3 months with a difference between boys and girls of 0.43 SD-Score which was larger than the largest difference found for the initial data (0.39 SD-Score at 3 months) (Appendix 9 Table 3/Fig 3.7).

When compared with the extremes of the distribution larger differences were found when length was revised. At 3 months 15.5% of girls lay below the 10th centile and 5.2% above the 90th centile although this was not statistically significant. For boys at 24 months 4.6% lay below the 10th centile and 21.5% above the 90th and this was statistically different than expected (Appendix 10 Table 7).

National Centre for Health Statistics (NCHS)

Glasgow boys and girls had fairly similar mean length at all ages when compared with NCHS references values (Table 3.4 and 3.5).

Cambridge Infant Growth Study

The mean SD-score of Glasgow boys was above the 50th centile of Cambridge boys at all ages in the first two years. The mean SD-score of girls was above the 50th centile at all age except at 2-3 months. A sex difference was only seen in the first 9 months but not at 9-24 months (Fig 3.8/Appendix 9 Table 4).

The percentages above the 90th and below the 10th centile showed sex differences at 1, 3 and 12 months but not at 24 months as with the SD-Scores. A greater percentage of boys lay above the 90th and a greater percentage of girls below the 10th centile at 1, 3 and 12 months. At 3 months 6.1% of boys compared with 15.5% of girls lay below the 10th and 13.6% of boys and only 6.9% of girls lay above the 90th centile. These, however, were not statistically different than expected. For boys at 12 months and boys and girls at 24 months there was a significantly greater than expected percentage below the 10th centile and above the 90th centile (Appendix 10 Table 8).

Table 3.4. Mean length of Glasgow boys compared with 'Tanner and Whitehouse', NCHS, Cambridge, 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	'Tanner and Whitehouse'	NCHS	Cambridge	'UK 1990'	'Revised UK 1990'
0	52.0	ND	50.5	ND	51.1	51.0
1	54.4	54.0	54.6	53.9	54.9	54.7
2	58.2	ND	58.1	57.4	58.3	58.1
3	61.3	60.7	61.1	60.1	61.4	61.1
4	63.8	ND	63.7	62.4	63.9	63.6
5	66.0	ND	65.9	64.4	66.0	65.7
6	68.1	68.2	67.8	66.1	67.8	67.5
9	72.4	72.7	72.3	71.8	72.1	71.8
12	76.1	76.3	76.1	75.1	75.8	75.5
18	82.5	82.1	82.4	81.1	82.0	81.7
24	88.3	86.9	87.6	86.1	87.1	86.8

ND=no data

Table 3.5. Mean length of Glasgow girls compared with 'Tanner and Whitehouse', NCHS, Cambridge, and 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	'Tanner and Whitehouse'	NCHS	Cambridge	'UK 1990'	'Revised UK 1990'
0	51.1	ND	49.9	ND	50.2	50.2
1	53.5	53.0	53.5	53.1	53.8	53.7
2	56.5	ND	56.8	56.3	57.0	56.9
3	59.1	59.0	59.5	58.9	59.9	59.7
4	61.7	ND	62.0	61.0	62.3	62.1
5	64.1	ND	64.1	62.9	64.3	64.1
6	65.9	65.5	65.9	64.6	66.0	65.8
9	70.3	70.2	70.4	70.0	70.3	70.1
12	74.1	74.2	74.3	73.3	74.0	73.9
18	80.7	80.5	80.9	79.3	80.4	80.5
24	86.3	85.6	86.5	84.4	85.7	85.8

ND=no data

3.3.3 Body mass index

French References

Glasgow boys had greater BMI at all ages when compared with the French data. Girls were fairly similar to the French data at birth, 12 and 18 months and had greater values at six months. (Table 8).

'UK 1990' References

The mean SD-score of boys for BMI compared with the 'UK 1990' references lay above the 50th centile at all ages in the first 2 years whereas the mean SD-score for girls lay below the 50th centile at all ages. For BMI there was a substantial sex difference, between 0.32-0.83 SD over the first two years (Fig 3.9; Appendix 9 Table 5)).

For BMI, the percentage of boys and girls falling below and above the 10th and 90th centiles showed large differences. At all 4 ages examined there was a greater proportion of girls below the 10th centile than boys and a greater proportion of boys above the 90th centile than girls. On examination of the boys, at some ages less than 10% lay above the 90th and below the 10th centile. This suggests that the range of BMI in Glasgow boys was less than that in the 'UK 1990' references for BMI. For example, at 1 month only 2.9% lay below the 10th centile and 5.9% above the 90th. This was not the case in girls (Appendix 10 Table 9).

'Revised UK 1990' References

BMI in boys showed differences between 0.06 to 0.22 SD-score (initial 'UK 1990' data: 0.13 to 0.39 SD-Score) and in girls between -0.33 to 0.07 SD-Score (initial 'UK 1990' data: -0.50 to -0.14 SD-Score, Fig 3.22) when compared with the revised data. The greatest sex difference was at 2 months with a difference of 0.46 SD-Score. This was smaller than the marked difference found from the initial 'UK 1990' data where the greatest difference found was 0.83 SD-Score at 24 months (Appendix 9 Table 6/Fig 3.10).

Cambridge Infant Growth Study

The mean SD-score of boys for BMI lay above the 50th centile at all ages (range 0.09 to 0.36 SD) when compared with Cambridge data. The mean SD-score of Glasgow girls lay below the 50th centile at 1 and 2 months and 12- 24 months (range -0.02 to -0.35

SD) but lay above from 3-9 months (0.02 to 0.22 SD). A sex difference was found at 1 and 2 months then at 12- 24 months. The greatest sex difference was at 2 years where boys had an SD-score 0.59 SD greater than girls (Appendix 9 Table 7/Fig 3.11).

For the percentages at the extremes of the centiles at 1 month, less than 10% of boys and girls lay above the 90th centile and less than 10% lay below the 10th centile suggesting less spread in the Glasgow infants. At 3 months 6.1% of girls and 6.9% of boys lay below the 10th and 9.1% of boys and 17.2% of girls lay above the 90th. At 24 months where the largest sex difference was observed, 3.1% of boys compared with 21.3% of girls were below the 10th centile with 7.7% boys and 8.5% girls above 90th. The observed percentages above and below the 90th and 10th centiles were statistically different only in girls at 24 months. Again in boys there appears to be less variability than in the Cambridge data (Appendix 10 Table 11).

Table 3.6. Mean BMI of Glasgow boys compared with, French, Cambridge, and 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	French	Cambridge	'UK 1990'	'Revised UK 1990'
0	13.45	13.21	13.26	13.24	13.28
1	15.15	ND	14.56	14.83	14.95
2	16.50	ND	16.04	15.97	16.14
3	17.13	ND	16.57	16.66	16.84
4	17.45	ND	16.99	17.06	17.26
5	17.80	ND	17.24	17.3	17.51
6	17.77	16.84	17.53	17.46	17.67
9	18.05	ND	17.76	17.58	17.8
12	17.98	17.42	17.48	17.43	17.64
18	17.52	17.06	16.94	16.91	17.13
24	16.82	16.58	16.48	16.36	16.66

ND=no data

Table 3.7. Mean BMI of Glasgow girls compared with, French, Cambridge, and 'UK 1990' and 'Revised UK 1990' data.

Age (months)	Glasgow	French	Cambridge	'UK 1990'	'Revised UK 1990'
0	12.86	12.92	13.47	13.07	13.03
1	14.16	ND	14.25	14.65	14.50
2	15.30	ND	15.43	15.78	15.55
3	16.45	ND	15.93	16.51	16.25
4	16.89	ND	16.32	17.00	16.73
5	17.20	ND	16.63	17.32	17.05
6	17.47	16.54	17.09	17.52	17.25
9	17.63	ND	17.28	17.68	17.41
12	17.32	17.20	17.12	17.50	17.25
18	16.73	16.88	16.62	16.99	16.74
24	16.09	16.44	16.34	16.54	16.34

ND=no data

3.3.4 Head circumference

Gairdner and Pearson Paediatric Standards

Large differences were found for both boys and girls when compared with the old paediatric head circumference references of Gairdner and Pearson. There were also sex differences. Boys had a mean SD-score of 0.35 to 0.90 over the first 18 months and girls 0.02 to 0.46. The sex difference was between 0.16 and 0.44 SD, boys being greater than girls (Appendix 9 Table 8/Fig 3.12).

The percentages at the extremes of the centiles also showed this difference. Boys and girls at all ages had less than 10% below the 10th centile. Boys had greater than 10% above the 90th at all ages and girls at all ages except 18 months. These differences were statistically significant at 1, 3 and 18 months in boys and 1 and 3 months in girls (Appendix 10 Table 13).

'UK 1990' References

The mean SD-score for boys lay above the 50th centile of the new references at all ages except 18 and 24 months while the mean SD-score of girls lay above the 50th to 6 months and below it from 9-24 months. Boys had a greater mean SD-score at every age than girls, with differences ranging from 0.10 to 0.24 SD over the two years. The sex difference was less than that found for the Gairdner and Pearson references (Appendix 9 Table 5/Fig 3.13).

At one and three months less than 10% of boys lay below the 10th centile and more than 10% above the 90th. At 1 year the percentages above and below the 10th and 90th centiles were near 10% and at 24 months 4.5% lay below the 10th centile with only 3% above the 90th centile, suggesting less spread at this age in the Glasgow boys. For girls at 1 month, 3.4% lay below the 10th and 20.7% above 90th centile and at 3 and 12 months about 10% lay above the 90th and below the 10th centile. At 24 months 14.9% lay below the 10th centile with only 6.4% above the 90th. These differences were only statistically significant at 1 month in boys and girls and 24 months in boys (Appendix 10 Table 12).

Cambridge Infant Growth Study

The mean SD-score relative to Cambridge data ranged from 0.09 to 0.36 SD in boys and -0.06 to 0.31 SD in girls. In boys the greatest difference compared with Cambridge references was at 1 month with 19.1% above the 90th centile and only 2.9% below the 10th. The greatest difference in girls was at 24 months where 12.8% lay below the 10th and 6.4% above the 90th centile. There was a sex difference when compared with the references at almost every age ranging from 0.06 to 0.46 SD (Appendix 9 Table 7/Fig 3.14).

At one and 24 months there was a greater percentage of boys than girls above the 90th centile. At one, three and 24 months there was a greater percentage of girls than boys below the 10th centile. The percentage difference between boys and girls was greatest at 1 month but fairly small at the other three ages. The percentage of boys above and below the 90th and 10th centile was statistically different than expected only at one month. None of the percentages in girls were statistically different than expected (Appendix 10 Table 24).

National Centre for Health Statistics (NCHS)

Glasgow infants had greater values than NCHS at all ages. These differences were greater than those found when compared with the 'Gairdner and Pearson' standards (Table 3.8 and 3.9).

Table 3.8. Mean head circumference of Glasgow boys compared with, Gairdner and Pearson, NCHS, Cambridge, and 'UK 1990' data.

Age (months)	Glasgow	Gairdner and Pearson	NCHS	Cambridge	'UK 1990'
0	35.4	35.3	34.8	ND	35.2
1	38.3	37.4	37.2	37.7	37.6
2	40.2	39.2	ND	39.4	39.7
3	41.5	40.9	40.6	40.9	41.3
4	42.8	42.1	ND	-42.1	42.6
5	44.0	43.1	ND	43.2	43.6
6	45.0	44.0	43.8	44.1	44.5
9	46.5	46.0	45.8	46.6	46.4
12	47.7	47.2	47.0	47.7	47.7
18	49.2	48.7	48.4	49.2	49.2
24	50.1	49.8	49.2	50.0	50.2

ND=no data

Table 3.9. Mean head circumference of Glasgow girls compared with, Gairdner and Pearson, NCHS, Cambridge, and 'UK 1990' data.

Age (months)	Glasgow	Gairdner and Pearson	NCHS	Cambridge	'UK 1990'
0	34.7	34.8	34.3	ND	34.5
1	37.2	36.9	36.4	37.2	36.9
2	38.9	38.5	ND	38.7	38.8
3	40.4	40.0	39.5	40.0	40.3
4	41.6	41.2	ND	41.1	41.5
5	42.7	42.1	ND	42.1	42.5
6	43.7	42.8	42.4	43.0	43.4
9	45.2	44.7	44.3	45.4	45.3
12	46.3	45.8	45.6	46.5	46.5
18	47.7	47.2	47.1	48.1	48.0
24	48.6	48.1	48.1	49.0	49.0

ND=no data

3.3.5 Triceps Skinfold

'Tanner and Whitehouse' Standards

When the triceps skinfold was compared with the older references of 'Tanner and Whitehouse' extremely large differences were found. These differences were larger than for any of the other measurements. Glasgow boys had a mean SD-score between -0.69 SD and -1.75 SD. The girls show a similar difference -1.26 to -1.76 SD. Boys had a greater mean SD-score than girls at 1-3 months and 18-24 months and girls a greater mean SD-score than boys at 5 months (Appendix 9 Table 9/Fig 3.15).

No boys or girls (0%) lay above the 90th centile of 'Tanner and Whitehouse' for triceps skinfold at any of the four ages examined. More than 10% of boys and girls lay below the 10th centile at all four ages examined. For example, at 12 months 73.1% of boys and 78.2% of girls lay below the 10th centile. At all ages the percentages observed and expected were significantly different (Appendix 10 Table 15).

Cambridge Infant Growth Study

The Glasgow infants were closer to the Cambridge data for triceps skinfold although differences were still observed. Glasgow infants had greater triceps skinfolds than Cambridge infants except for girls at 18 months (Fig 3.16/Appendix 9 Table 10). There was no consistent sex difference. At all four ages in boys and 1, 3 and 12 months in girls less than 10% lay below the 10th centile. However, at 3, 12 and 24 months in boys less than 10% lay above the 90th centile (Appendix 10 Table 16). This suggests that the spread of the Glasgow boys at these ages was less than that found for the Cambridge boys. This was also observed in girls at 3 and 12 months. The percentages, above the 90th and below the 10th centile, at three months for both boys and girls were significantly different than expected.

3.3.6 Subscapular Skinfold

'Tanner and Whitehouse' Standards

Large differences were also observed for subscapular skinfold between Glasgow infants and the older 'Tanner and Whitehouse' standards although the difference was not as marked as for triceps skinfold. Boys had a mean SD-score between -0.29 and -1.17 SD and girls between -0.67 and -1.24 SD in the first two years when compared to 'Tanner and Whitehouse'. At all 4 ages examined boys had a greater mean SD-score than girls ranging from 0.07 to 0.57 SD (Fig 3.17/Appendix 9 Table 9).

There were very few boys or girls lying above the 'Tanner and Whitehouse' 90th centile with a fairly large percentage below the 10th. At 1 year 26.9% of boys and 38.2% of girls were below the 10th centile. There was a greater percentage of girls than boys below the 10th centile at all four ages observed. At all ages these percentages were significantly different than those expected (Appendix 10 Table 17).

Cambridge Infant Growth Study

When subscapular skinfold was compared with the data from the Cambridge Growth Study differences were observed. In the first year the mean SD-score of boys and girls did not always lie above the 50th centile. In the second year Glasgow infants mean SD-scores were above the 50th centile (Fig 3.18/Appendix 9 Table 10). At 1 month less than 10% of boys and girls lay below the 10th and greater than 10% above the 90th. At 24 months in boys and 3 and 12 months in both boys and girls less than 10% lay above the 90th and below the 10th centile, indicating less spread. The only statistically significant difference was in boys at one month (Appendix 10 Table 18).

<u>3.3.7 Mid-upper arm circumference</u>

Cambridge Infant Growth Study

Mid-upper arm circumference (MUAC) of Cambridge infants was the only UK data set available. The mean SD-scores of boys and girls were above the 50th centile at all ages except at 2 and 3 months (boys -0.04 to 0.56 SD; girls -0.26 to 0.26). A dip was observed at three months (Fig 3.19/Appendix 9 Table 11/Fig 8). The percentage below the 10th centile at this age in both boys and girls was greater than 10% with less than 10% above the 90th centile (Appendix 10 Table 19).

A sex difference was observed at 1-3 months and 12-24 months boys having greater mean SD-score, compared with references, than girls. The greatest sex difference was at 24 months when boys had a mean SD-score 0.38 SD greater than girls. A greater percentage of girls than boys lay below the 10th centile at this age (Appendix 10 Table 19).

3.4 Discussion

When a representative sample of Glasgow infants was compared with the current and older reference data for growth and nutritional status, sex and age differences were found. A difference was found for length and head circumference but more markedly for weight and BMI when compared with the most recent references (Freeman et al, 1995; Cole et al, 1995). When compared with older references, 'Tanner and Whitehouse' for weight, length, triceps and subscapular skinfolds and 'Gairdner and Pearson' for head circumference, large sex and age differences were also found.

3.4.1 Weight

For weight at all ages boys showed a positive shift and girls a negative shift relative to 'UK 1990' references. This sex difference for weight due to a negative shift in girls was also observed in a representative sample of Newcastle children, n=3418 (Wright et al, 1996). By observing the extremes of the distribution (below 3rd and above 97th centiles, possible here because of larger sample size) this study also showed that this difference would lead to a gender bias in referral. The sample size in the Glasgow sample was too small to use these cut-offs at the extremes and the 10th and 90th centiles were used as cut-offs. The positive shift which was found for Glasgow boys was not found in the Newcastle children.

These differences may have arisen due to the methods used in constructing the charts or may be due to real differences between samples. When Glasgow infants were compared with the older 'Tanner and Whitehouse' references these sex differences were also found. More importantly, both boys and girls showed a substantial positive shift over the first five months which would lead to very few boys or girls being referred for poor growth over this period. From 6-24 months boys showed a positive shift compared with 'Tanner and Whitehouse' and girls showed a negative shift.

Weight was also compared with the Cambridge Infant Growth Study, one of the data sets of the new references. Boys showed a positive shift at all ages when compared with Cambridge and girls at all ages except 1-3 months. Sex differences were found at all ages but was greater at some ages than others.

3.4.2 Length

For length there were also differences compared with the 'UK 1990' references at some ages. From 1-5 months boys were similar to the references but girls showed a negative shift. From 6-24 months in boys and 9-24 months in girls both showed a positive shift being greatest at two years. A sex difference was seen at some ages. These sex and age differences compared with new references have not previously been described.

When length was compared with the older references of 'Tanner and Whitehouse' boys showed a positive shift except at age 5-12 months. Girls also showed a positive shift except at 9 and 12 months. There were small sex differences at some ages but not always in the same direction.

When length was compared with Cambridge data, boys showed a positive shift at all ages and girls at all ages except 2-3 months.

These differences for length and more markedly for weight relative to 'Tanner and Whitehouse' probably reflect a real difference between growth of the 'Tanner and Whitehouse' sample and growth of the Glasgow sample. The 'Tanner and Whitehouse' data for weight and length were collected in 1952-54, over 40 years ago, where feeding and weaning practices and the foods and milks given were different from today. The 'Tanner and Whitehouse' study followed 160 infants from a fairly well-educated area of London and were probably not representative of infants in the rest of the UK at this time.

The new references were based on the Cambridge Longitudinal Infant Growth Study, the Whittington Birth Data Study and the HUMAG study which was cross-sectional data from 17 areas of England and Wales. The HUMAG study was considered representative of the UK although no Scottish data were included for 0-2 years. The Cambridge data were adjusted against this data to be representative of the UK (Freeman et al, 1995).

The difference found between Cambridge and Glasgow data may reflect differences in feeding and weaning practice. Most mothers from Cambridge breast-fed their infants and weaned them later than usually found in the rest of the UK (Whitehead et al, 1989). The Cambridge study found anthropometric differences in infants weaned early and those weaned late, but little difference between breast-fed and formula-fed infants. A study on a sample of Dundee children (Forsyth et al, 1993) also found a difference in weight between those weaned early and those weaned late. The difference was only apparent till 6 months, but not at one or two years. However, a follow-up of these children (at 7 years) has shown that those weaned before 15 weeks had greater weight and percentage body fat (Wilson et al, 1998).

3.4.3 Head circumference

An important indicator of brain growth is the measurement of head circumference. Glasgow infants compared with the older references showed large positive shift in both sexes, but especially in boys and in the first six months. The new references and Cambridge fitted more closely but there were still some significant differences. The older references of 'Gairdner and Pearson' were constructed from the data of the Harvard Growth Study from America and not surprisingly differences were found.

3.4.4 Body mass index

For BMI large differences relative to the new reference data were found. Boys showed a positive shift at all ages and girls a negative shift at all ages. Large sex differences were observed at all ages and were greatest at 2 years. This was not entirely unexpected as there were differences in weight.

3.4.5 Skinfold thickness

Other important and widespread measurements of nutritional status ('protein-energy' status) are skinfold thicknesses. The existing references ('Tanner and Whitehouse') for triceps and subscapular skinfolds in infancy are too high should not be used to assess nutritional status in infants today. Similar discrepancies for triceps and subscapular skinfolds were also found from the Cambridge Infant Growth Study (Whitehead and Paul, 1989). When Glasgow infants were compared with Cambridge data for these skinfolds they were fairly similar although some differences were still observed.

There are two possible explanations for these large differences between 'Tanner and Whitehouse' and Glasgow data. First the methodology used for measuring these skinfolds may have differed and second, and most likely, the feeding and weaning practices of infants in the two samples differed greatly. The 'Tanner and Whitehouse' data was collected in the late 1960s when the breastfeeding rates in the UK were at their lowest and when weaning onto solid food was early. In addition the formula milks given to the infants were less modified than they are today and were more energy dense. It is also worth noting that the sample on which skinfold data was collected was different to the sample on which weights and lengths were measured. Weights and lengths were measured in the early 1950s.

The smaller differences observed between the Cambridge and the Glasgow sample may again be due to different feeding and weaning practices as mentioned above.

3.5 Conclusions

In conclusion, large sex and age differences were observed when Glasgow infants were compared with the older and the most recent references. The use of most of the older references should now be discontinued and comparison of anthropometric data of growth and nutritional status with more recent references should still be interpreted with caution.

Figure 3.1 Mean weight SD-scores of Glasgow children by sex compared with 'Tanner and Whitehouse' reference values.

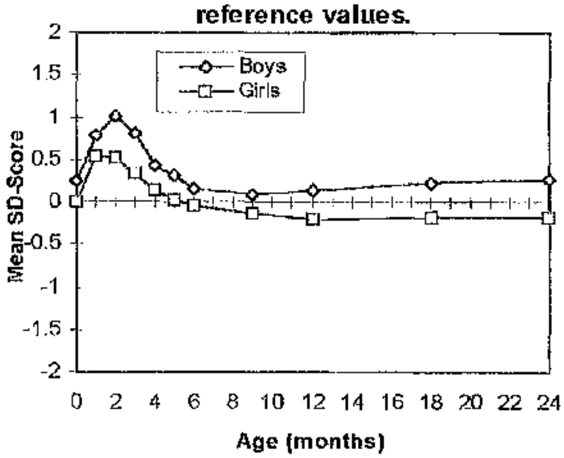


Figure 3.2 Mean weight SD-scores of Glasgow children by sex compared with 'UK 1990' reference values.

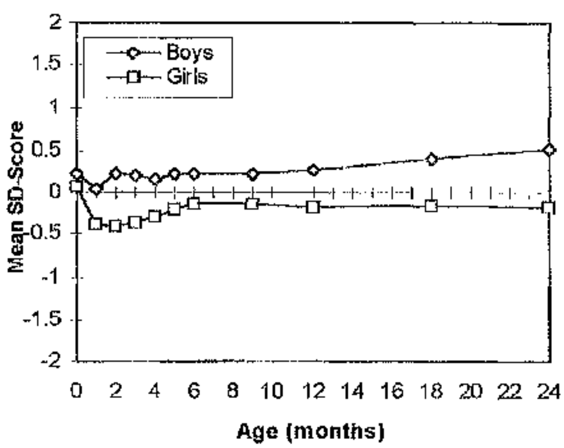


Figure 3.3 Mean weight SD-scores of Glasgow children by sex compared with 'Revised UK 1990' reference values.

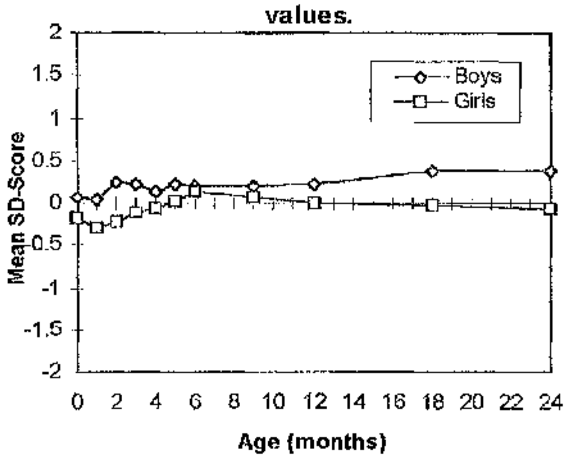


Figure 3.4 Mean weight SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

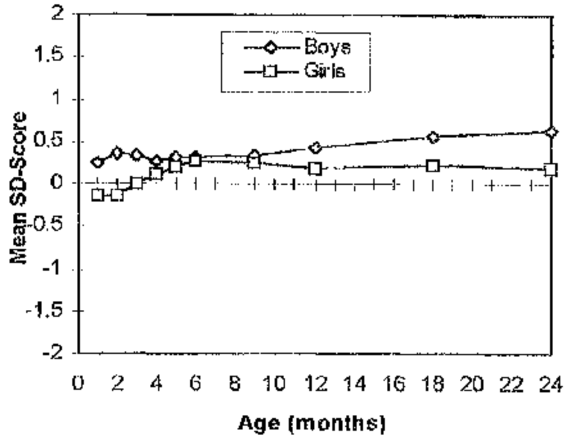


Figure 3.5 Mean length SD-scores of Glasgow children by sex compared with 'Tanner and Whitehouse' reference values.

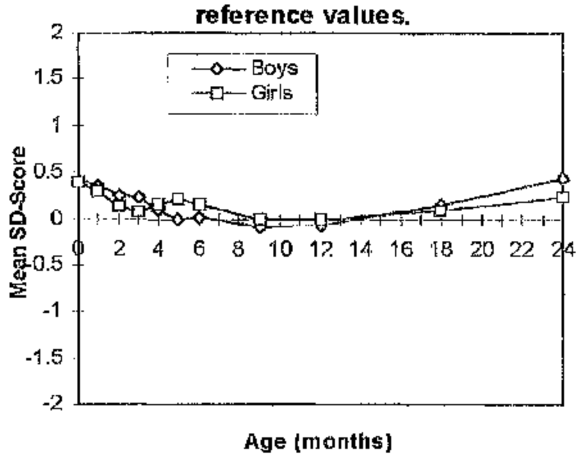


Figure 3.6 Mean length SD-scores of Glasgow children by sex compared with 'UK 1990' reference values.

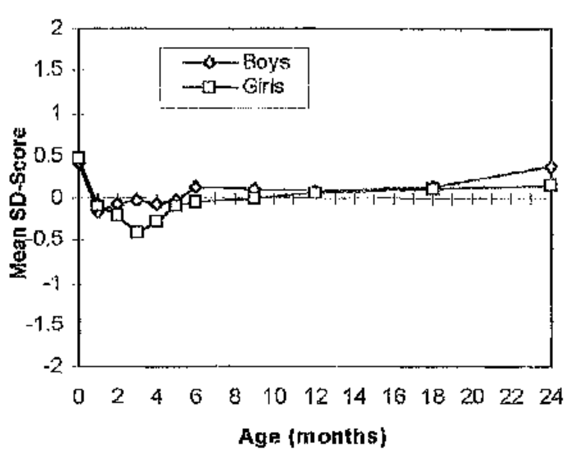


Figure 3.7 Mean length SD-scores of Glasgow children by sex compared with 'Revised UK 1990' reference values.

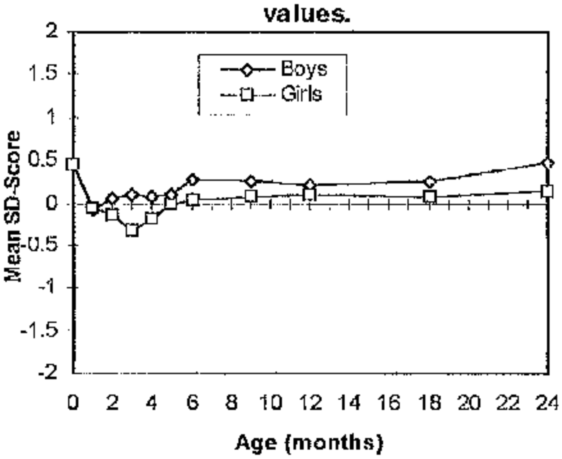


Figure 3.10 Mean BMI SD-scores of Glasgow children by sex compared with 'Revised UK 1990' reference values.

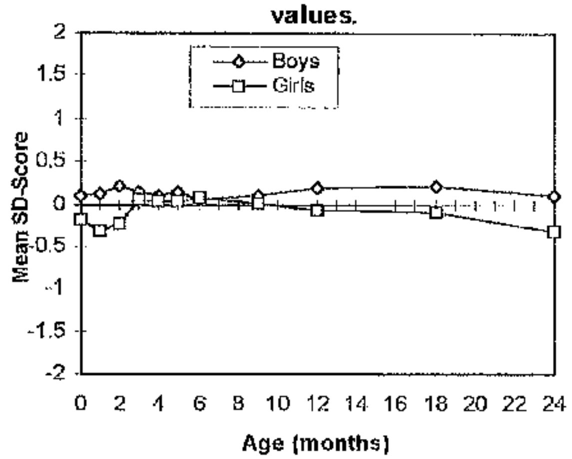


Figure 3.8 Mean length SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

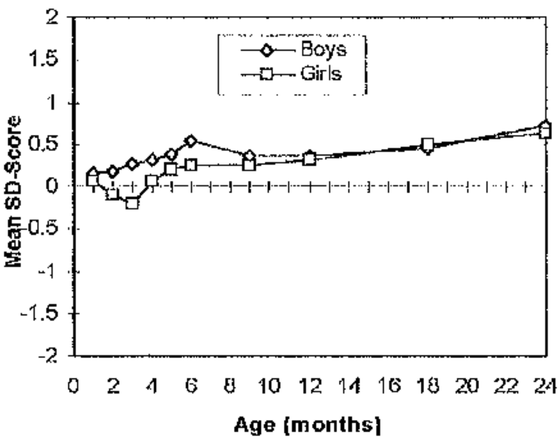


Figure 3.11 Mean BMI SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

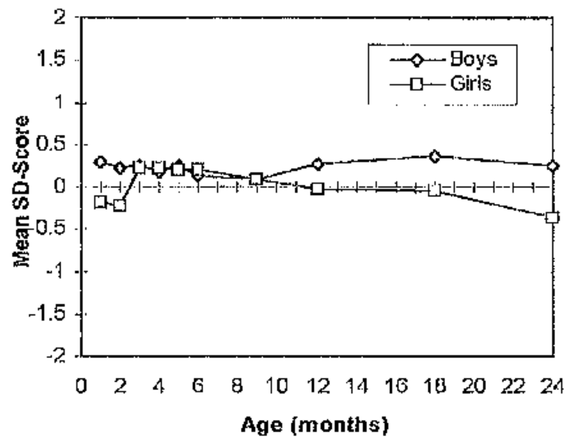


Figure 3.9 Mean BMI SD-scores of Glasgow children by sex compared with 'UK 1990' reference values.

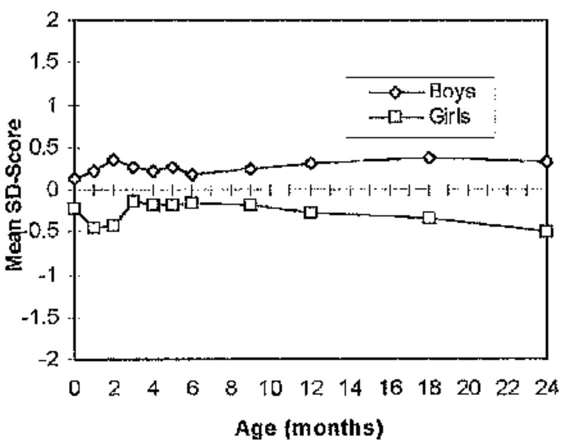


Figure 3.12 Mean head circumference SD-scores of Glasgow children by sex compared with 'Gairdner and Pearson' reference values.

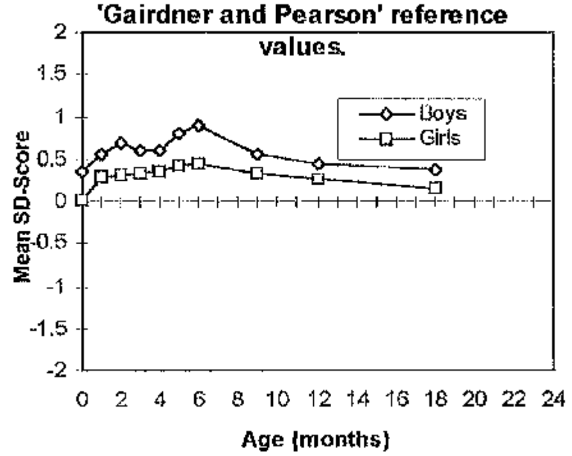


Figure 3.13 Mean head circumference SD-scores of Glasgow children by sex compared with 'UK 1990' reference values.

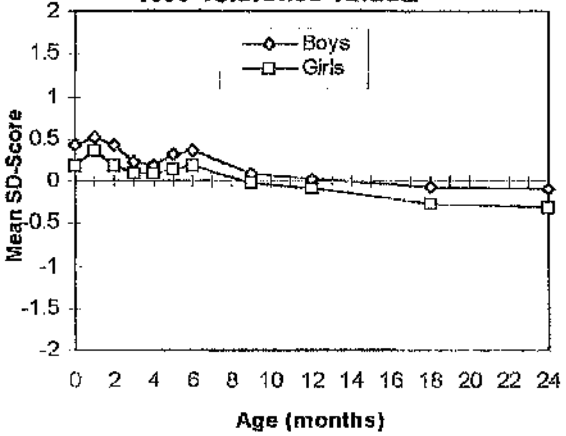


Figure 3.16 Mean triceps SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

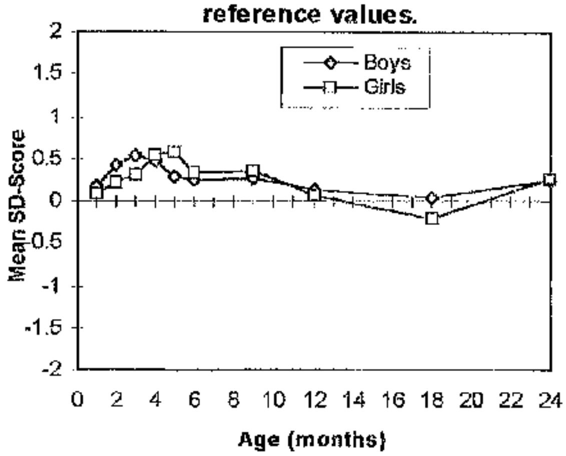


Figure 3.14 Mean head circumference SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

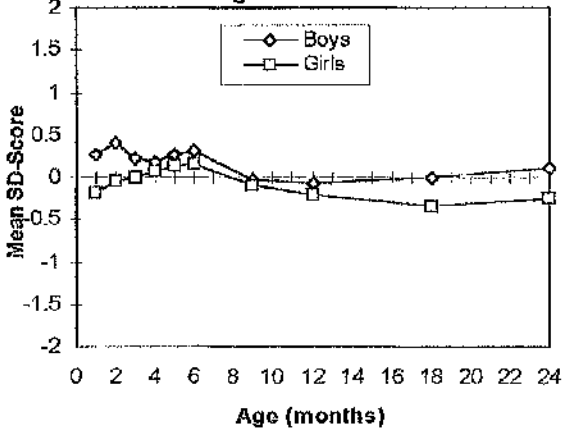


Figure 3.17 Mean subscapular SD-scores of Glasgow children by sex compared with 'Tanner and Whitehouse' reference values.

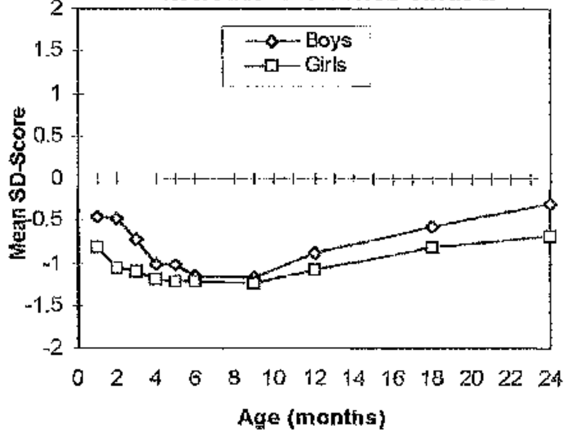


Figure 3.15 Mean triceps SD-scores of Glasgow children by sex compared with 'Tanner and Whitehouse' reference values.

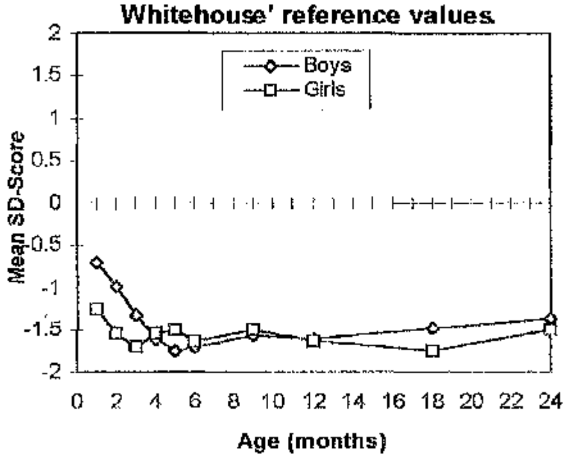


Figure 3.18 Mean subscapular SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

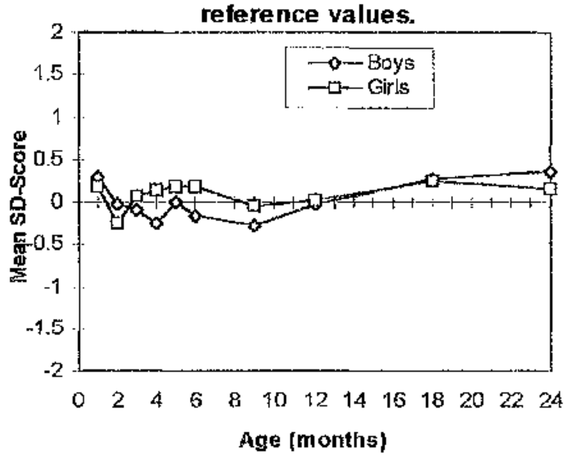


Figure 3.19 Mean MUAC SD-scores of Glasgow children by sex compared with 'Cambridge' reference values.

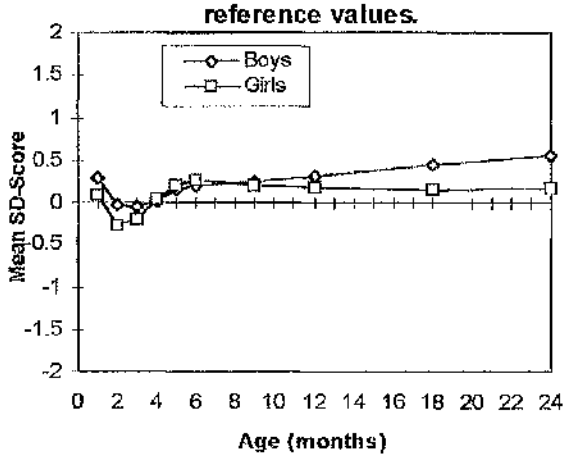


Figure 3.20 Mean weight SD-scores of Glasgow children by sex compared with 'UK 1990' and Revised UK 1990' reference values.

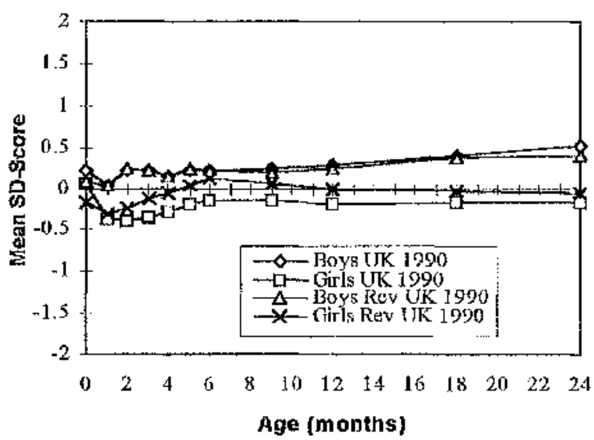


Figure 3.21 Mean length SD-scores of Glasgow children by sex compared with 'UK 1990' and Revised UK 1990' reference values.

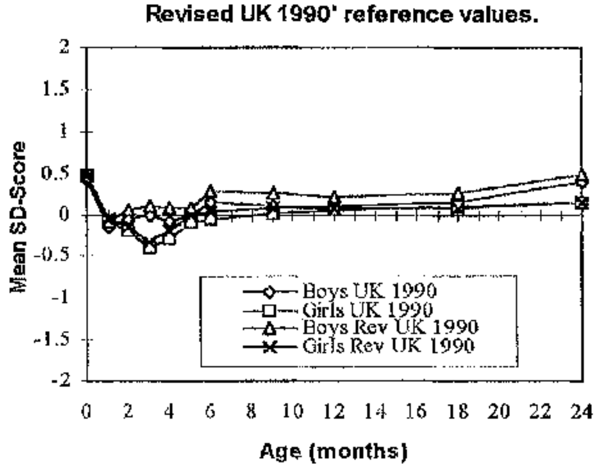
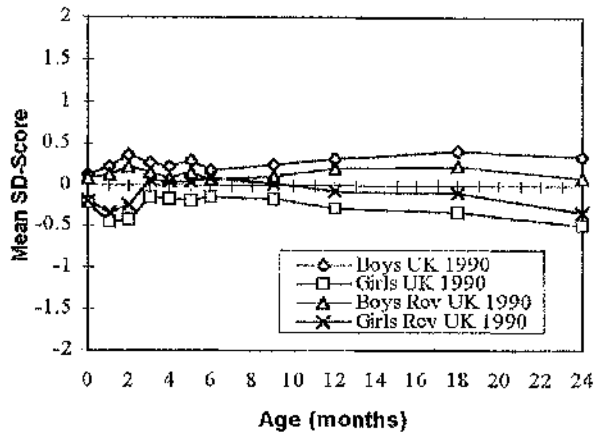


Figure 3.22 Mean BMI SD-scores of Glasgow children by sex compared with 'UK 1990' and Revised UK 1990' reference values.



Chapter 4

Growth and factors influencing growth

4.1 Introduction

Weight, length and head circumference are good, simple indicators of linear growth and brain growth in the infant. These measurements obviously also give some indication of nutritional status but other measurements and indices are much better indicators e.g. body mass index (BMI) by adjusting weight for height. For this reason, and for clarity, weight, length and head circumference were considered to be indicators of growth and the other measurements (mid-upper arm, calf and thigh circumference, triceps and subscapular skinfold, body mass index and mid-arm muscle circumference) were considered indicators of nutritional status in this thesis (discussed in Chapter 5).

The main aim of this chapter was to examine differences in growth between groups of infants characterised by different feeding practice, weaning practice, social class and mothers' smoking habit during pregnancy. Some of these comparisons have been carried out in other studies of differences between breast and formula-fed infants (Whitehead and Paul, 1984; Whitehead et al, 1986; Owen et al, 1984; Whitehead and Paul, 1981; Dewey et al, 1992), early and late weaned infants (Forsyth et al, 1993; Wilson et al, 1998; Whitehead and Paul, 1986; Heinig et al, 1993) and infants of higher and lower social class (e.g. Herngreen et al, 1994).

Many studies which found differences in growth between breast and formula-fed infants compared groups of infants which are of limited relevance to the situation in the UK. For example, infants who were exclusively breast-fed for long periods have been compared with those fed formula plus solids. In the UK exclusive breast-feeding for longer than three months is uncommon (White et al, 1992) and therefore exclusive breast-feeding for longer periods cannot be examined and is of limited relevance. What can be observed is whether breast-feeding for 2-3 months has any effect on linear growth and this is a more relevant issue for the UK.

'Early weaning' (weaning before the recommended time: 4 months), is common in the UK (White et al, 1992) and there is concern that this may increase the risk of obesity. A study carried out in Dundee (Forsyth et al, 1993) found that although greater weights were observed in early weaned infants (those weaned before 12 weeks) during the first year of life these had disappeared by the end of the first year. It was concluded that perhaps early weaning was not as harmful as previously thought. A study carried out in Cambridge (Whitehead and Paul, 1986) found that infants weaned before 4 months tended to gain more weight and length between 3 and 12 months than those weaned after 4 months. Our study was intended to test whether this effect of early weaning on weight and length is also observed in Glasgow infants and if there is any effect on other measurements of linear growth.

Social class is very closely linked to feeding and weaning practice of infants, with mothers of higher social class being more likely to breast-feed and introduce solids later (See Chapter 6; White et al, 1992). Therefore the effect of social class must also be examined to observe whether it is feeding and weaning or social class that is having an effect on growth.

Mother's smoking habit during pregnancy is also examined in this chapter. It was previously reported that mothers who smoked during pregnancy had smaller infants than those who did not smoke (White et al, 1992; Roquer et al, 1995; Bosley et al, 1981).

4.2 Methods

A comparison between boys and girls in the cohort was carried out for weight, length and head circumference. Differences in weight, length and head circumference were then examined for each sex for feeding method, age at weaning (introduction of first solid food), parental social class and mother's smoking habit during pregnancy.

4.2.1 Between group comparison for boys and girls

Tests of between group differences were made between boys and girls. Two-sample t-tests were used to make these comparisons at 1, 12 and 24 months and also for velocities from 1-12, and 12-24 months.

It was not appropriate to carry out t-tests at every age and hence these three ages were chosen for convenience. For velocities it was thought that the time between the two measurements should be at least one year (Gibson, 1990). One month measurement was used rather than birth as not all birth measurements were made by the trained observer as explained in Chapter 2.

4.2.2 Multiple regression analysis

As the factors which affect growth are closely related, multiple regression analyses were carried out to examine whether there were any differences between the groups studied. These analyses were carried out for attained weight, length and head circumference at 1, 12 and 24 months and for velocities of weight, length and head circumferences from 1-12 and 12-24 months.

Separate multiple regression analyses were carried out for boys and girls. The variables added to the multiple regression were:-

one month value for each measurement, actual value

feeding group, coded as 0 for breast, 1 for formula

age at introduction of solid food, actual value

social class, coded as 0 for I+II, 1 for lower social classes

mother smoking during pregnancy, coded as 0 for yes, 1 for no

Definitions of groups

Feeding method

It was extremely difficult to classify infants as breast or formula-fed for comparisons. Most other studies have defined a breast-fed child as those breast-fed for at least 3 or 4 months. As the breastfeeding rate in Glasgow was low and weaning early two months was considered to be a more appropriate cut-off point to define breastfeeding.

Therefore, for the purposes of this study infants who were still being breast-fed at two months were considered breast-fed and those formula-fed from birth or who were breast-fed for less than two months were considered formula-fed. It may have been more appropriate to have included a 'mixed fed' group, however, numbers of infants in the 'mixed fed' group would have been small and so this option was rejected.

The majority of infants in the formula-fed group who were initially breast-fed were breast-fed for less than one week. Of the 66 infants who were initially breast-fed, 49 were considered breast-fed by this definition and the other 17 considered formula-fed (13 of these were breast-fed for less than one week and four breast-fed for longer than one week: 2,3,4 and 7 weeks). A cut-off of one month was also considered and this would have meant that the infant breast-fed for seven weeks would be considered breast-fed. This decision would not affect the results and, therefore, two months was used.

Age at weaning

The actual age at first introduction of solid food in weeks was used.

Social class

For this comparison two groups were used. Social class I+II as one group and social class III non-manual, III manual, IV, V and unclassified as another group. This was thought to provide groups of adequate size in order to carry out analysis.

Mothers' smoking habit during pregnancy

Two groups were used for this comparison, simply mothers who smoked at all during pregnancy and those who did not.

One month value for anthropometry

Actual values of weights, lengths and head circumferences at one month were used as measured by the author.

4.3 Results

4.3.1 Between group comparisonn - gender

Tables 4.1-4.3 show mean and standard deviations for weight, length and head circumference at all time points for boys and girls.

Table 4.1. Boys and girls, mean weight (kg) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
0	69	3.59	0.45	58	3.34	0.42
1	68	4.52	0.51	58	4.07	0.55
2	68	5.60	0.62	56	4.91	0.66
3	66	6.44	0.68	58	5.76	0.78
4	69	7.11	0.78	58	6.45	0.89
5	67	7.77	0.88	57	7.09	0.94
6	69	8.27	0.93	58	7.62	1.03
9	69	9.47	1.08	58	8.74	1.20
12	67	10.42	1.15	55	9.54	1.29
18	66	11.93	1.29	50	10.89	1.39
24	65	13.14	1.37	47	12.01	1.54

Table 4.2. Boys and girls, mean length (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
0	44	52.0	2.1	41	51.1	2.1
1	68	54.5	2.1	58	53.5	2.1
2	68	58.2	2.2	56	56.5	2.2
3	66	61.3	2.1	58	59.1	2.4
4	69	63.8	2.4	58	61.7	2.3
5	67	66.0	2.4	57	64.1	2.3
6	69	68.1	2.4	58	65.9	2.4
9	69	72.4	2.6	58	70.3	2.8
12	67	76.1	3.0	55	74.1	2.8
18	66	82.5	3.1	51	80.7	3.0
24	65	88.3	3.5	47	86.3	3.3

Table 4.3. Boys and girls, mean head circumference (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
0	67	35.4	1.2	54	34.7	1.3
1	68	38.3	1.1	58	37.2	1.2
2	68	40.2	1.1	56	38.9	1.3
3	66	41.5	1.1	58	40.4	1.2
4	69	42.8	1.2	58	41.6	1.2
5	67	44.0	1.2	57	42.7	1.2
6	69	45.0	1.2	58	43.7	1.4
9	69	46.5	1.2	58	45.2	1.1
12	67	47.7	1.3	55	46.3	1.2
18	66	49.2	1.3	51	47.7	1.3
24	65	50.1	1.2	47	48.6	1.3

Boys were heavier, longer and had greater head circumference than girls at all ages. At 1, 12 and 24 months boys were significantly heavier ($p<0.001$, $p<0.01$ and $p<0.001$ respectively), longer ($p<0.01$, $p<0.001$ and $p<0.01$) and had greater head circumference ($P<0.001$ for all) than girls (Table 4.4).

Table 4.4. Boys and girls weight (kg), length (cm) and head circumference (cm) at 1, 12 and 24 months.

Attained	Boys		Girls		P-value
	Mean	SD	Mean	SD	
Weight					
1	4.52	0.51	4.07	0.55	***
12	10.42	1.15	9.54	1.29	***
24	13.14	1.37	12.01	1.54	***
Length					
1	54.5	2.1	53.5	2.1	**
12	76.1	3.0	74.1	2.8	***
24	88.3	3.5	86.3	3.3	**
Head Circumference					
1	38.3	1.1	37.3	1.2	***
12	47.7	1.3	46.3	1.2	***
24	50.1	1.2	48.6	1.3	***

Two-sample t-test *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant.

Boys had greater gain in weight, length and head circumference than girls from 1-12 months ($p<0.05$, $p<0.01$ and $p<0.01$ respectively) but not from 12-24 months (Table 4.5).

Table 4.5. Boys and girls weight, length and head circumference gain from 1-12 and 12-24 months.

Velocity	Boys			Girls			P-Value
	n	Mean	SD	n	Mean	SD	
Weight gain							
1-12 mths	66	5.89	0.96	55	5.43	1.00	*
12-24mths	65	2.72	0.64	47	2.50	0.77	NS
Length gain							
1-12 mths	66	21.5	2.6	55	20.5	2.0	**
12-24mths	65	12.2	1.4	47	12.1	1.7	NS
Head circ. gain							
1-12 mths	66	9.4	1.1	55	9.0	0.8	**
12-24mths	65	2.4	0.4	47	2.4	0.4	NS

Two-sample t-test *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant.

Large differences were observed between boys and girls. For this reason analyses were carried out separately for boys and girls. Differences in the factors which influence growth might differ between the sexes, and these may be masked by exclusively considering the sexes together.

4.3.2 Multiple regression analyses

The multiple regression analysis was carried out for weight, length and head circumference at 1, 12 and 24 months and for velocity over 1-12 and 12-24 months.

Feeding method

No difference was found between feeding groups in girls. Breast-fed boys had greater head circumference at 12 and 24 months ($p<0.001$ and $p<0.01$) and gained more head circumference over the second year than those formula-fed ($p<0.05$, Table 4.6).

Table 4.6 Multiple regression analyses for weight, length and head circumference by feeding method.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
Weight					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Length					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Head Circ					
Boys	NS	***a	**a	NS	*a
Girls	NS	NS	NS	NS	NS

Multiple regression *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant, a breast-fed>formula-fed

Age at weaning

Girls who were weaned earlier were heavier, longer and had greater head circumference at one month ($p<0.05$) and boys longer ($p<0.05$) and greater head circumference ($p<0.001$) at one month than those weaned later (Table 4.7).

Earlier weaned girls were heavier at 12 and 24 months ($p<0.05$), and gained more weight over the first year ($p<0.05$). They were also longer at 12 months ($p<0.05$), gained more length over the first year ($p<0.05$) and had greater head circumference at two years (p<0.05), compared with those weaned later. Earlier weaned boys gained significantly less head circumference over the first year than those later weaned (p<0.01, Table 4.7).

Table 4.7 Multiple regression analyses for weight, length and head circumference by age at weaning.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
Weight					
Boys	NS	NS	NS	NS	NS
Girls	*a	*a	*a	*a	NS
Length					
Boys	*a	NS	NS	NS	NS
Girls	*a	*a	NS	*a	NS
Head Circ					
Boys	***a	NS	NS	**b	NS
Girls	*a	NS	*a	NS	NS

Multiple regression *** p<0.001, ** p<0.01, * p<0.05 and NS not significant, a early>late, b late> early

Social class

Boys from social class I+II had significantly greater head circumference at one month than those from lower social classes (p<0.001). Girls from social classes I+II gained significantly more weight over the second year (p<0.01), had significantly greater head circumference at 2 years (p<0.05) and gained significantly more head circumference in the second year (p<0.01) than those from lower social classes (Table 4.8).

Table 4.8 Multiple regression analyses for weight, length and head circumference by social class.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
Weight					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	**a
Length					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Head Circ					
Boys	***a	NS	NS	NS	NS
Girls	NS	NS	*a	NS	**a

Multiple regression *** p<0.001, ** p<0.01, * p<0.05 and NS not significant, a social class I+II>lower social classes.

Mothers' smoking habit during pregnancy

Mothers smoking during pregnancy was found to have an adverse effect on the growth of the infants. Both boys and girls of mothers who smoked were significantly lighter (p<0.001 and p<0.01 respectively) and shorter (p<0.001 and p<0.01). Girls of mothers who smoked during pregnancy had significantly smaller head circumference than those whose mother did not smoke (p<0.001, Table 4.9).

Table 4.9 Multiple regression analyses for weight, length and head circumference by mothers' smoking habit during pregnancy.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
Weight					
Boys	***a	NS	NS	NS	NS
Girls	**a	NS	NS	NS	NS
Length					
Boys	***a	NS	NS	NS	NS
Girls	**a	NS	NS	NS	NS
Head Circ					
Boys	NS	NS	NS	NS	NS
Girls	***a	NS	NS	NS	NS

Multiple regression *** p<0.001, ** p<0.01, * p<0.05 and NS not significant, a non-smoking > smoking

One month value for anthropometry

Boys and girls who were heavier at one month were heavier at 12 and 24 months (p<0.001). Girls who were heavier at one month also gained significantly more weight over the first year than lighter girls (p <0.05, Table 4.10).

Boys and girls who were longer at one month tended to be longer at 12 and 24 months (p<0.001) but no significant differences were found for gain in length (Table 4.10).

This was also the case for head circumference with boys and girls with greater head circumference at one month more likely to have greater head circumference at 12 and 24 months (p<0.001). Girls with greater head circumference at one month gained less head circumference over the first year (p<0.05, Table 4.10).

Table 4.10 Multiple regression analyses for weight, length and head circumference by one month values for anthropometry.

	12 months	24 months	velocity 1-12 months	velocity 12-24 months
Weight				
Boys	***a	***a	NS	NS
Girls	***a	***a	*a	NS
Length				
Boys	***a	***a	NS	NS
Girls	***a	***a	NS	NS
Head Circ				
Boys	***a	***a	NS	NS
Girls	***a	***a	*b	NS

Multiple regression *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant, a higher 1 month measurement >lower one month measurement, b lower one month measurement> higher 1 month measurement.

4.4 Discussion

4.4.1 Feeding Method

Many studies have found differences for weight and length (Whitehead and Paul, 1984; Whitehead et al, 1986; Owen et al, 1984; Whitehead and Paul, 1981; Dewey et al, 1989) between breast and formula-fed infants. Many of these studies were not carried in the UK and used definitions of breastfeeding not appropriate to the UK and studied very small, highly selected, samples. One of the main American studies which has looked at the effect of feeding method on growth - The DARLING study (e.g. Dewey et al, 1992) found that those defined as breast-fed (breast-fed for at least 12 months) were lighter than those defined as formula-fed (formula-fed from birth or breast-fed for less than 3 months) between 6 and 18 months. No significant difference was observed for length or head circumference between feeding groups.

One of the main studies from the UK which has observed the effect of feeding method on growth was the Cambridge Infant Growth Study (Whitehead and Paul, 1984; Whitehead et al, 1989). The vast majority of the formula-fed infants were introduced to solid food before 4 months and were found to exhibit weight and length growth patterns similar to those breast-fed and introduced to solid food before 4 months.

The differences found in the DARLING study therefore may be due to the definitions of breast-feeding used since few differences in length and weight between feeding groups were found in the Cambridge or the present study. In the present study no differences in weight or length were found between breast and formula fed infants.

Although the DARLING study found no differences for head circumference the present study found large differences in boys. Breast-fed boys had significantly greater head circumference than formula-fed at one and two years and gained more over the second year than those formula-fed.

4.4.2 Age at weaning

Other studies have found differences in growth between infants weaned onto solids early and those weaned later (Forsyth et al, 1993; Whitehead and Paul, 1986; Heinig et al, 1993). The Cambridge study (Whitehead and Paul, 1986) found differences in weight and length between weaning groups using a cut-off of four months, the recommended time of weaning onto solid food (Dept of Health, 1994). Weight and length gain were greater in infants who were introduced to solids before four months.

Many mothers in the UK are not following the guidelines on infant feeding (Chapter 6; White et al, 1992; Savage et al, 1998a) and are weaning much earlier. For this reason another study carried out in Dundee (Forsyth et al, 1993) used 8 and 12 weeks as cut-off points to define early weaning. A large sample were followed (n=671). Infants weaned onto solid food early (<12 weeks) were heavier at 4, 8, 13 and 26 weeks of age but not at one or two years. However, when these infants were followed to 7 years, those who had not been introduced to solid food before 15 weeks had decreased percentage body fat and weight (Wilson et al, 1998).

For the present study, age at weaning onto solid food showed more association with growth than feeding method, especially in girls. For both boys and girls those who were heavier, longer and with greater head circumference at one month (before weaning) were found to be more likely to be weaned onto solid food 'early'. Early weaned girls were heavier and longer at 12 months and had greater weight and head circumference at 24 months than those later weaned. Early weaned girls also gained significantly more weight and length over the first year.

No statistically significant differences were found in boys for weight or at one or two years. For gain in head circumference late weaned boys gained more over the first year than those early weaned.

The present study observed differences in growth associated with timing of weaning in girls but less so in boys. One possible explanation of this is that early and late weaned boys have similar energy intakes whereas early and late weaned girls do not. This could occur if late weaned boys received additional breast or formula milk to equal the intake of those weaned early who were receiving milk and solids. Further studies would be required in order to test this.

4.4.3 Social class

Other studies have examined differences in growth in infancy between social classes (e.g. Herngreen et al, 1994) and found little difference between infants of parents of different socio-economic status. The present study found very minor differences in weight and length between social class groups at this age.

There were some differences between infants from different social classes in head circumference. Girls from social class I+II had greater head circumference at 24 months and gained more head circumference over the second year than those from lower social classes and boys from social classes I+II had greater head circumference at one month than those from lower social classes.

4.4.4 Mothers' smoking habit during pregnancy

The inhibition of growth caused by mothers smoking during pregnancy (White et al, 1992; Roquer et al, 1995; Bosley et al, 1981) was also found in this study. Mothers who smoked during pregnancy had babies who were lighter and shorter, and in girls also smaller head circumference than those mothers who did not smoke during pregnancy.

4.5 Conclusions

This study suggests that the differences which have been found between breast and formula-fed infants may be due to the definitions used i.e. infants being exclusively breast-fed for long periods (i.e. those weaning late) being defined as breast-fed. Alternatively in some of the earlier studies, older type formulas have been used which are very different in composition to those used today (Whitehead et al, 1987). Those studies which have found differences in growth have suggested that breast-fed infants may not grow as well as those formula-fed and perhaps separate growth charts should be constructed for breast and formula-fed infants (Dewey et al, 1992). However, neither the present study nor the Cambridge study have found this to be necessary as growth is broadly similar between the two groups in early life in this country.

Differences in growth were found between weaning groups especially in girls. This is similar to the results found in the Cambridge (Whitehead and Paul, 1986) and Dundee (Forsyth et al, 1993) studies. The differences in girls for all three measurements and in head circumference in boys were still apparent at two years. Therefore, it does appear that age at weaning onto solid food has more of an effect on growth than whether infants are breast or formula-fed.

The main differences found between the social classes were in head circumference with those from higher social classes having greater head circumferences than those from lower social classes. No differences were found for weight or length which was similar to the findings of other studies (Herngreen et al, 1994).

The inhibition of growth caused by mothers smoking during pregnancy (White et al, 1992) was also found in this study.

There were some drawbacks to the present study in particular the sample size. The sample size was small and therefore the results cannot be as conclusive as some of the larger studies. However, the sample size used was similar to those used in other studies (Dewey et al, 1992; Tanner et al, 1966) and does provide some indication of the extent to which growth is or is not influenced by certain factors. Another drawback is that, because the data are longitudinal with repeated measures over time, one measurement will very much influence subsequent measurements. However, following statistical advice it was decided to analyse at certain time points only, spaced in time, in order to minimise this 'carry over' effect.

Chapter 5

Nutritional status and factors influencing nutritional status

5.1 Introduction

The literature on infancy has focused largely on growth, with less emphasis on nutritional status. Weight-for-height, BMI and skinfold thicknesses are most often used as indicators of nutritional status. However, other anthropometric measurements such as mid-upper arm circumference (MUAC), mid-arm muscle circumference (MAMC), calf and thigh circumference can also be used and are fairly easy measurements to make in infancy. As explained in Chapter 4 many studies which observe the effect of feeding method on growth and nutritional status did so on cohorts which were not representative of the situation in the UK. There are few studies which describe nutritional status in samples which are representative of the UK. Therefore, the main aim of this chapter was to determine the factors which influence this nutritional status of infants from birth to two years in a sample representative for feeding and weaning practice of the UK (Chapter 6; Savage et al, 1998).

5.1.1 Feeding method

Early studies from late 1960s early 1970s found differences between breast and formula-fed infants in anthropometry (Taitz, 1971). Formula-fed infants were heavier than those breast-fed. However this can be explained by the fact that early infant formulas were more energy dense than more modern formulas. Later studies have shown more mixed results, some still found differences in growth (Dewey et al, 1993; Czajka-Nairns and Jung, 1986; Lucas et al, 1992) whereas others did not (Whitehead et al, 1989; Wells and Davies, 1995b; Harrison et al, 1987).

One study which found a difference for nutritional status between breast and formula-fed infants was the DARLING Study in California (Dewey et al, 1992). This study found differences between feeding groups for weight-for-length and skinfold thicknesses. Five skinfolds were measured, biceps, triceps, subscapular, flank and quadriceps and these were also used to estimate percentage body fat. Formula-fed infants were found to have greater weight-for-length from 7-24 months and greater skinfolds except for biceps in later infancy, especially 9-15 months when compared with breast-fed infants. The percentage fat was found to be greater from 5-24 months. This study claimed to have feeding groups which were matched for many confounding variables including socio-economic status. However, all the mothers from the DARLING study had a high level of education and the age at weaning onto solid food was not before 4 months in any of these infants. In the UK this is not the normal situation for introduction of solids (Savage et al 1998a; White et al, 1992). Even in the South of England, where mothers are more likely to follow guidelines for infant feeding, many weaned infants onto solid food before 4 months (White et al, 1992).

The differences in anthropometry observed by the DARLING Study might be explained by differences in energy intake. Formula-fed infants were found to maintain their formula intake when solids were introduced whereas breast-fed infants decreased their breast milk intake. Therefore, the energy intake of breast-fed infants remained the same but formula-fed infants increased their energy intake, the solid food being additive to the formula rather than replacing it.

Whitehead et al (Whitehead et al, 1989) observed large differences between 'Tanner and Whitehouse' triceps and subscapular data of the late 1960s (Tanner and Whitehouse, 1975) and their more recent data from Cambridge. They suggest that these differences were due to differences in feeding and weaning practices between the two samples. In the late 1960s breastfeeding rate was very low and introduction of solids extremely early. As well as this, the formulas which were used were much less modified than they are today and were more energy dense. In the Cambridge Infant Growth Study, most infants were breast-fed and were introduced to solid food usually in accordance with the recommendations, around 4 months.

However, infants from the Cambridge study who were formula-fed were found to have very similar triceps and subscapular skinfolds and weight for length to those breast-fed. Therefore, the older formulas and age at weaning onto solid food are more likely to explain the difference rather than whether the infants received breast or formula milk.

5.1.2 Age at weaning

The DARLING study found no difference for weight-for-length between those breast-fed weaned before 6 months and those breast-fed weaned after 6 months (Heinig et al, 1993). This was because infants who were introduced to solids decreased their breast milk intake and those who had not received solids maintained their breast milk intake. Therefore, the energy intakes between groups did not differ and this study suggests that late weaning after six months in breast-fed infants does not affect their nutritional status. However, again these groups would simply not exist in the UK as almost all mothers would have introduced solids by 6 months (White et al, 1992; Savage et al, 1998a).

The Cambridge Study (Whitehead and Paul, 1986) did observe differences between boys weaned onto solids before and after 16 weeks and for girls before and after 20 weeks. Infants weaned early had greater triceps and subscapular skinfolds and weight for length than those weaned later. This study was well conducted with one observer for most of the anthropometry. The one major problem of the study is that Cambridge is not representative in terms of infant feeding, weaning practice or social class of the rest of the UK. The Cambridge study consisted largely of well-educated mothers who were from higher social classes, with a high proportion of mothers breastfeeding and introducing solids after 4 months.

The present study in Glasgow had only one observer for all anthropometry. The Glasgow cohort when compared with the OPCS Infant Feeding Report (White et al, 1992) was more representative for feeding and weaning practice in Scotland and the UK than Cambridge (Savage et al, 1998a). The Glasgow cohort had lower breastfeeding rate than Cambridge (39% at 2 months, Chapter 6) and infants weaned onto solid food earlier (median age 11 weeks, Chapter 6). Therefore, using the Glasgow sample to observe differences in growth and nutritional status for feeding and weaning groups, will provide a better indication of whether these feeding practices, typical of those in the UK, affect growth and nutritional status. Other studies referred to above may answer certain questions in relation to feeding practices, but if very few mothers feed their infants in this way then the information is of limited value.

5.1.3 Social class

Despite a widespread belief that there are large social class differences in growth and nutritional status more recent studies have found no difference. A study from The Netherlands examined this in a representative sample of Dutch infants from birth-2 years (Herngreen et al, 1994). Very little difference was found between growth of weight or length between different socio-economic groups. These were the only measurements made and unfortunately they did not report on weight-for-height or BMI.

The American National Health and Nutrition Examination Study (HANES I+II) data (Miller et al, 1977, McDowell et al, 1981) showed very little difference in skinfolds, triceps and subscapular in early childhood between different poverty status groups (Jones et al, 1985).

5.1.4 Mothers' smoking habit during pregnancy

Smoking during pregnancy has been found to affect birth measurements in infants (Roquer et al, 1995; Bosley et al, 1981; White et al, 1992). Information has been collected on mothers' smoking behaviour during pregnancy from the Glasgow cohort and, therefore, the effect of this smoking behaviour on nutritional status as well as growth can be assessed.

The data collected from the present study was therefore used to assess differences in growth or nutritional status in infants with different feeding and weaning practice and also from different social classes. Other confounding factors such as mothers smoking during pregnancy (which may influence growth or nutritional status) were also examined.

5.2 Methods

A comparison between boys and girls in the cohort was carried out for BMI, MUAC, MAMC, calf circumference, thigh circumference, sum of skinfolds and triceps and subscapular skinfold. Differences in these measurements were then examined in each sex for feeding method, age at weaning (introduction of first solid food), parental social class and mothers' smoking habit during pregnancy.

The methods for between group comparison and multiple regression analyses are as Chapter 4 (Section 4.2.1 and 4.2.2).

5.3 Results

5.3.1 Between group comparison - gender

Summary statistics

Tables 5.1-5.8 show means and standard deviations for BMI, MUAC, MAMC, calf circumference, thigh circumference, sum of triceps and subscapular skinfold, triceps skinfold and subscapular skinfold.

Table 5.1 Boys and girls, mean BMI (kg/m^2) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
0	44	13.45	1.08	41	12.86	1.06
1	68	15.15	1.04	58	14.16	1.19
2	68	16.50	1.25	56	15.30	1.29
3	66	17.13	1.37	58	16.45	1.50
4	69	17.45	1.35	58	16.89	1.63
5	67	17.80	1.34	57	17.20	1.58
6	69	17.78	1.22	58	17.47	1.69
9	69	18.05	1.50	58	17.63	1.76
12	67	17.98	1.29	55	17.32	1.75
18	66	17.52	1.21	50	16.73	1.51
24	65	16.82	0.96	47	16.09	1.51

Table 5.2 Boys and girls, mean MUAC (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	11.5	0.9	58	11.0	0.9
2	68	12.5	0.8	56	11.8	0.9
3	66	13.3	0.9	58	12.7	0.9
4	69	14.0	1.0	58	13.5	1.0
5	67	14.5	1.0	57	14.1	1.0
6	69	14.9	1.0	58	14.5	1.1
9	69	15.5	1.1	58	15.0	1.1
12	67	15.8	1.1	55	15.3	1.3
18	66	16.2	1.1	50	15.7	1.3
24	65	16.5	1.0	47	16.0	1.4

Table 5.3 Boys and girls, mean MAMC (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	9.4	0.9	58	9.1	1.0
2	68	10.3	1.0	56	9.8	1.2
3	66	10.9	1.1	58	10.5	1.2
4	69	11.6	1.2	58	11.2	1.4
5	67	12.2	1.3	57	11.7	1.5
6	69	12.5	1.3	58	12.2	1.5
9	69	13.1	1.6	58	12.6	1.6
12	67	13.4	1.4	55	13.0	1.6
18	66	13.9	1.3	50	13.5	1.6
24	65	14.1	1.3	47	13.6	1.7

Table 5.4 Boys and girls, mean calf circumference (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	13.3	0.9	58	12.8	1.0
2	68	14.9	1.0	56	14.1	1.2
3	66	16.2	1.1	58	15.4	1.2
4	69	17.3	1.2	58	16.6	1.4
5	67	18.1	1.3	57	17.5	1.5
6	69	18.6	1.3	58	18.2	1.5
9	69	19.4	1.6	58	18.9	1.6
12	67	20.1	1.4	55	19.4	1.6
18	66	21.0	1.3	50	20.3	1.6
24	65	21.6	1.3	47	20.7	1.7

Table 5.5 Boys and girls, mean thigh circumference (cm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	18.1	1.5	58	17.7	1.4
2	68	20.4	1.5	56	19.5	1.6
3	66	22.1	1.7	58	21.3	1.7
4	69	23.5	1.8	58	22.8	2.0
5	67	24.7	1.8	57	24.0	2.1
6	69	25.6	1.9	58	25.0	2.2
9	69	26.7	2.2	58	26.3	2.4
12	67	27.5	2.1	55	26.8	2.3
18	66	28.6	2.1	50	27.8	2.5
24	65	29.4	2.0	47	28.7	2.8

Table 5.6 Boys and girls, mean sum of triceps and subscapular skinfolds (mm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	13.1	2.2	58	12.3	2.1
2	68	14.0	2.0	56	12.9	2.1
3	66	14.3	1.9	58	13.5	2.2
4	69	14.1	1.8	58	14.1	2.3
5	67	13.9	1.8	57	14.2	2.2
6	69	13.8	1.9	58	13.9	2.1
9	69	14.0	2.7	58	14.1	2.8
12	67	14.1	2.3	55	13.8	2.4
18	66	13.7	2.2	50	13.3	2.5
24	65	13.8	2.1	47	13.9	3.4

Table 5.7 Boys and girls, mean triceps skinfolds (mm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	6.6	1.1	58	6.1	1.1
2	68	7.1	1.0	56	6.5	1.1
3	66	7.4	1.0	58	6.8	1.0
4	69	7.4	1.0	58	7.2	1.2
5	67	7.2	1.0	57	7.5	1.0
6	69	7.3	1.1	58	7.2	1.0
9	69	7.7	1.7	58	7.6	1.6
12	67	7.5	1.3	55	7.3	1.3
18	66	7.4	1.3	50	7.0	1.5
24	65	7.5	1.3	47	7.6	1.8

Table 5.8 Boys and girls, mean subscapular skinfolds (mm) and SD from birth-24 months.

Age (months)	Boys			Girls		
	n	Mean	SD	n	Mean	SD
1	68	6.5	1.3	58	6.1	1.1
2	68	6.9	1.2	56	6.4	1.3
3	66	6.9	1.2	58	6.7	1.3
4	69	6.6	1.1	58	6.8	1.4
5	67	6.7	1.1	57	6.8	1.4
6	69	6.5	1.1	58	6.7	1.3
9	69	6.3	1.3	58	6.5	1.6
12	67	6.6	1.3	55	6.5	1.4
18	66	6.3	1.1	50	6.4	1.2
24	65	6.2	1.1	47	6.3	1.9

Body mass index

Boys had greater BMI than girls at 1 ($p<0.001$), 12 ($p<0.05$) and 24 ($p<0.01$) months. No difference was found for gain in BMI over the first or the second year (Table 5.9).

Table 5.9. Boys and girls BMI (kg/m^2) at 1, 12 and 24 months and gain in BMI from 1-12 and 12-24 months

BMI	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	15.15	1.04	58	14.16	1.19	***
12 mths	67	17.98	1.29	55	17.32	1.75	*
24 mths	65	16.82	0.96	47	16.09	1.51	**
Velocity							
1-12 mths	66	2.80	1.36	55	3.06	1.55	NS
12-24mths	65	1.66	1.12	47	1.91	1.34	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Mid-upper arm circumference

Boys had greater MUAC than girls at 1 ($p<0.01$), 12 ($p<0.05$) and 24 ($p<0.05$) months but no differences were found for velocities (Table 5.10).

Table 5.10. Boys and girls MUAC (cm) at 1, 12 and 24 months and gain in MUAC from 1-12 and 12-24 months

MUAC	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	11.5	0.9	58	11.0	0.9	**
12 mths	67	15.8	1.1	55	15.3	1.3	*
24 mths	65	16.5	1.0	47	16.0	1.4	*
Velocity							
1-12 mths	66	4.3	1.1	55	4.2	1.0	NS
12-24mths	65	0.7	0.8	47	0.7	0.9	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Mid-arm muscle circumference

For MAMC boys had greater values at 1 ($p<0.05$), 12 ($p<0.05$) and 24 ($p<0.01$) months the difference this time being greatest at 24 months with a difference of 0.5 cm. No difference was found for the gain in MAMC between the sexes (Table 5.11).

Table 5.11. Boys and girls MAMC (cm) at 1, 12 and 24 months and gain in MAMC from 1-12 and 12-24 months

MAMC	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	9.4	0.8	58	9.1	0.7	*
12 mths	67	13.4	1.0	55	13.0	1.1	*
24 mths	65	14.1	0.9	47	13.6	1.0	**
Velocity							
1-12 mths	66	4.0	1.1	55	3.9	0.9	NS
12-24mths	65	0.7	0.8	47	0.6	0.7	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Calf circumference

As with BMI, MUAC and MAMC boys had greater calf circumferences than girls at 1 ($p<0.01$), 12 ($p<0.05$) and 24 ($p<0.01$) months and no differences for velocities (Table

5.12). At 1 month the actual difference was 0.5 cm, with 0.7 cm at 12 months and 0.9 cm at 24 months.

Table 5.12. Boys and girls calf circumference (cm) at 1, 12 and 24 months and gain in calf circumference from 1-12 and 12-24 months

Calf	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	13.3	0.9	58	12.8	1.0	**
12 mths	67	20.1	1.4	55	19.4	1.6	*
24 mths	65	21.6	1.3	47	20.7	1.7	**
Velocity							
1-12 mths	66	6.8	1.4	55	6.6	1.2	NS
12-24mths	65	1.5	0.9	47	1.4	1.1	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Thigh circumference

Thigh circumference showed much less difference between sexes. There was a trend for boys to have greater thigh circumference at all three ages but no statistical significance was found. No differences in velocities of thigh circumference were found (Table 5.13).

Table 5.13. Boys and girls thigh circumference (cm) at 1, 12 and 24 months and gain in thigh circumference from 1-12 and 12-24 months

Thigh	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	18.1	1.5	58	17.7	1.4	NS
12 mths	67	27.5	2.1	55	26.8	2.3	NS
24 mths	65	29.4	2.0	47	28.7	2.8	NS
Velocity							
1-12 mths	66	9.4	2.2	55	9.0	2.2	NS
12-24mths	65	1.9	1.7	47	2.1	1.8	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Sum of skinfolds

Boys had greater sum of skinfolds at 1 month than girls ($p<0.05$) but not at 12 or 24 months. No differences were found for the gain in skinfolds between sexes (Table 5.14).

Table 5.14. Boys and girls sum of triceps and subscapular skinfolds (mm) at 1, 12 and 24 months and gain in sum of skinfolds from 1-12 and 12-24 months

Sum of skinfolds	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	13.1	2.2	58	12.3	2.1	*
12 mths	67	14.1	2.3	55	13.8	2.4	NS
24 mths	65	13.8	2.1	47	13.9	3.4	NS
Velocity							
1-12 mths	66	0.9	2.4	55	1.3	2.3	NS
12-24mths	65	-0.3	2.3	47	0.2	3.0	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Triceps skinfold

The only difference observed for triceps skinfold was at 1 month ($p<0.05$) where boys had a greater mean triceps skinfold by 0.5 mm (Table 5.15).

Table 5.15. Boys and girls triceps skinfold (mm) at 1, 12 and 24 months and gain in triceps skinfold from 1-12 and 12-24 months

Triceps skinfold	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	6.6	1.1	58	6.1	1.1	*
12 mths	67	7.5	1.3	55	7.3	1.3	NS
24 mths	65	7.5	1.3	47	7.6	1.8	NS
Velocity							
1-12 mths	66	0.9	1.3	55	1.1	1.4	NS
12-24mths	65	0.0	1.6	47	0.3	1.8	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

Subscapular skinfold

No statistically significant differences were found for subscapular skinfold between the sexes (Table 5.16).

Table 5.16. Boys and girls subscapular skinfold (mm) at 1, 12 and 24 months and gain in subscapular skinfold from 1-12 and 12-24 months

Subscapular skinfold	Boys			Girls			P-value
	n	Mean	SD	n	Mean	SD	
Attained							
1 mths	68	6.5	1.3	58	6.1	1.1	NS
12 mths	67	6.6	1.3	55	6.5	1.4	NS
24 mths	65	6.2	1.1	47	6.3	1.9	NS
Velocity							
1-12 mths	66	0.1	1.6	55	0.2	1.2	NS
12-24mths	65	-0.3	1.2	47	-0.1	1.6	NS

two-sample t-test *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and NS not significant

5.3.2 Multiple regression analyses

The multiple regression analysis was carried out for all measurements at 1, 12 and 24 months and for velocity over 1-12 and 12-24 months.

Feeding method

In boys the only difference found between feeding groups was in triceps skinfold. At 24 months boys who were formula-fed had significantly greater triceps skinfold than those breast-fed ($p<0.05$). Formula-fed girls had significantly greater BMI at 12 months ($p<0.05$), greater sum of skinfolds at 24 months ($p<0.01$), greater gain in BMI over the first year ($p<0.05$) and greater gain in sum of skinfolds ($p<0.05$) and triceps skinfold ($p<0.01$) over the second year than those breast-fed.

Table 5.17 Multiple regression analyses for nutritional status measurements by feeding method.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
BMI					
Boys	NS	NS	NS	NS	NS
Girls	NS	*b	NS	*b	NS
MUAC					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
MAMC					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Calf Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Thigh Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Sum of Skinfolds					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	**b	NS	*b
Triceps Skinfold					
Boys	NS	NS	*b	NS	NS
Girls	NS	NS	NS	NS	**b
Subscapular Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS

Multiple regression *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant, b formula-fed>breast-fed

Age at weaning

Girls who were weaned early had significantly greater MAMC at 12 and 24 months ($p<0.05$) and significantly greater thigh circumference at 24 months ($p<0.01$) than those weaned later. No differences were found in boys.

Table 5.18 Multiple regression analyses for nutritional status measurements by age at weaning.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
BMI					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
MUAC					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
MAMC					
Boys	NS	NS	NS	NS	NS
Girls	NS	*a	*a	NS	NS
Calf Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Thigh Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	**a	NS	NS
Sum of Skinfolds					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Triceps Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Subscapular Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS

Multiple regression *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant, a early weaned>late weaned

Social class

Boys from lower social classes had significantly greater gain in triceps skinfold over the second year of life than those from social class I+II ($p<0.05$).

Girls from social classes I+II had significantly greater calf circumference ($p<0.001$) and sum of skinfolds at 24 months ($p<0.01$) and significantly greater gain in MUAC (p<0.05), calf circumference (p<0.01), sum of skinfolds (p<0.01) and triceps skinfold (p<0.01) over the second year than those from lower social classes.

Table 5.19 Multiple regression analyses for nutritional status measurements by social class.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
BMI					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
MUAC					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	*a
MAMC					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Calf Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	***a	NS	**a
Thigh Circumference					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Sum of Skinfolds					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	**a	NS	**a
Triceps Skinfold					
Boys	NS	NS	NS	NS	*b
Girls	NS	NS	NS	NS	**a
Subscapular Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS

Multiple regression *** p<0.001, ** p<0.01, * p<0.05 and NS not significant, a SCI+II>lower SC, b lower SC>SCI+II.

Mothers' smoking habit during pregnancy

Smoking habit of mothers during pregnancy was found to have an adverse effect on the nutritional status of the infants.

Girls of mothers who smoked during pregnancy had significantly smaller BMI (p<0.05), MUAC (p<0.05), MAMC (p<0.01) and thigh circumference (p<0.05) at one month, smaller sum of skinfolds and triceps skinfold at 24 months (p<0.05) than those of mothers who did not smoke. Boys of mothers who smoked during pregnancy had significantly smaller calf ($p<0.01$) and thigh circumference ($p<0.001$) at one month than those of mothers who did not smoke during pregnancy (Table 5.20).

Table 5.20 Multiple regression analyses for nutritional status measurements by smoking habit during pregnancy.

	1 month	12 months	24 months	velocity 1-12 months	velocity 12-24 months
BMI					
Boys	NS	NS	NS	NS	NS
Girls	*a	NS	NS	NS	NS
MUAC					
Boys	NS	NS	NS	NS	NS
Girls	*a	NS	NS	NS	NS
MAMC					
Boys	NS	NS	NS	NS	NS
Girls	**a	NS	NS	NS	NS
Calf Circumference					
Boys	**a	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS
Thigh Circumference					
Boys	***a	NS	NS	NS	NS
Girls	*a	NS	NS	NS	NS
Sum of Skinfolds					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	*a	NS	NS
Triceps Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	*a	NS	NS
Subscapular Skinfold					
Boys	NS	NS	NS	NS	NS
Girls	NS	NS	NS	NS	NS

Multiple regression *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and NS not significant, a non-smoking > smoking

One month value for anthropometry

For all measurements at 12 and 24 months (except triceps skinfold at 24 months in boys) the one month measurement was a statistically significant factor i.e. the greater the measurement at one month the greater the measurement at 12 and 24 months.

The gain in measurement over the first year was negatively correlated with the one month measurement for all measurements except calf circumference in boys and in sum of skinfolds, triceps and subscapular skinfold in girls. No correlation was found for the gain in measurements over the second year (Table 5.21).

Table 5.21 Multiple regression analyses for nutritional status measurements by one month value for anthropometry.

	12 months	24 months	velocity 1-12 months	velocity 12-24 months
BMI				
Boys	**a	**a	*b	NS
Girls	***a	***a	NS	NS
MUAC				
Boys	***a	***a	**b	NS
Girls	***a	***a	NS	NS
MAMC				
Boys	**a	***a	***b	NS
Girls	***a	***a	NS	NS
Calf Circumference				
Boys	**a	***a	NS	NS
Girls	***a	***a	NS	NS
Thigh Circumference				
Boys	*a	**a	**b	NS
Girls	**a	**a	NS	NS
Sum of Skinfolds				
Boys	***a	**a	***b	NS
Girls	***a	**a	**b	NS
Triceps Skinfold				
Boys	***a	*a	**b	NS
Girls	**a	NS	**b	NS
Subscapular Skinfold				
Boys	***a	***a	*b	NS
Girls	*a	*a	***b	NS

Multiple regression *** p<0.001, ** p<0.01, * p<0.05 and NS not significant, a higher 1 month measurement >lower one month measurement, b lower one month measurement> higher 1 month measurement.

5.4 Discussion

5.4.1 Feeding method

There is still contradictory evidence on whether and how feeding and weaning practice of infants affects growth and nutritional status. There seems to be less doubt, however, about the earlier studies where the older energy dense formulas were in use. Most of the earlier studies did find a difference between breast and formula-fed infants with formula-fed infants being heavier than those breast-fed (Taitz, 1971). The 'Tanner and Whitehouse' triceps and subscapular skinfold references (Tanner and Whitehouse, 1975) are also evidence of this. These were collected in the late 1960s where the majority of infants were formula-fed and many were introduced to solid food extremely early. These infants had much greater skinfolds than have been found by more recent studies in Cambridge (Whitehead and Paul, 1989), Germany (Schulater et al, 1976), Australia (Boulton, 1981), and Canada (Yueng, 1983). Even when compared with infants who are formula-fed and are weaned early the 'Tanner and Whitehouse' skinfolds were still much greater. This suggests that it was the older formulas used which may have caused this difference between past and present skinfold data.

With the new highly modified formulas there are contradictory results on differences between breast and formula-fed infants. Some studies found differences (Dewey et al, 1993; Czajka-Nairns and Jung, 1986; Lucas et al, 1992) whereas others did not (Whitehead et al, 1986; Wells and Davies, 1995; Harrison et al, 1987). However, this may be due to the different ages which were chosen as cut-offs for breast/formula feeding.

The DARLING study reported significant differences for nutritional status as a difference in weight-for-length and skinfolds between feeding groups (Dewey et al, 1993). This difference may be due to the groups which were studied which were by most standards unusual. In the DARLING study, breast-fed infants were those who were breast-fed for at least 1 year, with less than 120 ml/ day of any other milk (n=60) and introduced to solid food after 4 months. The 'formula-fed' group in the DARLING study were those who were formula-fed from birth or breast-fed for less than 3 months (n=45) and introduced to solids after 4 months. These groups were unusual, first because the age at weaning onto solid food was very late. The majority of mothers in the UK have introduced solid food by the age of 4 months (White et al, 1992). Secondly the duration of breastfeeding was unusually long compared with mothers in the UK where mothers would rarely still be breastfeeding by the end of the first year with less than 120 ml/day of other milks (White et al, 1992). At nine months the OPCS Infant Feeding report found that only 11% of mothers in the UK were breastfeeding at all (White et al, 1992). An additional problem when interpreting the formula-fed group included mothers who had breast-fed for 2-3 months. Also, many mothers must have been excluded from the study because they did not fit into either category and therefore, this made the sample highly selective.

The Cambridge study carried out in the 1980s found no differences between breast and formula-fed infants with respect to weight-for-length, triceps and subscapular skinfold (Whitehead et al, 1986). Formula-fed infants in the cohort were weaned earlier than breast-fed and exhibited growth patterns similar to those breast-fed who were weaned early.

In the present study there were few differences between breast and formula-fed infants in nutritional status. At one month no differences were found for any of the measurements. Formula-fed boys had greater triceps skinfold at 24 months than breast-fed boys and formula-fed girls had greater BMI at 12 months and greater gain in BMI over the first year, greater sum of skinfolds at 24 months and greater gain in triceps and sum of skinfolds over the second year than breast-fed girls. The biological significance of these differences is unclear.

This difference which was found for the Glasgow cohort in girls for BMI was due mainly to a difference in length rather than a difference in weight (See Chapter 4). This is in contrast to the DARLING study where no difference was found for length but a large difference was found for weight leading to a difference in weight-for-length (Dewey et al, 1993).

5.4.2 Age at weaning

The evidence on differences in nutritional status between infants weaned early and those weaned late is contradictory. The Cambridge study (Whitehead and Paul, 1986) which observed this on breast fed infants (n=37) found that there were differences in triceps and subscapular skinfold and also for weight-for-length between the weaning groups, before and after 16 weeks in boys and before and after 20 weeks in girls.

In contrast, the DARLING study did not find any differences (Heinig et al, 1993) between breast-fed infants weaned before 6 months (n=41) and those weaned after 6 months (n=19) although this again involved a small sample. The explanation suggested for this was that those who were weaned decrease their intake of breast milk whereas those who are not weaned maintain their intake. Therefore, the total energy intakes of both groups were similar. As the DARLING study was carried out on highly educated mothers again this is not necessarily representative of what actually happens in practice outside the research setting.

As described in Chapter 4 a study carried out in Dundee found differences in growth during the first year but these had disappeared by the end of the first year (Forsyth et al, 1993). Although when followed up at seven years infants who were introduced to solid food after 15 weeks had greater weight and percentage body-fat (Wilson et al, 1998).

A study in Wales in the 1970s which followed 821 infants failed to show that weaning before 6 weeks, between 6-12 weeks and after 12 weeks had any effect on weight, length or head circumference (Davies et al, 1977). However, this study only observed infants till 3 months of age and it was impossible to say whether any differences emerged after this age.

In the present study the apparent influence of timing of weaning differed between the sexes. In the boys few differences were observed between early and late weaners. In girls less difference was found between weaning groups than was found for growth (Chapter 4). Girls who were weaned early had greater MAMC at 12 and 24 months and greater thigh circumference at 24 months than those weaned later.

5.4.3 Social class

Regarding social class, a study from the Netherlands (Herngreen et al, 1994) showed very few differences for weight or length between social class groups. The National Health and Nutrition Examination Study (HANES I+II) data (Miller et al, 1977, McDowell et al, 1981) also showed very few differences for skinfolds in infancy and early childhood between different poverty status groups.

For social class in the present study differences were found between groups. Boys from lower social classes had greater gain in triceps skinfold over the second year of life than those from social class I+II whereas girls from social classes I+II had greater calf circumference and sum of skinfolds at 24 months and greater gain in MUAC, calf circumference, sum of skinfolds and triceps skinfold over the second year than those from lower social classes.

5.4.4 Mothers' smoking habit during pregnancy

Studies have found that mothers who smoked during pregnancy had infants with lower birth measurements including a study by Roquer et al, 1995. This study was carried out in Spain and measured 129 new-borns of 37-41 weeks gestation. Reduced weight, length, cranial and thoracic parameters at birth were found when infants were exposed to active or passive smoking. The OPCS Infant Feeding Survey (White et al, 1992) found infants of mothers who smoked during pregnancy to have lower birthweight.

The same effect of smoking during pregnancy was found for growth and nutritional status of Glasgow infants in the present study. Girls of mothers who smoked during pregnancy had smaller BMI, MUAC, MAMC and thigh circumference at one month and sum of skinfolds and triceps skinfold at 24 months than those of mothers who did not smoke during pregnancy. Boys of mothers who smoked during pregnancy had significantly smaller calf and thigh circumference at one month than those of mothers who did not although these differences as with those for growth had disappeared by the end of the first year.

Very few well conducted studies have been carried out in representative samples of infants where extensive information was available on many other factors besides growth and nutritional status including feeding and weaning practice. Therefore, the Glasgow study was very valuable in being able to address these questions.

5.5 Conclusion

In conclusion, on the whole there were very few differences in nutritional status between the different feeding and weaning groups. The differences between social class groups seemed to emerge over the second year, but only in some of the measurements and mainly in girls. The effect of mothers smoking during pregnancy was apparent at one month but had disappeared by the end of the first year.

Chapter 6

Feeding and weaning practice

6.1 Introduction

It is important to describe the feeding and weaning practice of samples which are used in growth studies as we can then determine whether the sample is representative. This is not always done and in a number of growth studies the samples have been very unrepresentative.

In this chapter the feeding and weaning practice of infants and factors affecting this will be examined in more detail. Little work has been carried out in this country to characterise factors influencing the feeding and weaning practice in representative samples of infants in different parts of the country. Scotland has been described as a whole for feeding and weaning practice and factors which affect this (White et al, 1992) and the breastfeeding rate has been examined in Glasgow and other areas of Scotland (Ferguson et al, 1994). Age at weaning onto solid food, attitudes to weaning and types of weaning food given have not previously been examined in detail for infants in Glasgow in combination with growth and nutritional status.

Around the late 1960s - early 1970s breastfeeding in the UK was at its lowest and infants were weaned onto solid food extremely early. There was then an increase in the incidence of breastfeeding until the early 1980s where the percentage at birth was around 80% (Martin, 1978; Martin and Monk, 1982) but since this time there has been no further increase (Martin and White, 1988; White et al, 1992). The proportion of mothers weaning their infants early has decreased. In 1975, 85% of mothers in England and Wales had introduced some solid food by 3 months (Martin, 1978) compared with only 56% in Great Britain in 1980 (Martin and Monk, 1982). From 1980 to 1985 there was a slight increase in weaning before 3 months (62%) and a further increase by 1990 (68%) (Martin and White, 1985; White et al, 1992).

This feeding and weaning practice is not typical of what is happening in many other parts of Europe (WHO, 1990). In Norway, for example, almost all mothers initially breastfeed with 80% still breastfeeding at 3 months (National Nutrition Council, 1993).

It has been reported for many years that Scotland has different feeding and weaning practice than the rest of the UK (OPCS, Infant Feeding 1980-1990). Feeding practice has been reported by the OPCS since 1975 for England and Wales (Martin, 1978) and from 1980 onwards for Scotland (Martin and Monk, 1982; Martin and White, 1988 and White et al, 1992). However, it may be that the feeding and weaning practice of Glasgow mothers is different than that reported by the OPCS for the whole of Scotland. Ferguson et al (1994) found breastfeeding rates in some areas of Glasgow to be some of the lowest in Scotland. The overall breastfeeding rate at the end of the first week found by Ferguson et al for Glasgow was 27% (Ferguson et al, 1994) and information from the Greater Glasgow Health Board census information (personal communication) suggests that the area we recruited from had an overall breastfeeding rate of 45% by the end of the first week.

6.1.1 Breastfeeding

Breastfeeding has many advantages for both the infant and the mother (Table 6.1). Breast milk has a composition which is appropriate for the infant, is at the correct temperature and protects against infection (Howie at al, 1990 and Burr et al, 1993). It provides protection against the development of allergies (Lucas et al, 1990) and food intolerance, insulin dependant diabetes and infection in later childhood. Breastfeeding is convenient and cheap, may promote bonding between mother and infant and allows infants to regulate their own intake. For mothers breastfeeding helps involution of the uterus and may help them lose excess weight gained during pregnancy (Dewey et al, 1993).

Two recent, major surveys assessed breastfeeding rates in the UK. The OPCS, 1990 Infant Feeding survey (White et al, 1992) and the Maff 1986 survey on Food and Nutrient Intakes of British Infants 6-12 Months of Age (Mills and Tyler, 1992).

Overall breastfeeding rate at birth for the UK was reported as 63% in the OPCS survey (White et al, 1992) and 64% in the MAFF survey (Mills and Tyler, 1992). In Scotland the breastfeeding rate was 50%. Breastfeeding rates had not significantly changed since 1980 as noted above.

Table 6.1 Department of Health recommendations for feeding and weaning practice.

Breastfeeding " breast milk provides the best nourishment during the early months of life. Mothers should be encouraged and supported in breastfeeding for at least four months and may choose to continue to breastfeed as the weaning diet becomes increasingly varied."
Cow's Milk Feeding "infants can be given cow's milk in small amounts from 6 months of age but not as a main drink until 1 year."
Weaning "the majority of infants should not be given solid foods before the age of four months, and a mixed diet should be offered by the age of six months."
First Weaning Foods "Non-wheat cereals, fruit, vegetables and potatoes are suitable first weaning foods"

6.1.2 Factors influencing breastfeeding

The above two surveys also examined factors which may influence incidence or duration of breastfeeding. These included, social class, maternal age, birth order, smoking, age at completion of full time education, birthweight and previous experience of breastfeeding as described in Chapter 1.

The factors which affect breastfeeding are very closely related e.g. maternal smoking, social class and educational attainment and are all inter-related. This makes it very difficult to determine which factor is having the greatest effect. Factors affecting breastfeeding were only examined separately in the OPCS, no analysis was carried out to examine whether these factors operate independently for example by using multiple regression.

6.1.3 Formula feeding

The 1990 Infant Feeding Survey found no change in the incidence or duration of breastfeeding, however, there has been a trend towards formula-feeding with more mothers supplementing breast milk with formula. Thirty percent of mothers gave infant formula from birth and by six weeks, 38% of mothers who had initially breast-fed were formula-feeding with some of those mothers who continued breastfeeding supplementing with formula (White et al, 1992).

6.1.4 Cow's milk feeding

Continuing formula during the first year ensures an adequate intake of iron. Cow's milk can be given from six months but not be as a main milk till after one year (Table 6.1). However, other recommendations have been made which suggest that no cow's milk should be given before 1 year (Wharton, 1990). The reason for this recommendation was that cow's milk contains little vitamin D and iron, and has been found to cause subclinical gastrointestinal bleeding in a number of children (Ziegler et al, 1990). This conclusion has been disputed by some other authors (e.g. Fuchs et al, 1993; Thomas et al, 1986). In the UK as many as 76% of infants had been given cow's milk by 9-10 months (White et al, 1992) which was less than the corresponding figure of 88% found in 1985.

6.1.5 Weaning

Infants should be weaned onto solid food from 4-6 months because breast milk will no longer meet the infant's requirements for energy, protein, minerals and vitamins (Table 6.1). Formula milk would probably meet the micro-nutrient requirements but not the energy requirement (Department of Health, 1994). Weaning should not be delayed till after 6 months as this may affect growth and nutritional status and feeding skills such as chewing and biting should be learned before this age. Delaying the learning of such skills is not advisable as they are harder to acquire at an older age (Stephenson and Allaire, 1991).

The MAFF survey (Mills and Tyler, 1992) examined the energy and nutrient intakes of 6-12 month old infants to determine the adequacy of their diet. Nutrient and energy intakes were compared with the UK dietary reference values by seven day weighed record. Energy intakes tended to be adequate, average energy intake met the estimated average requirement. This was not the case in more recent studies where weaning foods used were found to be very low in energy, particularly home-prepared foods, and would be unlikely to meet the infants energy requirements (Stordy et al, 1995). This suggests that weaning infants early may be detrimental to their growth and nutritional status by not meeting their energy needs.

In many growth studies, however, infants weaned early were found to be heavier at least in the first year than those where weaning was delayed suggesting their energy intake was adequate (Whitehead et al, 1986, Forsyth et al, 1993; Kramer et al, 1985).

The MAFF survey carried out in 1986 (Mills and Tyler, 1992) also found that besides zinc which was 90% of the Reference Nutrient Intake (RNI) and vitamin D (50% of the RNI) average intakes of nutrients from food were well above the RNIs. Supplements, however, provided 43% of the sample with additional vitamin D and allowed them to reach the RNI (sunlight will also provide further vitamin D). Although the average daily intake for iron met the RNI, the median was only 7 mg which corresponds to 90% of the RNI (Mills and Tyler, 1992).

It is suggested that infants are not weaned before 4 months because the physiology and development of the infant are not mature enough to cope with non-milk food. However, the majority of infants in the UK are weaned before this time and there is contradictory evidence on the seriousness of any adverse effects of early weaning (Michaelson et al, 1995; Forsyth et al, 1993). This and the evidence that infants who are weaned earlier tend to be heavier at time of weaning than those not weaned (Forsyth et al, 1993) suggests that perhaps the recommended age of weaning and any adverse of early weaning should be examined in more detail.

As mentioned before many mothers in the UK do not follow the guidelines for weaning onto solid food. In both the OPCS and MAFF studies some mothers had introduced solid food as early as 3 weeks and by the time infants were 8 weeks old 16% (Mills and Tyler, 1992) and 13% (White et al, 1992) had received some solid food. Both surveys found that the majority of mothers given solid food at 3 months and by 6 months almost all.

Cereals and rusks were found to be the most common first foods given to infants in both the OPCS and the MAFF survey (White et al, 1992; Mills and Tyler, 1992) and these are one of the foods recommended (Table 6.1).

In summary, many mothers in the UK do not follow Department of Health recommendations in relation to infant feeding and weaning practice. The aims of this chapter were to describe feeding and weaning practice, (1) in order to assess the extent to which current recommendations are reflected in practice, (2) in order to provide supplementary information to the growth and nutritional status of the sample and the extent to which the sample was representative, discussed in earlier chapters (3) test the influences on feeding and weaning practice, including the importance of maternal attitudes. This chapter has now been published and can be found in the communication section of this thesis (Savage et al, 1998a).

From this study feeding and weaning practice and the factors influencing them combined with the effect of these on growth and nutritional status will allow us to re-examine the recommendations and to consider whether these should be changed.

6.2 Methods

6.2.1 Questionnaires

Three main questionnaires were used to obtain information on feeding and weaning practice:-

(i) Euronut questionnaire: standard questionnaire used in the Eurogrowth study (Appendix 4, 5, 6).

(ii) OPCS questionnaire: selected questions from the OPCS Infant Feeding Questionnaire (Appendix 7).

(iii) Weaning questionnaire: questionnaire devised to record timing of weaning onto solids, mothers attitudes to weaning and first weaning foods used (Appendix 8).

6.2.2 Statistical analysis and definitions

The total number of infants analysed was 127.

Four main statistical tests were used in this chapter:-

(i) Two sample t-tests were used to compare means between groups where data were normally distributed.

(ii) Mann-Whitney tests to compare means where the data were not normally distributed

(iii) Chi-square tests were used where proportions in different groups were examined.

(iv) Multiple regression analyses were used to determine which factors were affecting measurements at 1 month.

The following definitions were used in this chapter:-

Weaning - first introduction of solid food

Breast-fed - at each age infants were described as breast-fed if they were receiving any breast milk at this time. This therefore includes infants who were receiving breast and formula milk (i.e. mixed feeders).

Bottle-fed - at each age infants were described as bottle-fed if they were receiving *only* formula milk and/or cow's milk at this time (i.e. those who did not receive any breast milk).

6.2.3 Comparisons with other datasets

In this chapter comparisons were made with two main infant feeding surveys:-

(i) Office of Population Censuses and Surveys. Infant Feeding 1990. (White et al, 1992)

(ii) Ministry of Agriculture, Fisheries and Food. Food and Nutrient Intake of British Infants Aged 6-12 Months (Mills and Tyler, 1992).

Reference is also made to discrepancies between actual feeding and weaning practice and current recommendations (Dept of Health, 1994), summarised in Table 6.1.

6.3 Results

6.3.1 Feeding method

Breast-feeding and formula-feeding

In the Glasgow cohort 52% of mothers opted to breastfeed. One fifth of these mothers, however, had ceased breastfeeding before the end of the first week leaving 42% breastfeeding (Table 6.2). By far the greatest drop off in breastfeeding was during the first week, with 20% ceasing (n=13), probably due to problems in establishing feeding. After this initial drop off the incidence was fairly steady with few mothers stopping breastfeeding (4 mothers stopped between 1 week and 2 months, 12 mothers between 2 and 4 months, 2 mothers ceased between 4 and 6 months, 12 between 6 and 9 months, 10 between 9 and 12 months, 10 between 12 and 18 months and 1 between 18 and 24 months). Two mothers were still breastfeeding by the end of the study at 24 months (Table 6.2)

Table 6.2. Percentage breast-fed and bottle-fed at each age

Age	% Breast-fed	% Bottle-fed	% still breast-fed who were breast-fed initially	Base (n=100%)
Birth	52	48	100	127
1 week	42	58	80	127
2 weeks	42	58	80	127
4 weeks	40	60	77	127
6 weeks	39	61	76	127
2 months	39	61	76	127
3 months	34	66	64	127
4 months	29	71	56	127
6 months	28	72	53	127
9 months	18	82	36	127
12 months	10	90	20	124
18 months	3	97	5	118
24 months	2	98	3	116

6.3.2 Factors influencing feeding method

Sex

A slightly greater percentage of boys were initially breast-fed than girls (55% of boys compared with 48% of girls). This was observed at other ages although the difference was smaller than the initial percentages (Table 6.3). None of these differences were statistically significant (Chi-square test, p>0.05).

Table 6.3. Percentage of boys and girls breast-fed at each age and percentage still breast-fed of those who were initially breast-fed.

Age	Boys			Girls		
	% breast-fed	% of those who were initially breast-fed	Base (n=100%)	% breast-fed	% of those who were initially breast-fed	Base (n=100%)
Birth	55	100	69	48	100	58
1 week	42	76	69	41	86	58
4 weeks	42	76	69	38	79	58
2 months	41	74	69	36	75	58
3 months	36	66	69	29	61	58
4 months	30	55	69	28	57	58
6 months	30	55	69	24	50	58
9 months	22	39	69	16	32	58
12 months	10	18	68	11	21	56
18 months	3	5	67	2	4	51
24 months	1	3	67	2	4	49

Age of mother

Incidence of breastfeeding increased with maternal age. Only one mother (10%) from the age group 16-20 attempted to breastfeed and she opted for formula feeding before the end of the first week. In comparison, ten mothers (83%) aged 36-40 started breastfeeding with only one opting for formula feeding before the end of the first week.

Mothers over 30 were more likely to initially breastfeed, to breastfeed at one month, two months and nine months than those aged 30 years or under (Chi-square test, $p<0.001$) (Table 6.4).

Table 6.4. Percentage breast-fed in each age group at birth, 1 month, 2 months and 9 months

Mother's Age	% Breast-fed Birth	% Breast-fed 1 week	% Breast-fed 2 months	% Breast-fed 9 months	Base (n=100%)
16-20	10	0	0	0	10
21-25	33	21	12	8	24
26-30	46	34	32	7	41
31-35	70	63	60	33	40
36-40	83	75	75	42	12

Older mothers tended to breastfeed for longer. Thirty-eight mothers aged 31-40 started breastfeeding and 18 (47%) of them were still breastfeeding at nine months compared with mothers under 30 where 28 started breastfeeding with only five (18%) still breastfeeding at nine months. This difference was statistically significant (Chi-square test, $p<0.05$).

Social class

Of the mothers from social class I, 25 (93%) breast-fed their infant initially compared with 1 (11%) from social class V (Table 6.5). The proportions who breast-fed at birth in social class I+II were significantly greater than the proportions from lower social classes (Chi-square test, $p<0.001$).

Table 6.5. Percentage breast-fed and bottle-fed from each social class group at birth.

Social class	% Breast-fed	% Bottle-fed	Base (n=100%)
I	93	7	27
II	75	25	16
IIINM	57	43	14
IIIM	33	67	33
IV	24	76	16
V	11	89	10
Unclassified	50	50	6
No partner	40	60	5

The duration of breastfeeding was compared between different social classes. In social classes I, II, III non-manual there was an initial drop off in breastfeeding during the first week. However, those who were still breastfeeding after one week tended to continue breastfeeding till at least two months. In social classes III manual and IV this initial drop off was also observed but between one week and two months a few more mothers ceased breastfeeding. Only one mother in social class V and three from the unclassified group breast-fed their infant at all and they continued to do so beyond two months (Table 6.6).

Table 6.6. Percentage breast-fed at birth, 1 week, 2 months and 9 months in each social class group.

Social Class	% Breast-fed Birth	% Breast-fed 1 week	% Breast-fed 2 months	% Breast-fed 9 months	Base (n=100%)
I	93	78	78	33	27
II	75	63	63	25	16
IIInm	53	33	33	27	15
IIIm	37	29	20	6	35
IV	24	18	12	13	16
V	11	11	11	0	10
Unclassified	37	37	37	25	8

Age at completion of full-time education

A comparison was made for breastfeeding between mothers who went onto further/higher education and those who did not. Of mothers who had further/higher education 48 (76%) breast-fed initially compared with 18 (28%) of mothers who did not have further/higher education (Chi-square test, $p<0.001$). By nine months, 22 (35%) of mothers who had further/higher education were still breastfeeding compared with 2 (3%) of those who had no further/higher education (Chi-square test, p<0.001) (Table 6.7).

Table 6.7. Percentage breast-fed at birth, 1 week, 2 months and 9 months by whether mothers went onto further/higher education.

Further/higher education	% Breast-fed Birth	% Breast-fed 1 week	% Breast-fed 2 months	% Breast-fed 9 months	Base (n=100%)
Yes	76	63	66	35	63
No	28	20	17	3	64

Of the 48 mothers who had further/higher education who initially breast-fed, 22 (46%) were still breastfeeding at nine months. In comparison, only 2 (18%) of the 18 mothers with no further/higher education who initially breast-fed were still breastfeeding at nine months.

Mothers' smoking habit during pregnancy

Of the 33 mothers who smoked during pregnancy 8 (24%) initially breast-fed compared with 58 out of 94 (62%) of mothers who did not smoke during pregnancy (Chi-square test, p<0.001).

By nine months 3 out of 33 (10%) mothers who smoked during pregnancy were breastfeeding their child compared with 21 out of 94 (29%) of those who did not smoke (Table 6.8). However, numbers were small and this difference was not statistically significant (Chi-square, p>0.05).

Table 6.8. Percentage breast-fed at birth, 1 week, 2 months and 9 months by whether mothers smoked during pregnancy.

Smoking during pregnancy	% Breast-fed Birth	% Breast-fed 1 week	% Breast-fed 2 months	% Breast-fed 9 months	Base (n=100%)
Yes	24	21	18	10	33
No	62	49	46	29	94

Of those mothers who initially breast-fed, three out of eight (38%) mothers who smoked during pregnancy and 21 out of 58 (36%) who did not smoke during pregnancy were still breastfeeding at nine months.

Birth order

Mothers having their first child were found to be slightly more likely to breastfeed initially compared with those having their second or later child, 56% and 49% respectively (Table 6.9). This difference was not statistically significant although the numbers were very small.

At one week, two months and nine months there were very few differences in the incidence of breastfeeding between mothers having their first or later child.

Table 6.9. Percentage breast-fed at birth, 1 week, 2 months and 9 months by birth order.

Other children	birth	1 week	2 months	9 months	Base (n=100%)
Yes	56	40	40	15	52
No	49	43	37	20	75

Of those women who started breastfeeding, 8 out of the 29 (28%) women and who had other children were still breastfeeding at nine months compared with 15 out of 75 (41%) of those with no other children.

6.3.3 Cow's milk feeding

The percentage of mothers giving cow's milk as a main milk or in addition to breast milk or formula was examined at six, nine and 12 months. Only 2% mothers had given whole cow's milk as a main drink at six months with an other 6% who had given it in addition to breast milk or formula. By nine months, 17% of infants were receiving whole cow's milk as a main milk with 43% having whole and 2% having semi-skimmed cow's milk in addition to breast milk or formula (Table 6.10).

By the end of the first year almost half (45%) of all mothers were giving whole cow's milk as a main milk with another 4% giving semi-skimmed milk. Thirty-six percent of mothers gave whole cow's milk and 4% semi-skimmed in addition to either breast milk or formula milk. Overall, 89% of mothers were giving cow's milk in some form by the time their infant was one year old (Table 6.10).

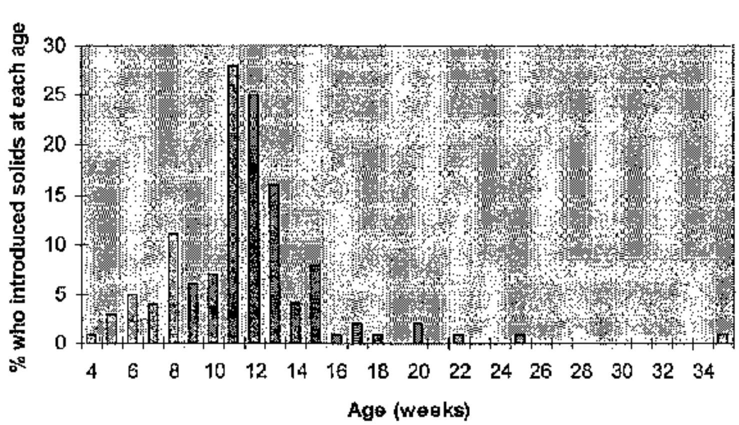
Table 6.10. Percentage giving cow's milk at 6, 9 and 12 months

Age (months)	Whole Cow's milk Main	Whole Cow's milk In addition	Semi-skimmed milk Main	Semi-skimmed milk In addition	Base (n=100%)
6	2	6	0	0	127
9	18	43	0	2	127
12	45	36	4	4	122

6.3.4 Introduction of solid food

The median age of introduction of solid food was 11 weeks - range 4-35 weeks (Fig 6.1). Ten percent of infants were introduced to solid food before 8 weeks, 71% by 3 months and all but one (99%) by 6 months.

Fig 6.1. Age at introduction of first solid food.



6.3.5 Factors influencing introduction of solid food

The same factors which influenced breastfeeding also tended to influence the age at introduction onto solid food. Mothers who tended to wean early were those: who formula-fed; from lower social classes; who did not receive any formal advice on weaning; having their first child; who smoked during pregnancy; who had heavier children and who were younger. These differences were all statistically significant.

Sex

The median age of weaning onto solid food was 11.0 weeks (range 5-20 weeks) in boys and 11.5 weeks (range 4-35 weeks) in girls. This difference was not statistically significant. The proportions of boys and girls weaned before and after 10 weeks was also examined. In boys 20% were weaned before 10 weeks compared with 28% in girls. Again this difference was not statistically significant (Table 6.11).

Table 6.11 Median age at weaning and proportions weaned before and after 10 weeks, by sex.

Sex	Median	<10 weeks	≥ 10 weeks	Base (n=100%)
Boy	11.0	20	80	69
Girl	11.5	28	72	58

Age of the mother

Younger mothers (aged 30 or under) introduced solids significantly earlier (median 11 weeks; range 4-35 weeks) compared with mothers over 30 (median 12 weeks; range 6-22 weeks, Mann-Whitney test, $p<0.01$). The percentage weaning before 10 weeks was also significantly greater in younger mothers (Table 6.12).

Table 6.12 Median age at weaning and proportions weaned before and after 10 weeks by age of mother.

Mothers Age	Median	<10 weeks	≥ 10 weeks	Base (n=100%)
16-20	8.5	60	40	10
21-25	11.0	32	68	24
26-30	11.0	20	80	41
31-35	12.0	13	87	40
36-40	12.5	25	75	12

Social class

Mothers from social class I and II introduced solid food later (median 12 weeks, range 6-22 weeks) than those from lower social classes (median 11 weeks; range 4-35 weeks, Mann-Whitney test, $p<0.01$). The proportions of mothers who introduced solid food before 10 weeks was significantly less in social class I+II group (9%) than in the lower social class group (31%, Chi-square, $p<0.01$) (Table 6.13).

Table 6.13. Median age at weaning and proportions weaned before and after 10 weeks by social class.

Social Class	Median	<10 weeks	≥10 weeks	Base (n=100%)
I	12.0	4	96	27
II	12.0	19	81	16
IIINM	11.0	27	73	15
IIIM	11.0	26	74	35
IV	11.0	33	67	16
V	11.5	12	88	10
Unclassified	9.0	62	38	8

Age at completion of full-time education

Infants of mothers who had further/higher education had a median age at weaning of 12 weeks (range 5-25 weeks) compared with 11 weeks (range 4-35 weeks) for those with no further/higher education (Mann-Whitney test, $p<0.05$). The proportion weaning before 10 weeks was slightly greater in those with no further/higher education than those who had further/higher education but this difference was not statistically significant (Table 6.14).

Table 6.14. Median age at weaning and proportions weaned before and after 10 weeks by whether the mother received further/higher education.

Further/higher education	median	< 10 weeks	≥ 10 weeks	Base (n=100%)
Yes	12.0	21	79	63
No	11.0	27	73	64

Mothers' smoking habit during pregnancy

Mothers who did not smoke during pregnancy weaned their infants significantly later (median 12 weeks; range 4-35 weeks) than those who did smoke during pregnancy (median 11 weeks; range 5-20 weeks, Mann-Whitney test, p<0.05). Mothers who smoked during pregnancy were more likely to wean their infants before 10 weeks compared with those mothers who did not smoke during pregnancy, 39% and 18% respectively (Table 6.15).

Table 6.15. Median age at weaning and proportions weaned before and after 10 weeks by whether mother smoked during pregnancy.

Mother smoking during pregnancy	Median	< 10 weeks	≥ 10 weeks	Base (n=100%)
Yes	11.0	39	61	33
No	12.0	18	82	94

Birth order

Those women having their first child were more likely to introduce solids early (median 11 weeks; range 4-15 weeks) compared with women having their second or later child (median 12 weeks; range 5-35 weeks, Mann-Whitney test, p<0.05). There were similar proportions of mothers of first and later children weaning before and after 10 weeks (Table 6.16).

Table 6.16. Median age at weaning and proportions weaned before and after 10 weeks by birth order.

Other children	Median	< 10 weeks	≥ 10 weeks	Base (n=100%)
Yes	12.0	23	77	74
No	11.0	25	75	53

Feeding method

Feeding method (breast or formula) influenced the age at which infants were weaned onto solid food. Breast-fed infants were weaned significantly later than those formula-fed (median 12.0; range 6-22 weeks and 11.0 weeks; range 4-35 weeks, respectively, Mann-Whitney test, $p<0.001$). Only 8% of mothers who breast-fed weaned their infants before 10 weeks compared with 33% of mothers who formula-fed (Chi-square test, $p<0.01$) (Table 6.17).

Table 6.17. Median age at weaning and proportions weaned before and after 10 weeks by feeding method.

Feeding Method	Median	< 10 weeks	≥ 10 weeks	Base (n=100%)
Breast	12.0	8	92	49
Formula	11.0	33	67	78

Advice on weaning

Fourteen percent of mothers who sought or received formal advice on weaning introduced their infants onto solid food compared with 36% of those who did not receive formal information (Chi-square $p<0.05$) (Table 6.18).

Table 6.18. Median age at weaning and proportions weaned before and after 10 weeks by whether mothers received formal information.

	No formal advice	Formal advice	Base (n=100%)
Total	34	66	98
Weaning < 10 weeks	36	14	21
Weaning ≥ 10 weeks	64	86	77

Weight

Infants who were heavier tended to be weaned earlier. Weight at one month for boys and girls was negatively correlated with age at weaning (Multiple Regression, $p<0.05$) i.e. the greater the weight at one month the earlier solid food was introduced.

<u>6.3.6 Maternal attitudes to weaning</u>

Why mothers weaned

Mothers were asked *"What factors made you start weaning your baby"*. The principal reason given by 74 % of mothers was the perception that the infant was *"not satisfied"*.

The next most popular reason reported by 20% of mothers was that *"the infant woke during the night"*. These two responses might reflect the same maternal attitude. Table 6.19 gives a list of all other reasons for starting weaning and the percentage of mothers giving each reason. (Total was greater than 100% as more than one reason could be given by each mother.)

Table 6.19. Reasons mothers gave for weaning their infants.

Reason	%	Base (n=100%)
Baby not satisfied	74	98
Baby waking during night	20	98
Advice from health visitor/friends	8	98
Leaflets and Books	6	98
Time to start	8	98
Trouble with milk feeding	5	98
Baby big for age	3	98
Other	5	98

Knowledge of weaning and weaning foods

Mothers were asked *"How did you know when to wean and what weaning foods to use"*. More than half the mothers (54%) cited previous experience, 44% from leaflets/ books/ advertising, 32% had advice from health visitor/doctor and 15% had advice from friends/ family.

Formal information

Sixty-six percent of mothers sought or received some formal information leaving 34% who received none. Some of the mothers who received no formal information were mothers having a second or later child who had received formal information before. The main source of formal information was from health visitors with other sources being books, leaflets and doctors (Table 6.20).

Table 6.20. Sources of formal information on weaning.

Source of formal advice	%	Base (n=100%)
Health visitor	77	65
Reading - books/leaflets	32	65
Doctor/nurse/hospital	6	65

Greatest influence on weaning

Mothers were asked *"Who or what had the biggest influence on when you began weaning and what weaning foods to use"*. Previous experience was the greatest influence for 35% of mothers and the baby themselves not being satisfied for 29%. Other influences included advice from health visitor/doctor, books/leaflets and family/friends (Table 6.21).

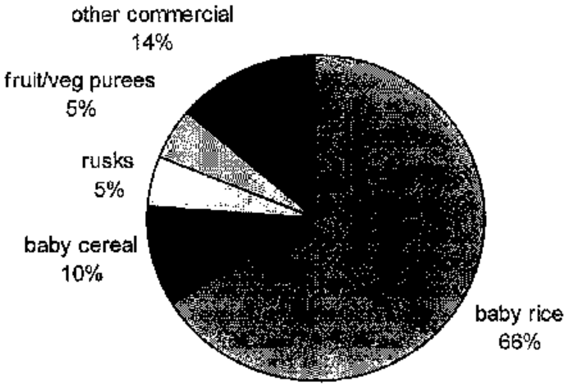
Table 6.21. Mothers' greatest influence for weaning and the weaning foods used.

Influence	%	Base (n=100%)
Previous Experience	35	98
Baby Themselves	29	98
Health visitor/doctor	16	98
Books/leaflets	11	98
Family/friends	8	98

6.3.6 First solid foods given

Commercial cereal preparations were by far the most common food given to infants as their first weaning food, 103 out of the 127 (81%) mothers gave these. Baby rice was the most popular (66%), then baby cereal (10%) and rusks (5%). Only 6 mothers (5%) introduced fruit and vegetable purees. The first weaning food for the remaining 14% was other commercial baby foods (Fig 6.2).

Fig 6.2 First solid food given to infants.



6.4 Discussion

6.4.1 Breastfeeding

Although the proportion of mothers opting to breastfeed was smaller in the Glasgow sample than other UK studies the factors influencing breastfeeding were similar to those previously found (White et al, 1992). The overall breastfeeding rate found for Glasgow at the end of the first week was 27% (Ferguson et al, 1994) and the rate for the areas of Glasgow we recruited from census information was 45% (personal communication). Therefore, the breastfeeding rate from the present study at one week was similar to that of the area we recruited from but less than that found for the whole of the Glasgow area.

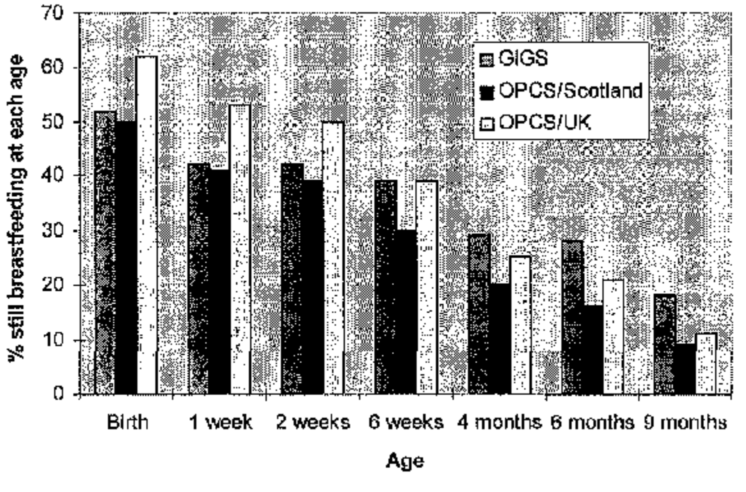
The 1990 OPCS Infant Feeding Report (White et al, 1992) reported that the incidence of breastfeeding in Scotland was lower at all ages up to and including nine months than that for the UK as a whole (Table 6.22). Initially, the breastfeeding incidence of the Glasgow sample was similar to that reported by OPCS for Scotland, however, there was a tendency for the duration of breastfeeding to be longer than the OPCS (Scotland)

(Table 6.22/Fig 6.3). This difference may be due to the fact that mothers from the Glasgow sample were more motivated than those from the OPCS survey as our study involved a long term commitment over 2 years. As with any study it was very difficult to achieve an entirely representative sample for every factor.

Table 6.22. Incidence of breast-feeding over the first nine months in the Glasgow cohort compared with the OPCS, Scotland and UK.

Age	Glasgow	OPCS (Scotland)	OPCS (UK)
Birth	52	50	62
1 week	42	41	53
2 weeks	42	39	50
6 weeks	39	30	39
4 months	29	20	25
6 months	28	16	21
9 months	18	9	11

Fig 6.3. Breastfeeding rates in the Glasgow cohort (GIGS) compared with the OPCS 1990 Infant Feeding Report.



It was also observed from the Glasgow sample and the OPCS that by far the greatest drop-off in breastfeeding was in the first week. Twenty percent of those from the Glasgow cohort, 17% from the OPCS (Scotland) and 15% from the OPCS (UK) ceased breastfeeding during the first week. Initial breastfeeding incidence and duration of breastfeeding in the Glasgow cohort and the OPCS (White et al, 1992) was greater in older mothers.

A greater proportion of mothers in social class I from the Glasgow sample breast-fed when compared with the OPCS (Scotland), 93% and 84% respectively. The opposite was the case in social class V where the Glasgow sample had a lower incidence than the OPCS, 11% compared with 28% (Table 6.23). This difference may be due to the small size of the Glasgow sample or may represent a real difference i.e. mothers from the manual social classes in Glasgow were less likely to breast-feed than those from manual social classes in the rest of Scotland. This is possible as breast-feeding rates in some other urban areas of Scotland were found to be higher than in Glasgow e.g. Edinburgh and Aberdeen (Ferguson et al, 1994) and it may be that these differences reflect differences are due to differences in breastfeeding among the manual social classes. Mothers of higher socio-economic status also tended to provide breast milk for a longer period.

Table 6.23. Incidence of breastfeeding by social class for Glasgow and OPCS (Scotland).

Social class	Glasgow	OPCS (Scotland)
I	93	84
II	75	72
IIINM	57	61
IIIM	33	47
IV	24	40
V	11	28
Unclassified	50	50
No partner	40	23

The incidence and duration of breastfeeding was greater in older mothers and those from higher social classes probably because these mothers were more motivated and more likely to follow infant feeding guidelines than younger mothers and those from lower social classes.

The Glasgow study and OPCS (White et al, 1992) found that mothers who had been in full time education for longer, who did not smoke during pregnancy and with their first child were more likely to breastfeed.

In summary, feeding practice in the Glasgow sample was similar to that of Glasgow as a whole and the factors which have been suggested to influence feeding practice (OPCS) also applied to the Glasgow sample.

6.4.2 Cow's milk feeding

Current recommendations suggest that cow's milk should not be given as a main milk before 1 year (Dept. of Health, 1994, Table 6.1) but there is some evidence (White et al, 1992) that this advice is widely ignored. The OPCS reported as many as 11% by six months and 36% by nine months gave cow's milk as a main milk. Perhaps surprisingly there were far fewer women in the Glasgow sample using cow's milk as a main milk, 2% at six months and 18% at nine months. Mothers from the OPCS were also more likely to be giving cow's milk as a second milk or to mix with food than the Glasgow mothers. By six months, 3% of OPCS mothers had given cow's milk as a second milk and 26% to mix with food and by nine months as many as 13% as a second milk and 63% to mix food. For Glasgow mothers only 6% at six months and 43% at nine months had given cow's milk as a second milk or to mix with food.

At one year almost all mothers in the Glasgow sample gave cow's milk in one form or another (89%), with 49% giving it as a main milk and 40% giving it as a second or main milk.

Although semi-skimmed and skimmed milk are not recommended for children under five (Department of Health 1994) there was evidence from the OPCS and Glasgow study that mothers were using it. Of the Glasgow mothers 2% and 8% were giving semi-skimmed at nine and 12 months respectively. This figure is similar to the UK (OPCS) where 6% of mothers were giving semi-skimmed milk as a main or second milk at 9 months.

In summary, it appears on the whole that Glasgow mothers were less likely to be giving cow's milk than mothers in the rest of the UK (OPCS) in the second half of infancy, but many mothers were still ignoring the Department of Health recommendations.

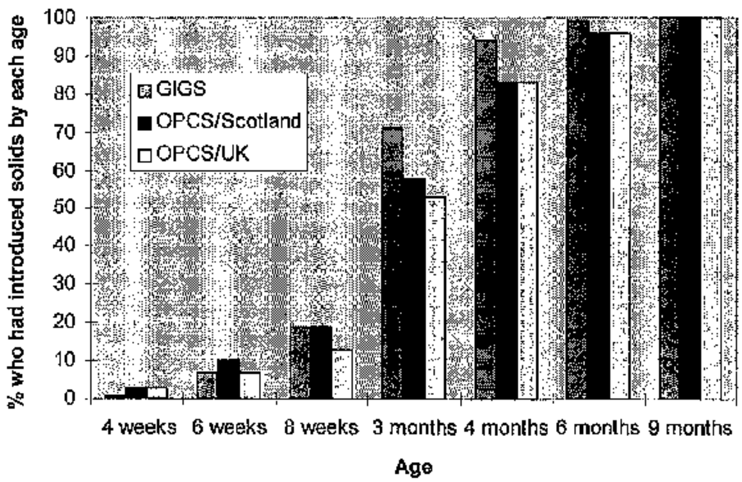
6.4.3 Timing of weaning

Timing of weaning onto solid food was similar in Glasgow to that of Scottish mothers from the OPCS. By six weeks 7% of mothers from the Glasgow sample had already introduced solid food compared with 10% from the OPCS survey (Scotland) and 7% for OPCS survey (UK). By three months 71% of infants from Glasgow had introduced solid food compared with only 58% from the OPCS Survey (Scotland) and 53% from the OPCS Survey (UK). By six months almost all infants from both Glasgow and OPCS had introduced solids (Table 6.24/ Fig 6.4).

Table 6.24. Percentage giving solid food at each age for Glasgow and the OPCS (Scotland and UK).

Age	Glasgow	OPCS (Scotland)	OPCS (UK)
4 weeks	1	3	3
6 weeks	7	10	7
8 weeks	19	19	13
3 months	71	58	53
4 months	94	83	83
6 months	99	96	96
9 months	100	100	100

Fig 6.4. Percentage of the Glasgow (GIGS) cohort who had introduced solid food by each age compared with OPCS 1990 Infant Feeding Report.



Although the breastfeeding rate was greater in the Glasgow sample at three months than the rest of Scotland (OPCS), the age at weaning was earlier in the Glasgow sample (Table 6.24). It was expected that if the mothers were more motivated to breastfeed for longer they would also be more likely to follow the guidelines for weaning. This does not seem to have been the case.

It may be, however, that 'early' weaning in the Glasgow sample may have been an appropriate response to infant growth. It is possible that heavier babies have a more demanding appetite which is difficult to satisfy with milk alone. The results suggest that this may be the case: mothers who had heavier babies at one month were more likely to wean early. This relationship was also found between birthweight and age at weaning in the OPCS (White et al, 1992). Forsyth et al in 1993 reported that perhaps early weaning was not as harmful as previously thought although a more recent study on this group of infants (Wilson et al, 1998) found that solid feeding before 15 weeks was associated with an increased probability of wheeze and increased percentage body fat and weight in childhood.

Our findings that formula-fed infants were weaned earlier confirmed the results of the OPCS and other studies (MAFF, 1986; Whitehead et al, 1986; Wilkinson and Davies, 1978).

As with breastfeeding mothers, those from higher social classes and those who were older tended to introduce solid food later. There was also a trend towards later weaning in mothers who had gone onto further/higher education.

6.4.4 First weaning food

The first food given to the infants in Glasgow was similar to those given in both the OPCS and the MAFF surveys and were mainly baby rice, cereal or rusks. These non-wheat cereals along with fruit and vegetable purees are the recommended first weaning foods (Department of Health, 1994). However, very few mothers gave fruit or vegetable purees (6% of the sample).

6.5 Conclusions

Although the recommendations suggest that mothers should be encouraged to breastfeed, many mothers do not and of those who do many do so for only very short periods. This suggests that there should be more information available for mothers on breastfeeding and help available when a mother encounters problems.

Recommendations and actual feeding and weaning practice were very different and perhaps the recommendations should be reconsidered. Alternatively a more aggressive approach to promoting the infant feeding and weaning recommendations (Dept of Health, 1994) should be considered probably best targeted on families of lower social class. The study also confirms the importance of maternal attitudes to infant feeding and weaning found by earlier studies (Morgan et al, 1995; Stordy et al, 1995). The Glasgow sample was found to be representative in terms of feeding and weaning practice. The study also confirmed the factors influencing feeding and weaning practice which have already been described.

Chapter 7

General discussion and conclusions

7.1 Introduction

Growth in infancy is important for later growth, and is now believed to be important for health in later life (Barker et al, 1992). The present study was a detailed investigation of growth and nutritional status in a sample of infants representative of Glasgow which were well characterised. This allowed us to describe the growth and nutritional status of these infants and examine how they compared with other datasets, especially those used to construct the references from which growth and nutritional status of infants in the UK are to be compared.

Adults in Glasgow are known to have an "unhealthy diet", are at greater risk of many diseases (The Scottish Diet, 1993) and also have smaller final adult height than adults from other parts of the UK. Does this mean that infants in Glasgow also have an 'unhealthy' diet compared with other infants and do they have different growth and nutritional status at this age or do such differences emerge at an older age?

7.2 Comparison with reference data

This study has shown that in terms of growth and nutritional status Glasgow infants do not grow less well than those cohorts that were used to construct the reference values. In fact, in boys, anthropometric measurements were greater than those of the most recent growth and nutritional status references (Freeman et al, 1995; Cole et al, 1995; Savage et al, 1998b).

7.3 Factors influencing growth

Few differences in growth and nutritional status were found between breast and formula-fed infants. This may have been due to the definition of breast-feeding used and also to the sample size (any infant still receiving any breast milk at two months). With other studies, where differences were found, longer periods of exclusive breast feeding were examined (e.g. Dewey et al, 1992). However, exclusive breast feeding for greater than 2-3 months is not common in the UK and it would be pointless to examine the effect of this.

The evidence on the effect of age at weaning onto solid food is more convincing. Two recent well-conducted studies in the UK (Forsyth et al, 1993; Wilson et al, 1998; Whitehead and Paul 1986) found differences in growth associated with weaning at different ages. The present study also found differences in growth and nutritional status, especially in girls, depending on the age they were weaned onto solid food. The further finding from the Dundee study (Forsyth et al, 1993) that infants who were heavier tended to be weaned earlier was also found in the present study (Chapter 4; Savage et al, 1996b).

In the present study few differences in growth were found between infants from different social classes: this was consistent with a study from The Netherlands (Herngreen et al, 1994). Differences were found for nutritional status, especially in girls, between infants of different social classes at two years. Whether these differences persist into later childhood is unknown.

Mothers' smoking habit during pregnancy in the present study was found to affect anthropometric measurements as previously observed by the OPCS Infant Feeding survey (White et al, 1992) but this effect had disappeared by the end of the first year.

7.4 Feeding and weaning practice

The present cohort of infants had similar feeding and weaning practice to that found for Scotland and the UK (White et al, 1992, Savage et al, 1998a) and therefore it was useful to observe whether these practices had any effect on growth and nutritional status. Many infants in all three data sets (Glasgow, OPCS UK, OPCS Scotland) had been weaned before the recommended age of 4 months and by 6 months nearly all infants from all three datasets had been weaned.

The factors found to affect feeding and weaning practice in the Infant Feeding Report (White et al, 1992) including maternal age, social class, educational attainment and birth order were also found in the present study (Savage et al, 1994a, Savage et al, 1998a). Whether mothers received any formal information and the anthropometric measurements at one month also influenced when mothers weaned their infants onto solid food.

7.5 Conclusion

This detailed longitudinal study of growth and nutritional status allowed comparison with anthropometric reference values, both old and new and has shown that the use of many of the older references especially for skinfold thickness (Tanner and Whitehouse, 1975) and head circumference (Gairdner and Pearson, 1971) should be discontinued. It has also shown that, even with the most recent references there were still differences when compared with growth and nutritional status of infants from the present study.

One of the main problems with the study was the relatively small sample size and, therefore, the results may not be as conclusive as those from larger samples. However, many of the other major studies had a similar sample size (e.g. Tanner et al, 1966; Dewey et al, 1992) Another problem was analysing longitudinal data (with repeated measures over time) because one measurement will very much influence subsequent measurements. However, following statistical advice it was decided to analyse at certain time points only, spaced in time, in order to minimise this 'carry over' effect.

The importance of maternal attitudes to breastfeeding has long been recognised as an important element in achieving compliance with UK recommendations (Clements et al, 1997) but parental attitudes to weaning practice has received much less attention but would appear to be misinformed (Morgan et al, 1995), with potentially adverse consequences for the infant (Stordy et al, 1995). The fact that many mothers are failing to comply with current guidelines on feeding and weaning implies that these are not reaching their target audience. Our evidence that weaning practice is sensitive to education, social class and the input of health professionals implies that there is some scope in this area.

The present study represents a detailed investigation of growth and nutritional status in a representative sample of Glasgow infants which was well characterised. The study achieved its aims and allowed us to (1) confirm the need for newer anthropometric reference data, (2) identify some of the factors which influence infant growth and nutritional status in a representative sample not characterised by abnormal feeding practices and (3) confirm the non-compliance with the guidelines for feeding and weaning practice and identify factors associated with compliance

Communications

Abstracts:

Weaning practice in Glasgow (1994). S.A.H. Savage, J.J. Reilly, C.A. Edwards and J.V.G.A. Durnin, University of Glasgow, Department of Human Nutrition, Yorkhill Hospitals, Glasgow G3 8SJ. *Proceedings of the Nutrition Society* **53,** 104A. Presented at The Nutrition Society meeting in Edinburgh, April 1994.

Weight and length of Glasgow infants compared with Tanner and Whitehouse standards and new British standards for growth (1996). S.A.H. Savage, J.J.Reilly, and J.V.G.A Durnin, University of Glasgow, Department of Human Nutrition, Yorkhill Hospitals, Glasgow G3 8SJ. *Proceedings of the Nutrition Society* **55**, 81A. Presented at The Nutrition Society meeting in Aberdeen, July 1995.

The effect of feeding and weaning practice on growth and nutritional status of Glasgow boys and girls in the first year of life (1996). S.A.H. Savage, J.J. Reilly and J.V.G.A. Durnin, University of Glasgow, Department of Human Nutrition, Yorkhill Hospitals, Glasgow G3 8SJ. *Proceedings of the Nutrition Society* **55,** 247A. Presented at The Nutrition Society meeting in Dundee, April 1996.

Papers:

Weaning practice, and factors influencing it, in the Glasgow longitudinal infant growth study (1998). Savage SAH, Reilly JJ, Edwards CA, Durnin JVGA. Arch. Dis. Child **79**: 153-156.

Adequacy of standards for assessment of growth and nutritional status in infancy and early childhood (1998). Savage SAH, Reilly JJ, Edwards CA, Durnin JVGA. Arch. Dis. Child. **80**: 121-124.

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Appendix 1

THE HEALTH OF COMMUNITIES WITHIN THE GGHB AREA

NEIGHBOURHOOD ANALYSIS

The purpose of this analysis is to make it possible to assess the health status of communities within the GGHB area. It is often difficult to analyse health in individual communites because the number of events (deaths, hospital admissions etc) is very low. For example there are only about 135 infant deaths each year in the entire GGHB area, and so it would be necessary to aggregate data for a large number of years in order to produce a meaningful rate for infant mortality in Clydebank or Govan. It would be even more difficult to identify any trend. For this reason it is useful to group similar areas together so that data can be aggregated over reasonably large geographical areas. These areas we have called neighbourhood types. Postcode sectors were used as the basic building block for these areas. There are 137 complete postcode sectors which lie entirely within the GGHB area, and 11 in which a major part lies within the area. The method used was as follows:

Almost 60 socio demographic variables which were likely to reflect social and environmental differences across GGHB were selected and some variables which were closely associated with one another were eliminated by a technique known as principal component analysis. The remaining 30 variables were then used in a form of cluster analysis (CLAN) in order to identify groups of postcode sectors which were broadly similar to one another. Almost any number of groups could have been selected, but the best differentiation between groups was achieved with eight - both on statistical grounds and in qualitative terms. The eight cluster groups or 'neighbourhood types' describe the known mix of housing and socioeconomic characteristics in each postcode sector within the GGHB area very effectively:

1. Large owner-occupied housing with two or more cars, mainly professional and non-manual workers eg Eastwood, Bearsden and Milngavie (13% of population).

2. Mainly owner-occupied housing, families with young children, professional and non-manual workers eg South Cambuslang, Stepps and Milton of Campsie (9% of population).

3. Mixed tenure accommodation, high proportion of families with no children, single persons and students. Mainly non-manual and professional workers eg Shawlands, Broomhill, Kelvinside (10% of population).

4. Mainly inter-war local authority housing with ageing and elderly population eg Knightswood, Mosspark and Riddrie (17% of population).

5. Mainly post-war local authority housing with young families and skilled workers eg Pollok, West Castlemilk and Faifley (20% of population).

6. Mixture of small rented furnished and owner-occupied households with shared amenities; single persons, students, immigrants and high unemployment eg Woodlands, Strathbungo and Govanhill (5% of population).

7. Post-war local authority housing with young families, high unemployment and mainly unskilled workers eg Drumchapel, Easterhouse and Nitshill (10% of population).

8. Mixed tenure-type but mainly local authority, vacant properties and small, over crowded households sharing amenities. Ageing population with few children and high unemployment, mainly unskilled workers eg Govan, Bridgeton and Ruchill (17% of population).

CHARACTERISTICS OF NEIGHBOURHOOD TYPES

		1	2	3	4	5	6	7	8	GGHB
FAMILY STRUCTURE										
Population	- large families	6.5	7.0	3.6	4.4	9.1	5.7	15.3	5.7	7.0
	- elderly	4.7	3.4	7.7	7.3	3.3	5.9	1.7	6.0	5.0
	- pre-school children	5.9	8.0	5.2	3.4	6.2	6.2	8.5	5.5	6.0
	- ethnic communities	1.2	0.8	1.7	0.3	0.3	10.4	0.1	1.0	1.0
TYPES OF HOUSING										
Household	- owner occupied	81.1	62.0	56.7	14.2	11.4	50.9	2.5	15.5	32.0
	- local authority	14.8	32.6	23.0	79.2	85.2	9.8	94.2	69.8	58.0
	- overcrowding	4.2	11.0	14.3	21.4	26.1	27.3	39.4	35.6	23.0
	- lacking amenity	0.3	0.5	4.9	1.7	0.5	7.5	0.2	9.1	3.0
SOCIO-ECONOMIC										
Population	- social class IV & V	4.5	10.6	8.9	15.2	19.9	10.3	27.7	23.0	16.0
	- low SEG*	5.4	12.4	11.8	21.2	26.0	15.4	31.9	30.9	21.0
	- unemployment	5.1	9.0	9.4	15.7	19.3	14.7	30.7	25.7	17.0

* *Socio-economic group*

The table is based on percentage data derived from 1981 CENSUS.

GGHB POST CODE SECTORS BY NEIGHBOURHOOD TYPE

1	2	3	4	5	6	7	8
G41.4	G33.6	G11.5	G13.2	G21.3	G3.6	G15.7	G1
G43.2	G44.5	G11.7	G13.3	G22.7	G3.7	G15.8	G2.0
G44.3	G64.1	G12.0	G13.4	G23.5	G4.9	G33.1	G3.8
G46.6	G64.4	G13.1	G14.9	G32.0	G5.8	G33.4	G4.0
G46.7	G65.8	G31.2	G15.6	G33.3	G12.8	G33.5	G5.0
G61.1	G66.3	G41.3	G20.0	G45.9	G12.9	G34.0	G5.9
G61.2	G66.5	G41.5	G22.6	G46.8	G20.6	G34.9	G11.6
G61.3	G69.0	G42.9	G32.6	G53.5	G41.1	G45.0	G14.0
G61.4	G69.6	G44.4	G32.8	G53.7	G41.2	G53.6	G20.7
G62.6	G72.8	G60.5	G32.9	G65.7	G42.8		G20.8
G62.7	G76.8	G66.1	G33.2	G65.9			G20.9
G62.8	G81.6	G73.2	G42.0	G66.2			G21.1
G64.2		G73.3	G43.1	G69.7			G21.2
G64.3			G51.4	G69.8			G21.4
G66.4			G52.1	G69.9			G22.5
G67.4			G52.2	G72.7			G31.1
G76,0			G52.3	G73.4			G31.3
G76.7			G52.4	G73.5			G31.4
G76.9			G71.7	G81.1			G31.5
G77.5			G81.3	G81.2			G32.7
G77.6			G81.4	G81.5			G40.1
							G40.2
							G40.3
							G40.4
							G42.7
							G51.1
							G51.2
							G51.3
							G73.1

Appendix 2

CONSENT FORM

GLASGOW/INFANT GROWTH STUDY

In order to assess the growth of babies in this country we currently depend on a set of "growth standards" which have been obtained from studies on the growth of babies in the USA. We believe that these American figures are unsatisfactory and the aim of this research is to collect new information on the growth of healthy babies which is more relevant to the situation in the West of Scotland. The study means that we need to make the following simple measurements at regular intervals (initially monthly) in each baby.

1. Measure weight, length, and head circumference.

2. Measure the fatness and muscularity of the baby using a set of calipers.

We will also ask you to complete a questionnaire which will give us details of your health and health of the baby, and some information on how the baby is fed. This information will be treated in confidence.

Particpation in the study is unlikely to benefit your baby directly, but will help us produce growth standards which will be useful to other babies in the future. If your baby does take part in the study your General Practitioner will be informed. If you agree to take part in the study but later wish to withdraw from the study you are free to do so: just let us know; your child's care will not be affected.

CONSENT

I ....

of ....

..

give my consent to the participation of ....

in the procedures described above which have been explained to me by

...

Signed .... Date ....

Witness .... Date ....

Appendix 3

INITIAL INTERVIEW

QUESTIONNAIRE

Research centre ____________

Subject number ____________

Subject's initials ____________

Measurement occasion ____________

Date of interview ____________

Interviewer ____________

Date of birth ____________

BABY

Sex (m=1, f=2) ____________

Birthweight ____________

Length ____________

Head circumference ____________

Gestational age ____________

Number of siblings (surviving) ____________

MOTHER

Age ____________

Weight before pregnancy ____________

Guess = 1, record = 2. ____________

Estimate of weight gain ____________

Height ____________

Haemoglobin

1. ________ Date ________

2. ________ Date ________

3. ________ Date ________

Ethnic origin; Caucasian=1, other=2, ____________

If 2, specify ____________

YEARS OF EDUCATION

a) 1 = 0 - 8; 2 = 9 - 12; 3 = 12
4 = student; 5 = university degree ______

b) Education still going on (yes = 1, no = 2) ______

c) Age at which education stopped ______

ENVIRONMENT

a) Mother alone = 1; With father = 2;
Extended community = 3. ______

b) Urban = 1; Rural = 2; Little green = 3. ______

c) Central heating. No = 1; Yes = 2. ______

d) Number of children at home ______

e) Unemployed. Neither = 0; Father = 1;
Mother = 2; Both = 3. ______

PREGNANCY DISEASE

None = 0; High B/P = 1; Oedema = 2;

Proteinuria = 3; Combination = 4; Other = 5. ______

______

MEDICATIONS DURING PREGNANCY (except minerals and vitamins)

None = 0; Yes = 1; ______

Specify ______

Iron supplementation during pregnancy ______
No=0; Yes=1;

DRUG ABUSE BEFORE PREGNANCY

No = 0; Yes = 1. ______
Specify ______

DRUG ABUSE DURING PREGNANCY

No = 0; Yes = 1. ______
Specify ______

SMOKING BEFORE PREGNANCY

No = 0; Yes = no. of cigarettes per day ______________

SMOKING DURING PREGNANCY

No = 0; Yes = no. of cigarettes per day ______________

DID YOU DRINK ALCOHOL BEFORE PREGNANCY?

No = 0; Yes = grams of alcohol per day ______________

DID YOU DRINK ALCOHOL DURING PREGNANCY?

No = 0; Yes = grams of alcohol per day ______________

PROPOSED FEEDING METHOD 1=Breast; 2=Formula; ______________

FATHER

Age ______________

Weight ______________

Height ______________

Years of education 1 = 0 - 8; 2 = 9 - 12; 3 = 12;

4 = student; 5 = university degree ______________

Is education still going on? (yes = 1, no = 2) ______________

Age at which education stopped ______________

Number of cigarettes smoked yesterday ______________

Drinks last week, grams of alcohol per day ______________

Ethnic origin; Caucasian=1; Other=2 ______________
If 2, Specify ______________

Food avoided due to suspected or proven allergy
or hypersensitivity. No=0; Yes=1; ______________
Specify ______________

Appendix 4

FOLLOW-UP INTERVIEW

Subject Number__________ Date________________

Occassion_____________

OTHER

Has the environmental situation changed?
No = 0; Yes = 1. ____________________________________

Mother alone = 1; With father = 2;
Extended community = 3. ______________________

Urban = 1; Rural = 2; Little Green = 3. ________________

Central heating. No = 0; Yes = 1. __________________

Number children at home________________________________

Unemployed. Neither = 0; Father = 1; Mother = 2;
Both = 3. ________________________________

Mother's work outside home (Hrs/day)_____________________

Did you smoke during the last days?______________________

No. of cigarettes smoked in the appartment yesterday_______

Grams alcohol/day in last week.__________________________

Special dietary habits_________________________________

1.Lacto ovo vegetarian______ 4.Lactovegetarian_________
2.Pure vegetarian___________ 5.Macrobiotic____________
3.Other health diet_________ 6.Specify_______________
____

Food items avoided because of suspected or proven allergy or hypersensitivity No = 0; Yes = 1; Specify_______________________
____

IRON SUPPLEMENT: After pregnancy No = 0; Yes = 1;___________

NUTRITIONAL INTAKE No = 0; Yes = 1; Partially = 2.

Breastfeeding: Fully_______ Partially_________

Infant Formula: 1.Cow milk based____ 4.Soya______________
Highly modified 2.Hypoallergenic____ 5.Hydrolysate________
e.g. cow + gate 3.Iron fortified____
premium

Follow up milk: 1.Cow milk based____ 3.Soya______________
Modified 2.Iron fortified____
e.g. cow + gate
plain

Cow's milk: No = 0; Diluted = 1; Undiluted = 2;

Skim milk: ______________________________

How many times does he eat each day, including milk or formula?______________________________

If the baby drinks milk or formula, what is the usual amount in a day?______________________________

Have you changed the formula______________________________
If so, why?______________________________

Foods:	never or hardly ever (less than once a week) (=0)	sometimes (not daily but at least once a week) (=1)	every day or nearly every day (=2)
Fruit and fruit juices			
Home prepared	______	______	______
Commercial	______	______	______
Vegetables and veg. juices			
Home prepared	______	______	______
Commercial	______	______	______
Beans, Peas....	______	______	______
Milk based infant cereal			
Home prepared	______	______	______
Commercial	______	______	______
Gluten containing cereal	______	______	______
Bread, pasta, other cereals	______	______	______
Rice, potatoes	______	______	______
Milk products, yogurt, cheese	______	______	______
Eggs, yolk	______	______	______
whole	______	______	______
Meat, fish, poultry	______	______	______

Does the baby take iron drops?______________________________

Does the baby take vitamins?______________________________
Specify______________________________

DISEASE

How many days was the infant sick during the last month_____

Infectious diseases: None________ 1.Acute diarrhoea_____
2.Upper respiratory________ 3.Otitis media________
4.Skin____________________ 5.Other____________
Specify____

Suspected hypersensitivity reactions to food
None = 0; Food = 1; Other = 2;_______________

Systemic: 1.Anaphylaxis_______
G.I.T. 2.Vomiting__________ 3. Abdominal Pain_______
4.Colic_____________ 5. Diarrhoea__________
6.Diarrhoea(blood)___ 7. Diarrhoea(mucus)_____
Respiratory: 8.Rhinitis__________ 9. Wheezing__________
10.Secretory otitis media____________
Cutaneous: 11.Rash____________ 12.Urticaria__________
13.Eczema___________

Are you excluding foods No=0; Yes=1; Specify____________

Do you think the child has a feeding problem?____________
Specify____

NUTRITIONAL ADVICE

1.Paediatrician____________ 2.G.P.________________
3.Nurse, health worker______ 4.Family______________
5.Friends__________________ 6.Infant food industry__________
7.Television_______________ 8.Newspapers, books__________
9.Staff of study____________ 10.Nobody____________________

REPEAT ANTHROPOMETRY

Weight (g)____________________

Triceps Skinfold (.1mm)____________________

Subscapular Skinfold (.1mm)____________________

Head Circumference(mm)____________________

Mid arm Circumference(mm)____________________

Thigh Circumference(mm)____________________

Calf Circumference (mm)____________________

Triceps Skinfold(.1mm)____________________

Subscapular Skinfold(.1mm)____________________

Length(mm)____________________

Appendix 5

B. ENTER OCCASIONS 9 10

Patnr	###	Subject number
Initials	______	Subject initials
Occasion	##	
Dateint	<dd/mm/yy>	Date of interview
Intervie	______	Interviewer

G. General Information (only for occasion 9 = 18 months)

G7	#	Is the mother living in a endemic goiter area
G8	#	Is the family using iodized salt
G9	#	Are there preventive measures/iodine deficiency
G10	#	How often eating fish or seafood per week less then 1=0 1=1 more then 1=2

A. Mother

Am07	#	Type household Mother alone = 1 With father = 2 Extended community = 3
Am07a	#	Environment Urban = 1 Rural = 2 Little green = 3
Am07b	#	Central heating No = 1 Yes = 2
Am07c	##	Number of children at home
Am07d	#	Unemployment No = 0 Father = 1 Mother = 2 Both = 3
Am19	##	Mother work outside home (hours per day)
Am14	###	Mother number of cigarettes smoked during the last days (no = 0) 0 - ...
Am15	###	Number of cigarettes smoked in the appartment yesterday 0 - ...
Am18	###	Mother grams of alcohol per day during last week
Am20	#	Mother; are you on special diet No = 0 Yes =
Am20a	#	Lacto ovo vegetarian
Am20b	#	Lacto vegetarian

Am20c # Pure vegetarian

Am20d # Macrobiotic

Am20e # Other diet
Am20f ____ Other diet specify 4 digits

Am20g # Mother; are you avoiding any food item
No = 0 Yes = 1
Am20h ____ Avoiding, specify 4 digits

Do you have an allergy No=0 Yes=1 dont know=2
Am22a # skin
Am22b # respiratory tract
Am22c # GI tract
Do you think the father has an allergy
No = 0 Yes = 1 dont know = 2
Am23a # skin
Am23b # respiratory tract
Am23c # GI tract
Do you think the siblings have an allergy
No = 0 Yes = 1 dont know = 2
Am24a # skin
Am24b # respiratory tract
Am24c # GI tract

(Questions Am25 and Am25a only for occasion 9 = 18 months)
Am25 # Ethnic origin of father
Caucasian = 1 Other = 2
Am25a ____ If 2 Specify 4 digits
C. Nutrition (general milk solids)

C12 # Breast feeding No = 0
Partially = 1
Offered general comfort = 2
Fully = 3
During night = 4

Drinking from bottle No = 0 Yes = 1
C19a # milk/formula
C19b # tea
C19c # fruit juices
C19d # other (if yes, specify)
C19d1 ________

C19e # Bottle to bed No = 0
Usually with milk/formula = 1
Usually with instant tea = 2
Usually with tea/sugar = 3
Usually with fruit juices = 4
Usually with water = 5
Usually with other = 6
C19e1 ________ (if 6, specify)
Infant formula (this item only for occasion 9)

C20a # Bottle No = 0
Yes = 1
only at night = 2

```
C20b        ####     daily amount with bottle    (ml)
C20c        #     Cup     No              = 0
                          Yes             = 1
C20d        ####     daily amount with cup       (ml)

                  Follow up milk
C21a        #             No                  = 0
                          Cow milk based      = 1
                          Soy based           = 2
C21b        #             Iron fortified      No  = 0    Yes  = 1
C21c        #     Bottle  No              = 0
                          Yes             = 1
                          only at night   = 2
C21d        ####          amount with bottle   (ml)

C21e        #     Cup     No              = 0
                          Yes             = 1
C21f        ####          amount with cup      (ml)
                  Cow's milk

C22a        #     Bottle  No              = 0
                          Yes             = 1
                          only at night   = 2
C22b        ####          amount with bottle   (ml)

C22c        #     Cup     No              = 0
                          Yes             = 1
C22d        ####          amount with cup      (ml)

                  (Partially) skimmed milk
C23a        #     No                = 0      0.5 - 0.9 % fat    = 1
                  1.0 - 1.4 % fat   = 2      1.5 - 1.9 % fat    = 3
                  2.0 - 2.4 % fat   = 4      2.5 - 2.9 % fat    = 5
C23a        #     Bottle  No              = 0
                          Yes             = 1
                          only at night   = 2
C23b        ####          amount with bottle   (ml)

C23c        #     Cup     No              = 0
                          Yes             = 1
C23d        ####          amount with cup      (ml)
                  Adding sugar to formula or cow's milk
                    No = 0    Yes = 1
C24a        #         Sometimes
C24b        #         Regularly
C24c        #         Evening meal
C24d        #         During the night
C24e        #         during the day


                  Adding cereals to formula or cow's milk
                    No = 0    Yes = 1
C25a        #         Sometimes
C25b        #         Regularly
C25c        #         Evening meal
C25d        #         During the night
C25e        #         during the day

                  How many times does the child eat each day
C26a        #         regular meals (incl milk or formula)
```

C26b	#	snacks and drinks

Snacks the child has most often **No = 0** **Yes = 1**

C27a	#	Chocolade
C27b	#	Cookies
C27c	#	Cheese
C27d	#	Candy, sweets
C27e	#	Chips
C27f	#	Icecream
C27g	#	Other (if yes, specify)
C27g1	______	

Nutrition (solids)
(Never = 1 Sometimes = 2 Every day = 3)

C15a1a	#	Home prepared fruits
C15a2a	#	Commercial fruits
C15a1b	#	Home prepared fruit juices
C15a2b	#	Commercial fruit juices
C15b1	#	Home prepared vegetables
C15b2	#	Commercial vegetables
C15h	#	Eggs
C15i1	#	Meat
C15i2	#	Fish
C15i3	#	Poultry
C15e	#	Bread
C15f2	#	Potatoes
C15g1	#	Cheese
C15g2	#	Youghurt

Cereals (never = 1 Sometimes = 2 Every day = 3)

f15j	#	Oats (eg Grit)
C15k	#	Pasta
C15l	#	Rice
C15m	#	Breakfast cereals (eg Kellog's)
C15n	#	Other cereals (if "every day", specify)
C15na	______	

Fruits no = 0 yes = 1

C15p1	#	Apple
C15p2	#	Orange
C15p3	#	Pear
C15p4	#	Banana
C15p5	#	Tomatoe
C15p6	#	Berries
C15p7	#	Grapes
C15p8	#	Kiwi

C15p9	#	Other (if yes, specify)
C15p9a	________	

Vegetables no = 0 yes = 1

C15q1	#	Carrots
C15q2	#	Beans
C15q3	#	Peas
C15q4	#	Greens
C15q5	#	Cabbage
C15q6	#	Other (if yes, specify)
C15q6a	________	
C16	#	Does the child take iron drops No = 0 Yes = 1
C16a	####	If yes, dosage
C17	#	Does the child take vitamins No = 0 Yes = 1
C17a	____	Vitamins specify 4 digits
C18	#	Does the child take fluoride supplements No = 0 Yes, drops = 1 Yes, tablets = 2 If yes
C18a	####	Dosage
C18b	##	Started at age (months)

B. Disease (infant)

B10a	##	How many periods of illness (> 24 hours) during the last 6 months
B10b	##	How many days was the child ill since the last 6 months
B101	#	Acute diarrhoea No = 0 Yes = 1
B102a	#	upper respiratory (fever, cough, runny noise)
B102b	#	lower respiratory
B103	#	Otitis media
B104	#	Skin infection
B105	#	Other disease No = 0 Yes = 1
B106	____	Other disease, specify

Hypersensitivity Reactions (None=0 Related to food intake=1 Other=2)

B1101	#	Systemic: anaphylaxis
B1101a	____	If 2, specify
B1102	#	Gastrointestinal: vomiting
B1102a	____	If 2, specify
B1103	#	Abdominal pain
B1103a	____	If 2, specify
B1104	#	Colic
B1104a	____	If 2, specify
B1105	#	Diarrhea
B1105a	____	If 2, specify
B1106	#	Diarrhea with blood
B1106a	____	If 2, specify
B1107	#	Diarrhea with mucus
B1107a	____	If 2, specify
B1108	#	Respiratory: rhinitis
B1108a	____	If 2, specify
B1109	#	Wheezing
B1109a	____	If 2, specify
B1110	#	Secretory otitis media
B1110a	____	If 2, specify
B1111	#	Cutaneous: rash
B1111a	____	If 2, specify
B1112	#	Urticaria
B1112a	____	If 2, specify
B1113	#	Eczema
B1113a	____	If 2, specify
B11a	#	Suspected hypersensitivity probably caused by No=0 Food=1 Allergens=2 Unknown agents=3
B11b	#	Do you think the child has got a feeding problem No = 0 Yes = 1
B11ba	____	Feeding problem specify 4 digits
B11c	#	If feeding problem, get the child a special diet No = 0 Yes = 1
B11ca	____	Special diet specify 4 digits

D. Nutrition advice (No = 0 Yes = 1)

D1801	#	Pediatrician
D1802	#	General practitioner
D1803	#	Nurse, health worker
D1803a	#	Trained health professional
D1804	#	Family
D1805	#	Friends
D1806	#	Food industry

D1807	#	Television
D1808	#	Newspapers, books
D1809	#	Staff of the study
D1810	#	Nobody

B. Antropometry (infant)

B02	#####	Weight in grams
B04	###.#	Head circumference in cm
B05	##.#	Triceps skinfold 1 in mm
B06	##.#	Subscapularis skinfold 1 in mm
B07	##.#	Midarm circumference left side in cm
B08	##.#	Thigh circumference left side in cm
B09	##.#	Calf circumference left side in cm
B05a	##.#	Triceps skinfold 2 in mm
B06a	##.#	Subscapularis skinfold 2 in mm
B03a	###.#	Length (supine) in cm
B03b	###.#	Height (standing) in cm

Appendix 6

Code: ....

Name: ....

Date: ....

1. Which kind of milk do you give your baby most of the time at the moment?

PLEASE TICK <u>ONE</u> BOX ONLY

Cow and Gate Premium (powder)	[]
Cow and Gate Premium (ready to feed)	[]
Cow and Gate Plus (powder)	[]
Cow and Gate Plus (ready to feed)	[]
Cow and Gate Formula S (powder)	[]
Ostermilk Two (powder)	[]
Ostersoy (powder)	[]
SMA Gold Cap (powder)	[]
SMA Gold Cap (ready to feed)	[]
SMA White Cap (powder)	[]
SMA White Cap (ready to feed)	[]
Wysoy (powder)	[]
Milupa Milumil (powder)	[]
Milupa Aptamil (powder)	[]
Milupa Prematil (powder)	[]
Progress (powder)	[]
Farley's Junior Milk (powder)	[]
Boots Junior Milk (powder)	[]
Liquid Cow's Milk - whole	[]
- semi-skimmed	[]
- skimmed	[]
Another kind of milk	[]

(please tick and write in the name)

2. How old was your baby when you started giving this kind of milk?

PLEASE ENTER A NUMBER IN THE BOX

[ ] weeks old

3. Do you give your baby foods such as cereal, rusk or any other kind of solid food including any that you make yourself?

Yes [] (a)

No [] 7

(a) How old was your baby when he/she first had any food apart from milk?

PLEASE ENTER A NUMBER IN THE BOX

[ ] weeks old

4. Can you list all the cereal, rusks or solid food your baby ate yesterday. Please describe each fully, giving the brand name or if its home made, whether commercial baby food is dried or tinned/jarred and also the time of the feed.

Time of Feed	Type of food	Brand (or home made)	Please tick to show whether	
			dried	tinned /jarred

5. Do you use milk to mix up your baby's food?

yes [] (a)

No [] 6

(a) Do you use:-

infant formula milk []

or liquid cow's milk []

or something else []

(please tick and write in)

....

6. How old was your baby when he/she regularly started having three meals of solid foods a day?

Please enter a number in the box [ ] weeks old

7.

(a) Do you give your baby any extra vitamins? Yes [] No []

(b) Specify

....

....

8. Do you take your baby to a child health clinic for advice or regular check-ups?

Yes [] No []

9. About how often do you take your baby to a child health clinic?

Once a week []

Once a fortnight []

Once a month []

Less than once a month []

10. Do you take your baby to your family doctor (GP) for advice or regular check-ups?

Yes []

No []

11. About how often do you take your baby to your family doctor (GP) for advice or regular check-ups?

Once a week	[]
Once a fortnight	[]
Once a month	[]
Less than once a month	[]

12. Have you had any problems with your baby since the time when you filled in the previous questionnaire?

Yes [] (a)

No [] 14

(a) What problems have you had?

....

....

....

13. Did anyone give you help or advice about these problems?

yes [] (a)

No [] 14

(a) **Who helped or advised you?**

Please tick one or more boxes

Health Visitor []

Doctor at the child health clinic []

Nurse at the doctor's surgery []

Voluntary support groups (eg. National Childbirth Trust, Lac Leche League or Association of Breastfeeding Mothers) []

Friend or relative []

Someone else (please tick and write in) []

....

....

14. Do you smoke cigarettes at all nowadays?

Yes []

No []

15. Does your husband/partner smoke cigarettes at all nowadays?

Yes []

No []

16. About how many cigarettes a day do you usually smoke now?

Please enter number in the box [ ]

17. About how many cigarettes a day does your husband/partner usually smoke now?

Please enter number in the box [ ]

18. Are you doing any paid work at the moment?

Yes	[]	
On paid maternity leave	[]	19
On unpaid maternity leave	[]	
No	[]	(a)

(a) Do you plan to start work again within the next two years?

Yes, full-time	[]
Yes, part-time	[]
No	[]
Do not know	[]

19. What is your job?

....

20. Father's job?

....

Unemployed Y/N

Appendix 7

ADDITIONAL QUESTIONS FOR MOTHERS AFTER WEANING HAS STARTED

When did you start weaning your baby (what age?)

What factors made you start weaning your baby?

How did you know when to wean and what weaning foods to use?

Have you had any formal information or instruction on weaning?

Who or what had the biggest influence on when you began weaning and what weaning foods you used?

Appendix 8

GLASGOW INFANT GROWTH STUDY

QUESTIONNAIRE FOR NON-PARTICIPANTS

We appreciate that you do not wish to participate in this study, but the study depends on obtaining some information on mothers and babies in Glasgow, even those who do not wish to participate. **This information will be treated in confidence.**

We would therefore greatly appreciate it if you could answer the following questions and send your replies in the enclosed stamped addressed envelope.

Date ....

Name (please print) ....

Date of birth ....

YOUR DETAILS

Your height (approx.) ....

Your weight (approx.) just before your pregnancy ....

How many years did you spend in full time education?

Years at school ....

Years of further or higher education if applicable ....

Your family:-

Do you live alone? ....

With the baby's father? ....

Do you have any other children?....................................

DETAILS OF YOUR BABY

Weight at birth (approx.) ....

Sex of baby (please delete as appropriate) Male/Female

THANK YOU FOR YOUR HELP

PLEASE RETURN COMPLETED QUESTIONNAIRE IN THE SAE PROVIDED

Appendix 9

Appendix 9. SD-score of Glasgow infants compared with reference values.

Table 1. Mean weight and length SD-scores of Glasgow children by sex compared with Tanner and Whitehouse references.

Age (months)	Boys n	Boys Mean SD-Score Weight	Boys Mean SD-Score Length	Girls n	Girls Mean SD-Score Weight	Girls Mean SD-Score Length	Differences Difference Weight	Differences Difference Length
0	69	0.24	0.43	58	0.00	0.41	0.24	0.02
1	68	0.79	0.36	58	0.53	0.29	0.26	0.07
2	68	1.02	0.25	56	0.51	0.14	0.51	0.11
3	66	0.81	0.24	58	0.34	0.07	0.47	0.17
4	69	0.42	0.10	58	0.13	0.16	0.29	0.06
5	67	0.31	-0.02	57	0.02	0.21	0.29	-0.23
6	69	0.15	0.02	58	-0.05	0.16	0.20	-0.14
9	69	0.10	-0.10	58	-0.13	-0.01	0.23	-0.09
12	67	0.13	-0.07	55	-0.21	-0.01	0.34	-0.06
18	66	0.23	0.15	50	-0.19	0.09	0.42	0.06
24	65	0.27	0.44	47	-0.17	0.23	0.44	0.21

Table 2. Mean weight and length SD-scores of Glasgow children by sex compared with 'UK 1990' references.

Age (months)	Boys n	Boys Mean SD-Score Weight	Boys Mean SD-Score Length	Girls n	Girls Mean SD-Score Weight	Girls Mean SD-Score Length	Differences Difference Weight	Differences Difference Length
0	69	0.22	0.43	58	0.06	0.47	0.16	-0.04
1	68	0.04	-0.15	58	-0.38	-0.10	0.42	-0.05
2	68	0.22	-0.06	56	-0.41	-0.20	0.63	0.14
3	66	0.21	-0.02	58	-0.35	-0.41	0.56	0.39
4	69	0.15	-0.07	58	-0.29	-0.28	0.44	0.21
5	67	0.22	-0.02	57	-0.20	-0.10	0.42	0.08
6	69	0.22	0.14	58	-0.14	-0.05	0.36	0.19
9	69	0.23	0.11	58	-0.14	0.01	0.37	0.10
12	67	0.28	0.10	55	-0.19	0.06	0.47	0.04
18	66	0.40	0.14	50	-0.16	0.11	0.56	0.03
24	65	0.51	0.39	47	-0.18	0.16	0.69	0.23

Table 3. Mean weight and length SD-scores of Glasgow children by sex compared with 'Revised UK 1990' references.

Age (months)	Boys n	Boys Mean SD-Score Weight	Boys Mean SD-Score Length	Girls n	Girls Mean SD-Score Weight	Girls Mean SD-Score Length	Differences Difference Weight	Differences Difference Length
0	69	0.07	0.46	58	-0.17	0.46	0.24	0.00
1	68	0.04	-0.07	58	-0.30	-0.06	0.34	-0.01
2	68	0.24	0.06	56	-0.23	-0.15	0.47	0.21
3	66	0.22	0.11	58	-0.12	-0.32	0.34	0.43
4	69	0.14	0.07	58	-0.06	-0.19	0.20	0.26
5	67	0.23	0.09	57	0.03	-0.02	0.20	0.11
6	69	0.21	0.29	58	0.13	0.04	0.08	0.25
9	69	0.20	0.26	58	0.06	0.07	0.14	0.19
12	67	0.23	0.21	55	-0.01	0.09	0.24	0.12
18	66	0.38	0.26	50	-0.03	0.07	0.41	0.19
24	65	0.39	0.49	47	-0.06	0.15	0.45	0.34

Table 4. Mean weight and length SD-scores of Glasgow children by sex compared with Cambridge data.

Age (months)	Boys n	Boys Mean SD-Score Weight	Boys Mean SD-Score Length	Girls n	Girls Mean SD-Score Weight	Girls Mean SD-Score Length	Differences Difference Weight	Differences Difference Length
1	68	0.24	0.15	58	-0.13	0.06	0.36	0.09
2	68	0.37	0.18	56	-0.13	-0.08	0.51	0.26
3	66	0.34	0.27	58	0.00	-0.21	0.34	0.48
4	69	0.27	0.32	58	0.11	0.07	0.14	0.25
5	67	0.32	0.38	57	0.21	0.20	0.08	0.18
6	69	0.32	0.54	58	0.27	0.25	0.05	0.29
9	69	0.33	0.37	58	0.25	0.25	0.08	0.12
12	67	0.42	0.35	55	0.19	0.32	0.23	0.03
18	66	0.56	0.46	50	0.22	0.49	0.34	-0.03
24	65	0.63	0.71	47	0.19	0.62	0.44	0.09

Table 5. Mean BMI and head circumference SD-scores of Glasgow children by sex compared with 'UK 1990' references.

Age (months)	Boys n	Boys Mean SD-Score BMI	Boys Mean SD-Score Head Circ.	Girls n	Girls Mean SD-Score BMI	Girls Mean SD-Score Head Circ.	Differences Difference BMI	Differences Difference Head Circ.
0	69	0.13	0.43	58	-0.22	0.19	0.35	0.24
1	68	0.22	0.51	58	-0.44	0.37	0.66	0.14
2	68	0.36	0.42	56	-0.42	0.18	0.78	0.24
3	66	0.26	0.22	58	-0.14	0.08	0.40	0.14
4	69	0.22	0.19	58	-0.18	0.08	0.40	0.11
5	67	0.28	0.32	57	-0.19	0.14	0.47	0.18
6	69	0.17	0.37	58	-0.15	0.17	0.32	0.20
9	69	0.24	0.08	58	-0.17	-0.02	0.41	0.10
12	67	0.32	0.02	55	-0.28	-0.10	0.60	0.12
18	66	0.39	-0.06	50	-0.33	-0.27	0.72	0.21
24	65	0.33	-0.10	47	-0.50	-0.31	0.83	0.21

Table 6. Mean BMI SD-scores of Glasgow children by sex compared with 'Revised UK 1990' references.

Age (months)	Boys n	Boys Mean SD-Score	Girls n	Girls Mean SD-Score	Difference
0	69	0.09	58	-0.20	0.29
1	68	0.12	58	-0.32	0.44
2	68	0.22	56	-0.24	0.46
3	66	0.15	58	0.06	0.09
4	69	0.09	58	0.03	0.06
5	67	0.15	57	0.03	0.12
6	69	0.06	58	0.07	-0.01
9	69	0.10	58	0.02	0.08
12	67	0.19	55	-0.08	0.27
18	66	0.22	50	-0.11	0.33
24	65	0.09	47	-0.33	0.42

Table 7. Mean BMI and head circumference SD-scores of Glasgow children by sex compared with Cambridge data.

Age (months)	Boys n	Boys Mean SD-Score BMI	Boys Mean SD-Score Head	Girls n	Girls Mean SD-Score BMI	Girls Mean SD-Score Head	Differences Difference BMI	Differences Difference Head
1	68	0.29	0.28	58	-0.19	-0.18	0.48	0.46
2	68	0.23	0.41	56	-0.23	-0.05	0.46	0.46
3	66	0.25	0.23	58	0.22	0.00	0.03	0.23
4	69	0.18	0.19	58	0.22	0.07	-0.04	0.12
5	67	0.25	0.28	57	0.20	0.13	0.05	0.15
6	69	0.13	0.31	58	0.20	0.15	-0.07	0.16
9	69	0.09	-0.02	58	0.09	-0.08	0.00	0.06
12	67	0.28	-0.06	55	-0.02	-0.20	0.30	0.14
18	66	0.36	0.01	50	-0.05	-0.33	0.41	0.34
24	65	0.24	0.12	47	-0.35	-0.25	0.59	0.37

Table 8. Mean head circumference SD-scores of Glasgow children by sex compared with Gairdner and Pearson references.

Age (months)	Boys n	Boys Mean SD-Score	Girls n	Girls Mean SD-Score	Difference
0	69	0.35	58	0.02	0.33
1	68	0.56	58	0.29	0.27
2	68	0.70	56	0.31	0.39
3	66	0.60	58	0.33	0.27
4	69	0.61	58	0.35	0.26
5	67	0.80	57	0.42	0.38
6	69	0.90	58	0.46	0.44
9	69	0.56	58	0.33	0.23
12	67	0.44	55	0.28	0.16
18	66	0.38	50	0.16	0.22

Table 9. Mean triceps and subscapular skinfolds SD-scores of Glasgow children by sex compared with Tanner and Whitehouse references.

Age (months)	Boys n	Boys Mean SD-Score Triceps	Boys Mean SD-Score Subscapular	Girls n	Girls Mean SD-Score Triceps	Girls Mean SD-Score Subscapular	Differences Difference Triceps	Differences Difference Subscapular
1	68	-0.69	-0.45	58	-1.26	-0.80	0.57	0.35
2	68	-0.98	-0.48	56	-1.54	-1.05	0.56	0.57
3	66	-1.33	-0.73	58	-1.70	-1.10	0.37	0.37
4	69	-1.61	-1.02	58	-1.55	-1.18	-0.06	0.16
5	67	-1.75	-1.01	57	-1.51	-1.21	-0.24	0.20
6	69	-1.70	-1.15	58	-1.64	-1.22	-0.06	0.07
9	69	-1.58	-1.17	58	-1.51	-1.24	-0.07	0.07
12	67	-1.61	-0.88	55	-1.65	-1.08	0.04	0.20
18	66	-1.49	-0.56	50	-1.76	-0.82	0.27	0.26
24	65	-1.36	-0.29	47	-1.51	-0.67	0.15	0.38

Table 10. Mean triceps and subscapular skinfolds SD-scores of Glasgow children by sex compared with Cambridge data.

Age (months)	Boys			Girls			Differences	
	n	Mean SD-Score Triceps	Mean SD-Score Subscapular	n	Mean SD-Score Triceps	Mean SD-Score Subscapular	Difference Triceps	Difference Subscapular
1	68	0.19	0.29	58	0.08	0.19	0.09	0.10
2	68	0.42	-0.02	56	0.22	-0.24	0.20	0.22
3	66	0.55	-0.10	58	0.32	0.07	0.23	-0.17
4	69	0.47	-0.24	58	0.53	0.14	-0.06	-0.30
5	67	0.30	-0.01	57	0.59	0.17	-0.29	-0.18
6	69	0.25	-0.16	58	0.34	0.18	-0.09	-0.24
9	69	0.28	-0.26	58	0.37	-0.05	-0.09	-0.21
12	67	0.13	-0.02	55	0.07	0.03	0.06	-0.05
18	66	0.04	0.27	50	-0.21	0.24	0.25	0.03
24	65	0.25	0.36	47	0.26	0.15	-0.01	0.21

Table 11. Mean MUAC circumference SD-scores of Glasgow children by sex compared with Cambridge data.

Age (months)	Boys		Girls		Difference
	n	Mean SD-Score	n	Mean SD-Score	
1	69	0.30	58	0.10	0.20
2	68	-0.02	58	-0.26	0.24
3	68	-0.04	56	-0.20	0.16
4	66	0.03	58	0.04	-0.01
5	69	0.15	58	0.21	-0.06
6	67	0.20	57	0.26	-0.06
9	69	0.25	58	0.21	0.04
12	69	0.32	58	0.17	0.15
18	67	0.46	55	0.16	0.30
24	66	0.56	50	0.18	0.38

Appendix 10

Appendix 10. Percentages of Glasgow infants below the 10th centile and above the 90th centile compared with reference data.

Table 1. Percentage of Glasgow children falling below the 10th and above the 90th centile for weight compared with Tanner and Whitehouse References.

	< 10th centile		> 90th centile	
Age (months)	Boys	Girls	Boys	Girls
1	1.5***	5.2***	29.4***	25.9***
3	3.0***	6.9	30.3***	19.0
12	4.5	18.2	11.9	9.1
24	4.6	12.8	10.8	8.5

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 2. Percentage of Glasgow children falling below the 10th and above the 90th centile for weight compared with 'UK 1990' References.

	< 10th centile		> 90th centile	
Age (months)	Boys	Girls	Boys	Girls
1	8.8	24.1***	8.8	1.7***
3	4.5	19.0	12.1	6.9
12	4.5	18.2	16.4	10.9
24	3.1*	14.9	18.5*	10.6

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 3. Percentage of Glasgow children falling below the 10th and above the 90th centile for weight compared with 'Revised UK 1990' References.

	< 10th centile		> 90th centile	
Age (months)	Boys	Girls	Boys	Girls
1	8.8	15.5	10.3	1.7
3	6.1	13.8	15.2	3.4
12	6.0	10.9	16.4	9.0
24	3.0	10.6	15.4	10.6

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 4. Percentage of Glasgow children falling below the 10th and above the 90th centile for weight compared with Cambridge data.

	< 10th centile		> 90th centile	
Age (months)	Boys	Girls	Boys	Girls
1	2.9	10.3	11.8	5.2
3	4.5	13.8	15.2	8.6
12	4.5**	10.9*	20.9**	20.0*
24	3.1***	8.5	23.1***	12.8

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 5. Percentage of Glasgow children falling below the 10th and above the 90th centile for length compared with Tanner and Whitehouse References.

	< 10th centile		> 90th centile	
Age (months)	Boys	Girls	Boys	Girls
1	2.9	5.2	14.7	13.8
3	3.0	13.4	12.1	12.1
12	9.0	10.9	9.0	10.9
24	3.1**	6.4	21.5**	10.6

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 6. Percentage of Glasgow children falling below the 10th and above the 90th centile for length compared with 'UK 1990' References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	14.7	15.5	7.4	5.2
3	10.6	19.0*	4.5	3.4*
12	9.0	10.9	14.9	10.9
24	4.6**	8.5	21.5**	12.8

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 7. Percentage of Glasgow children falling below the 10th and above the 90th centile for length compared with 'Revised UK 1990' References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	13.2	12.1	8.8	5.2
3	9.1	15.5	10.6	5.2
12	7.5**	7.3	22.4**	10.9
24	4.6**	4.3	21.5**	10.6

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 8. Percentage of Glasgow children falling below the 10th and above the 90th centile for length compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	8.8	13.8	11.8	10.3
3	6.1	15.5	13.6	6.9
12	4.5**	10.9	20.9**	14.5
24	1.5***	2.1***	29.2***	27.7***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 9. Percentage of Glasgow children falling below the 10th and above the 90th centile for BMI compared with 'UK 1990' References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	2.9	17.2*	5.9	1.7*
3	6.1	15.5	12.1	8.6
12	7.4	21.8*	16.2	9.1*
24	0.0*	25.5**	9.2*	8.5**

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 10. Percentage of Glasgow children falling below the 10th and above the 90th centile for BMI compared with 'Revised UK 1990' References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	2.9**	10.3	4.4**	5.2
3	6.1	6.9	10.6	1.7
12	4.5	12.7	13.4	7.3
24	3.1	17.0	6.2	6.4

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 11. Percentage of Glasgow children falling below the 10th and above the 90th centile for BMI compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	4.4	8.6	4.4	6.9
3	6.1	6.9	9.1	17.2
12	7.5	16.4	13.4	14.5
24	3.1	21.3*	7.7	8.5*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 12. Percentage of Glasgow children falling below the 10th and above the 90th centile for head circumference compared with 'UK 1990' References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	0.0**	3.4**	19.1**	20.7**
3	4.5	6.9	12.1	10.3
12	9.0	9.1	10.4	7.3
24	4.5*	14.9	3.0*	6.4

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 13. Percentage of Glasgow children falling below the 10th and above the 90th centile for head circumference compared with Gairdner and Pearson References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	1.5**	3.4*	20.6**	19.0*
3	1.5*	1.7*	18.2*	19.0*
12	7.5	3.6	17.9	14.5
18	3.0**	7.7	19.7**	7.7

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 14. Percentage of Glasgow children falling below the 10th and above the 90th centile for head circumference compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	2.9*	12.1	19.1*	6.9
3	4.5	12.1	12.1	13.8
12	10.4	10.9	8.9	7.3
24	3.1	12.8	10.8	6.4

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 15. Percentage of Glasgow children falling below the 10th and above the 90th centile for triceps skinfold compared with Tanner and Whitehouse References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	17.6**	51.7***	0.0**	0.0***
3	53.0**	75.9***	0.0**	0.0***
12	73.1***	78.2***	0.0***	0.0***
24	47.7***	59.6***	0.0***	0.0***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ (chi square goodness of fit)

Table 16. Percentage of Glasgow children falling below the 10th and above the 90th centile for triceps skinfold compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	2.9	3.4	5.9	12.1
3	0.0*	0.0*	10.6*	6.9*
12	8.9	6.9	4.5	3.6
24	3.1	10.6	6.2	14.9

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 17. Percentage of Glasgow children falling below the 10th and above the 90th centile for subscapular skinfold compared with Tanner and Whitehouse References.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	14.7*	27.6***	1.5*	0.0***
3	24.2***	36.2***	0.0***	0.0***
12	26.9***	38.2***	0.0***	0.0***
24	9.2*	23.4**	0.0*	2.1**

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 18. Percentage of Glasgow children falling below the 10th and above the 90th centile for subscapular skinfold compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	2.9*	3.4	17.6*	13.8
3	9.1	6.9	3.0	8.6
12	6.0	7.3	4.5	9.1
24	3.1	12.8	7.7	10.6

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)

Table 19. Percentage of Glasgow children falling below the 10th and above the 90th centile for MUAC circumference compared with Cambridge data.

Age (months)	< 10th centile		> 90th centile	
	Boys	Girls	Boys	Girls
1	5.9	5.2	16.2	10.3
3	13.4	17.2	3.0	6.9
12	9.0	12.7	11.9	18.2
18	3.1*	14.9	16.9*	17.0

* p<0.05, **p<0.01, ***p<0.001 (chi square goodness of fit)