INFANT FEEDING AND OBESITY
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Introduction

The association between adult obesity and increased risk of chronic diseases like diabetes and cardiovascular diseases is well known. The observed rapid escalation of overweight and obesity in the past two decades is therefore a cause for great concern. The rising prevalence of childhood obesity is receiving greater attention because of its association with adult obesity and its complications. Increasing consumption of energy-dense diets and reduced physical activity are recognized as major contributing factors. Recent studies suggest that nutritional practices in early life can also influence subsequent obesity, which has now become the focus of interest. This paper reviews the studies on early life risk factors, including birth weight, infant feeding and growth.

Prevalence of childhood obesity

An increasing prevalence of obesity is reported in children and adults in both industrialised and developing countries. Data from National Health and Nutrition surveys in US showed that the prevalence of overweight in children (6-19 yr) was 15.4 % in 1999-2000, as compared to 10.9 % in 1988-94. Similar trends are seen in developing countries that are undergoing rapid economic and epidemiological transition. For example, in Brazil, a fast-growing developing country, the prevalence of overweight and obesity in children (6-14 yr) more than tripled (from 4.1% to 13.9%) between 1975 and 1997. In China, the prevalence of overweight in children of similar age increased from 7.7 % to 12.4 % within a 6-year period (1991-1997). The prevalence rates are higher in urban than in rural populations. Reports from India also indicate a high prevalence of obesity among the affluent urban populations. In Punjab, ~10 % of adolescent children (10-15yr) belonging to affluent families were found to be overweight, and 5-6 % were obese. A recent survey of affluent school children in Delhi showed that 22 % were overweight and 6 % were obese.

The rising prevalence of childhood obesity is of great concern because of its association with adult-onset diseases. Long-term studies show that childhood obesity affects adult morbidity and mortality. Approximately 50% of adolescents with BMI above the 95th percentile become obese adults. Furthermore, the rates of cardiovascular disease and diabetes also increase, and a higher mortality risk from all causes especially cardiovascular disease was demonstrated in men who had been obese during their adolescence. Obesity prevention has now become a global public health priority, but preventive strategies focused on adults or those in their late childhood years have largely been unsuccessful. The focus has now shifted to early-life risk factors, including birth weight, infant feeding and growth.

Birth weight, child growth and adult health

There is mounting evidence that events occurring early in life, even before
birth, can influence health and disease in adulthood later. Maternal nutrition is an important determinant of birth weight, and there is evidence that birth weight can influence child growth and long-term health. A higher maternal BMI in pregnancy is associated with higher birth weight, more rapid growth during childhood, and an increased risk of obesity in adult life. Low birth weight (LBW) is associated with central obesity in adulthood, which confers increased cardiovascular risk. Epidemiological studies by Barker showed an inverse relationship between LBW and coronary heart disease (CHD) decades later. Subsequent studies have shown that LBW also increases the risk of insulin resistance and diabetes. Barker’s group also examined the effect of postnatal growth on disease risk. They surveyed >8000 persons in Finland, whose childhood growth had been carefully recorded. A total of 444 subjects were admitted to hospital with CHD or died of the disease. These individuals had had a relatively small body size in the first two years of life, and grew more rapidly from 2-11 years. This pattern of small body size at birth, low weight gain in infancy and adiposity rebound in childhood was also associated with type 2 diabetes in adult life. Studies in adolescent children showed similar results. LBW and high BMI during childhood were associated with impaired glucose tolerance in Indian children and hypertension in Jamaican adolescents. These findings indicate that interventions to improve foetal growth and to control obesity in childhood are likely to be important factors in the prevention of chronic diseases in later life.

Infant growth and childhood obesity

One issue that remains unresolved is the role of early postnatal growth in the first two years of life. In contrast to Barker’s observations, other studies on full term and premature infants suggest that rapid growth during infancy can result in subsequent obesity. Stettler et al. reported a multi-centre study wherein complete data were available for over 19,000 children from birth to 7 yr. The prevalence of overweight at 7 yr was 5.4%. They found that rapid weight gain during the first 4 months of life was associated with increased risk of overweight status at 7 yr. This association was independent of birth weight and remained significant even after adjustment for several confounding factors.

Baird and colleagues conducted a systematic review of studies on both size and growth in infancy in relation to later obesity. This included 22 cohort and 2 case control studies. Of these, 18 assessed the relationship between infant size and subsequent obesity, most of them showing that infants who were obese, and who were at the highest end of the distribution for weight or BMI were at increased risk of obesity. Ten studies assessed the relation between infant growth and subsequent obesity, and most showed that infants who grew more rapidly were at increased risk of obesity in later life.

Childhood BMI and adult obesity

There are several studies showing that childhood obesity is associated with increased risk of adult obesity. Whitaker et al. investigated the association in over 800 young adults born in Washington State, USA, between 1965 and
1971; 16% of them were overweight, with BMI > 85th percentile. The probability of obesity in adulthood was higher among those who were obese during childhood. After adjustment for parental obesity, the odds ratio for the association ranged from 1.3 for obesity at 1-2 yrs of age to 17.5 for obesity at 15-17 yrs. Thus, the study showed that childhood obesity is an important predictor of adult obesity, regardless of whether the parents are obese.

A Swedish study examined the association between rapid weight gain in early childhood and body composition at the age of 17 yr. It was a prospective cohort study in 248 children. The results showed that increasing weight gain during infancy and early childhood were both independently associated with larger BMI, fat mass and fat-free mass at 17 yr. Thus, rapid weight gain in infancy and in childhood is a risk factor for later adiposity. It is hypothesized that these are different processes and may allow separate opportunities for early intervention against obesity in later life.

Eriksson et al. tracked obesity from early life into adulthood in a birth cohort of approximately 4500 people in Finland. The cumulative incidence of obesity in adults was 33.8%. The incidence increased with increasing body size at birth. Adult obesity was associated with significantly higher weight and BMI at all ages from 6 months to 12 yr. Childhood BMI was a stronger predictor of adult obesity as compared to body size at birth.

**Infant feeding and early growth**

Since early growth is related to feeding pattern, the relationship between infant feeding and obesity has become the focus of interest. WHO recommends exclusive breastfeeding for the first 6 months but many infants are fed commercial infant formula during this period, and follow up studies show that their growth pattern is different from that in breastfed infants. For example, in a longitudinal study of American infants, weight for length was similar in the first two months, but thereafter breastfed infants grew less rapidly as compared to formula-fed infants. There were significant differences in skin fold thickness and percent body fat in later infancy, indicating that breastfed infants were leaner than formula-fed infants even in populations of high socioeconomic status. Several studies have confirmed these growth patterns and led to the development of new WHO growth charts taking the breastfed infant as the normative growth model.

The observed differences in growth patterns of infants may be related to the feeding behaviour, with self regulation of intake being inherent in breastfeeding as against fixed amounts in bottle feeding. Mothers who breastfeed their infants are more responsive to infants’ needs, while formula feeding is highly controlled, with the mother deciding when and how much the child should consume. Mothers who bottle-feed their infants are anxious to see that the bottle is finished, and this often results in overfeeding. Studies measuring the milk intake have shown that the milk volume per feed, as well as total milk consumption in a day, is higher in formula-fed than in breastfed infants. Consequently, energy and protein intakes are also higher, accounting for more rapid weight gain in formula-fed infants. The age at which...
solid foods are introduced can also influence nutritional intakes and growth rates. Whitehead et al. found that bottle-fed infants were introduced to solid foods sooner than were breastfed infants23.

**Infant feeding and childhood obesity**

Growth studies show that weight gain is slower in breastfed infants than in formula-fed ones. There is also evidence that growth rate during infancy can influence subsequent weight gain and BMI. This has led to the hypothesis that breastfeeding protects against obesity, while formula feeding may increase the risk. This raises the question of whether the effect is clinically relevant, and if so what measures can be taken to offer protection for non-breastfed infants.

In recent years, several studies have been published with conflicting data on the relationship between breastfeeding and childhood obesity. Some studies show a protective effect while others find no effect. For example, Bergmann et al. examined 480 children from a longitudinal birth cohort who were breastfed or formula-fed24. By 3 months, formula-fed infants showed higher BMIs and thicker skin folds than breastfed infants did. Significant differences were seen from 6 months onwards. In formula-fed infants, the prevalence of obesity nearly doubled, and then tripled from the age of 4 yr to 6 yr. Thus the study shows that early formula feeding brings on the obesity rebound in early childhood, predictive of obesity in later life. On the other hand, Zive et al. found no association between infant feeding and childhood obesity in 4-yr-old American children25. BMIs and skin fold thickness were not related to any of the infant feeding variables, namely, duration of breast feeding, formula feeding, or the age at which complementary foods were introduced. The main limitation of these studies is the small sample size.

Subsequent studies included large numbers of children. For example, Armstrong et al. conducted a population-based study in a cohort of approximately 32,000 Scottish children26. A health check at 3-4 yr of age showed a significantly lower prevalence of obesity among breastfed infants even after adjusting for confounding effects of socioeconomic status and birth weight. These results suggest that breastfeeding reduces obesity risk in childhood. Von Kries conducted a cross-sectional survey of >9000 German children aged 5-6 yr at the time of entering school27. Their weights were analyzed in relation to data relating to feeding in early life, as obtained from their mothers. Results showed that the prevalence of obesity in children who had been exclusively formula-fed was 4.5% as compared to 2.8% in exclusively breastfed children. There was a clear dose-response effect of breastfeeding. Prevalence of obesity decreased with increasing duration of breastfeeding. Thus the study suggests that prolonged breastfeeding can reduce the risk of obesity in later life.

Other studies have shown variable results. Grummer et al. examined the link between breastfeeding in the first 2 yr of life and weight status at 4 yr of age, using data from the Pediatric Nutrition Surveillance System, covering over 170,000 children28. They found a dose-response relationship between breastfeeding and the risk of overweight only among non-Hispanic whites; but
there was no such significant association in Blacks or Hispanics. Hediger et al. examined data from the National Health and Nutrition Survey of children at 3-5 yr\textsuperscript{29}. The sample included diverse ethnic groups, as in the earlier study. Although breastfeeding appeared to protect against obesity, there was no statistically significant association with duration of breastfeeding. In a longitudinal analysis of an Australian cohort, infants breastfed for 12 months were found to be leaner at that age, but no differences were found at 8 yr of age\textsuperscript{30}. Wadsworth et al. suggest that the observed association between breastfeeding and obesity may be accounted for by social factors associated with breast feeding\textsuperscript{31}.

The effect of breastfeeding can be modified by early dietary factors. For example, a recent study showed that exclusive breastfeeding for 4 months had a protective effect against obesity risk at 7 yr among children who had consistently low fat intake at 12, 18 and 24 months\textsuperscript{32}. This effect was not seen in those with high fat intake in the second year of life. In another study, higher intake of animal protein at 12 months and 5 yr was positively associated with higher body fat percentage at 7 yr\textsuperscript{33}. These results indicate that dietary intakes during childhood are as important as breastfeeding during infancy for preventing obesity.

**Infant feeding and adolescent obesity**

In most of the earlier studies, children were examined up to 6-8 yrs. Others examined obesity in adolescent groups. Gillman et al. analyzed a cohort of approximately 15,000 young adolescents aged 9-14 yr, who were children of women who participated in the Nurses Health Study\textsuperscript{34}. About 85% of them had been breastfed for at least 6 months. After analyzing for a number of confounding factors, they found that infants who were exclusively or mostly breastfed for 6 months had significantly lower risk of obesity than children who were breastfed for a shorter period of 3 months. A school-based study in the Czech Republic found that breastfeeding was associated with a 20% reduction in the risk of obesity up to the age of 14 yr\textsuperscript{35}. Similar observations were made by Tuldahl et al., who measured body composition with dual energy X-rays\textsuperscript{36}. Children who were exclusively breastfed for more than 3 months were leaner than non-breastfed infants. However, others found no consistent relationship between breastfeeding and adolescent measurements\textsuperscript{37,38}. Although breastfed infants tended to be shorter and leaner, the effect was markedly reduced or no longer significant after adjusting for confounding factors.

There are several reasons for the inconsistent results. These include retrospective collection of data, inadequate control of confounding factors, differences in sample size, short duration of breastfeeding and inadequate information on infant feeding practices. For example, both breastfed and non-breastfed infants received additional forms of nutrition, such as cow’s milk or cereal, and the timing of introduction of these foods was not clearly delineated. Furthermore, data were collected over a 40-year time span during which there substantial changes in infant formulas and environmental factors had taken place. These limitations compromise the interpretation of studies relating to the effects of breastfeeding versus formula feeding.
Notwithstanding these limitations, systematic reviews and meta-analysis of published studies suggest that breastfeeding has a small but consistent protective effect against obesity risk in childhood\textsuperscript{39-41}. On the basis of 11 studies, Dewey concluded that breastfeeding reduces the risk of childhood obesity to a moderate extent\textsuperscript{39}. There is an inverse relationship between breastfeeding duration and childhood obesity. An analysis of 9 studies by Arenz\textsuperscript{40} and 17 studies by Harder\textsuperscript{41} confirmed the dose-response association.

The evidence for the protective effect of breastfeeding against obesity comes almost entirely from observational studies, which have a potential for confounding and selection bias. Recently, Kramer \textit{et al.} assessed the effect of breastfeeding in the Promotion of Breastfeeding Intervention Trial (PROBIT), which is a cluster-randomized trial of a breastfeeding promotion intervention based on the WHO/UNICEF Baby-Friendly Hospital Initiative\textsuperscript{42}. Nearly 14,000 infants enrolled at Belarussian maternity hospitals were followed up to the age of 6 yr. The intervention led to a much greater prevalence of exclusive breastfeeding at 3 months in the experimental group than in the control group (43.3\% as compared to 6.4\%) and a higher prevalence of any breastfeeding throughout infancy. But no significant effects of the intervention were observed on height, BMI, skin fold thickness or blood pressure. These results are consistent with those of the recently published meta-analysis conducted by Owen, and they suggest that previously reported beneficial effects on these outcomes may be the result of uncontrolled confounding and selection bias\textsuperscript{43}.

**Infant feeding and adult obesity**

Promotion of breastfeeding has been suggested as a strategy for reducing obesity in adult populations. Although overweight children tend to become obese adults, few studies have directly addressed the relation between infant feeding and adult body weight. In a recent study, Michels \textit{et al.} investigated the association in approximately 36,000 participants in the Nurses Health Study II. The participants were followed prospectively from 1989-2001\textsuperscript{44}. Mothers of participants provided information on the duration of breast- and bottle-feeding, and information on body weight at ages 5, 10 and 18 yr, and the current weight was reported by the participants. The results showed that the duration of breastfeeding was not related to being overweight or obese during adult life. Women who had been exclusively breastfed as infants for more than 6 months had a risk of 0.94 of becoming obese as adults, as compared to those who had not been breastfed as infants. Exclusive breastfeeding for more than 6 months was associated with leaner body shape at age 5 yr as compared to those who were not breastfed, but this association did not persist during adolescence or adulthood. Thus the study shows that breastfeeding is unlikely to play an important role in controlling the obesity epidemic.

**Summary**

There are numerous studies suggesting that breastfeeding offers a protective effect against obesity in childhood. Promotion of breastfeeding has been suggested as a strategy for reducing obesity. Although overweight children
tend to become obese adults, few studies have directly addressed the relationship between infant feeding and adult body weight, and the results of research are variable. This may be due to retrospective collection of data, inadequate information on feeding practices and inadequate control of confounding factors. An alternative explanation may be that infant feeding and weaning practices exert a relatively greater influence on adiposity in early childhood, but that thereafter, genetic and environmental factors play a larger role in determining obesity. These include dietary habits and physical activity, which are known to influence BMI and body composition throughout life. Regardless of its role in preventing obesity, breastfeeding has many advantages for the mother and child, and its continued promotion and support remains a public health priority. However, promotion of breastfeeding is unlikely to have much impact on the current obesity epidemic, unless additional measures are taken to promote healthy diets and active life styles.

References


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