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Breast development and control of milk synthesis

Constituents of human milk

Problems of establishing lactation

Social and biological determinants of lactation

Breastfeeding and the suppression of fertility

Demographic effects of breastfeeding

Effects of breastfeeding on maternal health

Protective effect of breastmilk against infection

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Early weaning and infection

Breastfeeding and child development

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Editorial policy

The *Food and Nutrition Bulletin* is intended to make available policy analyses, state-of-the-art summaries, and original scientific articles relating to multidisciplinary efforts to alleviate the problems of hunger and malnutrition in the developing world. It is not intended for the publication of scientific articles of principal interest only to individuals in a single discipline or within a single country or region. Notices of relevant books and other publications will be published if they are received for review. The *Bulletin* is also a vehicle for notices of forthcoming international meetings that satisfy the above criteria and for summaries of such meetings.

The *Food and Nutrition Bulletin* also serves as the principal outlet for the publication of reports of working groups and other activities of the UN ACC Sub-committee on Nutrition (SCN) and its Advisory Group on Nutrition. The SCN itself is a focal point for coordinating activities of FAO, WHO, UNICEF, the UNU, UNESCO, the World Bank, the World Food Programme, the World Food Council, the United Nations Environment Programme, and other bodies of the United Nations system that have an interest in food and nutrition.

Submissions. Unsolicited manuscripts of articles of the type published in this and previous issues may be sent to the editor at the Boston office address given above. *They must be typed, double-spaced, with complete references and must include original copy for any figures used* (see the "Note for contributors" in the back of this issue).

Any disciplinary or conceptual approach relevant to problems of world hunger and malnutrition is welcome, and controversy over some of the articles is anticipated. Letters to the editor are encouraged and will be printed if judged to have an adequate basis and to be of sufficient general interest.

Peer review. The *Bulletin* is a peer-reviewed journal. Every article submitted first receives editorial review. If it is consistent with the editorial policy and is not obviously deficient in some way, it is sent to two or sometimes three experienced and knowledgeable reviewers. Occasionally a paper may be returned to the authors by the editor with suggestions for improvement before it is submitted to the reviewers.

If two reviewers agree that the paper should be published in the *Bulletin*, it is accepted and either sent immediately for copy-editing or returned to the authors for consideration of suggestions from the reviewers and the editor. If both reviewers agree that the paper should not be accepted, the editor writes a personal letter to the authors explaining the reason and enclosing the comments of the reviewers anonymously. If the reviewers do not agree with each other, either the paper is sent to a third reviewer or a decision is taken by the editor. In these cases, the authors are usually given a chance to respond to the reviewers' comments.

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Foreword

Recognizing the nutritional and immunologic benefits of breastfeeding to infants and the health benefits of lactation to mothers, the Pontifical Academy of Sciences and The Royal Society co-sponsored a Working Group that met in Vatican City 11–13 May 1995. The meeting brought together a multidisciplinary group of scientists engaged in social and biological research and in the clinical study of lactation. The purpose of the meeting was to create a forum for the presentation of accumulated research and to conduct a high-level scientific discussion of its implications. The *Food and Nutrition Bulletin* has provided the opportunity to publish the papers and the discussions, thereby making them available to a wider audience. We are profoundly grateful to the publishers for their cooperation, assistance, and patience in preparing the manuscripts.

We are grateful to the participants for their studies and their work in preparing their presentations. The papers and discussions address available scientific data in a competent and objective fashion. They do not represent the official teaching of the Roman Catholic Church or the moral and pastoral application of that teaching. Nor do they represent the official positions of The Royal Society or the policies of the United Kingdom. The workshop's aim was a comprehensive overview that met the highest scientific standards. We are confident it will be of great value to scholars, clinicians, and all others who work daily to enrich the lives of mothers and infants.

Msgr. Renato Dardozzi
Pontifical Academy of Sciences

PONTIFICIA ACADEMIA SCIENTIARUM

Dr. Ann McLaren
The Royal Society

The Royal Society

Solemn Papal Audience

On the morning of 12 May 1995, His Holiness John Paul II granted a Solemn Audience in the Apostolic Palace of the Vatican to the participants in the Working Group on "Breastfeeding: Science and Society."

The group, introduced by His Excellency Msgr. James T. McHugh, Bishop of Camden, New Jersey, USA, was paternally received by the Holy Father, who at the end of the Audience greeted all the participants.

The Holy Father pronounced the following discourse:

Your Eminences,
Your Excellencies,
Ladies and Gentlemen,

1. As always, it is a great pleasure to meet the distinguished participants in the study sessions organized by the Pontifical Academy of Sciences, and I thank Bishop James McHugh for his kind words of introduction. Today I am especially happy to extend my appreciation to The Royal Society, which has cosponsored this significant meeting.

True to its purpose and statutes, the Pontifical Academy of Sciences addresses itself to a wide range of scientific, social, and ethical issues which have a bearing on the Church's service to the human family, a service which springs from the fundamental Gospel commandment of love. The Academy plays a resourceful role in helping the Church, in particular the Holy See, to fulfil this task of service with the benefit of the most expert scientific knowledge and insights. Your studies and enquiries contribute to the Church's supreme effort to journey hand in hand with humanity on its path through temporal realities towards man's great and inexorable transcendent destiny.

2. On this occasion you have been invited to share your expertise on the specific subject of "Breastfeeding: Science and Society," as a part of the overall study which the Academy has been pursuing since 1990 on Population and Resources. As scientists you direct your enquiry towards a better understanding of the advantages of breastfeeding for the infant and for the mother. As your Working Group can confirm, in normal circumstances these include two major benefits to the child: protection against disease and proper nourishment. Moreover, in addition to these immunological and nutritional effects, this natural way of feeding can create a bond of love and security between mother and child, and enable the child to assert its presence as a person through interaction with the mother.

All of this is obviously a matter of immediate concern to countless women and children, and something which clearly has general importance for every society, rich or poor. One hopes that your studies will serve to heighten public awareness of how much this natural activity benefits the child and helps to create the closeness and maternal bonding so necessary for healthy child development. So human and natural is this bond that the Psalms use the image of the infant at its mother's breast as a picture of God's care for man [1]. So vital is this interaction between mother and child that my predecessor Pope Pius XII urged Catholic mothers, if at all possible, to nourish their children themselves [2]. From various perspectives, therefore, the theme is of interest to the Church, called as she is to concern herself with the sanctity of life and of the family.

3. Worldwide surveys indicate that two-thirds of mothers still breastfeed, at least to some extent. But statistics also show that there has been a fall in the number of women who nourish their infants in this way, not only in developed countries where the practice almost has to be reinstituted, but also increasingly in developing countries. This decline is traced to a combination of social factors such as urbanization and the increasing demands placed on women, to health-care policies and practices, and to marketing strategies for alternative forms of nourishment.

Yet the overwhelming body of research is in favour of natural feeding rather than its substitutes.

Responsible international agencies are calling on governments to ensure that women are enabled to breastfeed their children for four to six months from birth and to continue this practice, supplemented by other appropriate foods, up to the second year of life or beyond [3]. Your meeting therefore intends to illustrate the scientific bases for encouraging social policies and employment conditions which allow mothers to do this.

In practical terms, what we are saying is that mothers need time, information, and support. So much is expected of women in many societies that time to devote to breastfeeding and early care is not always available. Unlike other modes of feeding, no one can substitute for the mother in this natural activity. Likewise, women have a right to be informed truthfully about the advantages of this practice, as also about the diffieulties involved in some cases. Health-care professionals too should be encouraged and properly trained to help women in these matters.

4. In the recent Encyclical *Evangelium vitae* I wrote that "A family policy must be the basis and driving force of all social policies ... It is also neeessary to rethink labour, urban, residential, and social service policies so as to harmonize working schedules with time available for the family, so that it becomes effectively possible to take care of children and the elderly" [4].

Is this a vague utopia, or is it the obligatory path to the genuine well-being of society? Even this brief reflection on the very individual and private act of a mother feeding her infant can lead us to a deep and far-ranging critical rethinking of certain social and economic presuppositions, the negative human and moral consequences of which are becoming more and more difficult to ignore. Certainly, a radical reexamination of many aspects of prevailing socioeconomic patterns of work, economic competitiveness, and lack of attention to the needs of the family is urgently necessary.

5. I am therefore very grateful to all of you for offering your time and eo-operation to this meeting co-sponsored by the Pontifical Academy of Sciences and The Royal Society. I look forward to the synthesis and report of your findings so that this information may be widely circulated to our Church agencies and interested institutions throughout the world. I pray for the success of your research and for your own personal well-being. May God's blessings of strength, joy, and peace be with each one of you and the members of your families.

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Address to the Holy Father

At the Solemn Audience granted to the Working Group participants on 12 May 1995, His Excellency Msgr. James T. McHugh, Bishop of Camden, NJ, USA, delivered the following address:

Most Holy Father,

I am pleased to present to you the participants in the Working Group on "Breastfeeding: Science and Society." The meeting of this Working Group is co-sponsored by the Pontifical Academy of Sciences and The Royal Society of London. The persons taking part in this meeting are physicians and scientists who are engaged in scientific research and who have accumulated much important data on the advantages of breastfeeding for both mother and child.

There is considerable evidence that breastfeeding provides proper nutrition for children and also protects the child against life-threatening infections in the earliest years of life. The mother also benefits by knowing that she is providing good nourishment and research shows that breastfeeding is associated with a reduction in the risk of breast cancer. The return of ovulation is inhibited in the fully breastfeeding woman, at least during the first six months after birth, thereby providing important health benefits to the family because of improved birth spacing.

We are now coming to a better understanding of the nutritional components of human milk and of the receptivity and response on the part of the child. The efforts of our participants are directed towards enabling women to initiate and sustain breastfeeding and enabling infants to benefit fully. The research papers and the discussions within our Working Group are a valuable contribution.

Unfortunately there are many factors that discourage or inhibit women from this important practice. In developed countries the rapid pace of life and time demands on women are obstacles. Absence of stable family life and familial support affects many women. Employment patterns, the work environment, and the absence of sufficient maternal leave time create difficulties.

In developing countries where breastfeeding has been a more common practice, urbanization, work outside the home, and other aspects of modernization tend to diminish the practice of breastfeeding. It is important to protect and strengthen the cultural support for breastfeeding practices within the family.

Our Working Group has also recognized that although breastfeeding primarily involves mother and child, there is also an important role for fathers. Every element of child care is a mutual responsibility and commitment of both parents. The father should be particularly sensitive to the physical demands placed on the mother and assist her in obtaining proper nutrition and rest. The father should give approval and encouragement to help the mother sustain the practice. Every woman should be supported in every aspect of her motherhood, by her family and by society.

Our Working Group is pleased with this opportunity to present and review the important research data. We are grateful to be able to meet with you, Holy Father, and we ask your blessing and your prayers.

Breast development and control of milk synthesis

Peter E. Hartmann, Robyn A. Owens, David B. Cox, and Jacqueline C. Kent

Abstract

We have developed a computerized breast measurement system that can quantitate both long-term (lactation cycle) and short-term (between breastfeedings) changes in breast volume. The increase in breast volume during pregnancy was not related to milk production at one month of lactation, whereas milk production from one to six months of lactation remained constant and was not controlled directly by the suckling-evoked secretion of prolactin. From the measurement of circadian changes in breast volume, it was concluded that infants rarely emptied the breasts at a single breastfeeding and that short-term variation in the rate of synthesis during the day and between the left and right breasts was closely related to the degree of breast fullness. Furthermore, differences between women in the storage capacity of the breasts dictated their flexibility in frequency of breastfeeding. These observations are consistent with the autocrine (local) control of milk synthesis during established lactation in women.

Introduction

Breastfeeding and breastmilk must be considered in the context of maternal physiology and infant development rather than just the narrow role of optimizing infant nutrition (table 1). The lactating breast has a high metabolic activity. Indeed, the energy output in milk represents approximately 25% of the total energy intake in the maternal diet for women exclusively breastfeeding single infants, and up to 50% for those breastfeeding twins [1]. In addition, milk is a very complex secretion, consisting of cells (leucocytes, macrophages, and epithelial cells), lipids (triacylglycerols, free fatty acids, phospholipids, sterols, hydrocarbons, and fat-soluble vitamins), carbohydrates (lactose, oligosaccharides, galactose, glucose, and glycoproteins), proteins (caseins, α-lactalbumin, lactoferrin, secretory IgA and other immunoglobulins, lysozyme, enzymes, hormones, and growth factors), non-protein nitrogenous compounds (urea, creatine, creatinine, uric acid, amino acids including glutamine, nucleic acids, nucleotides, and polyamines), water-soluble vitamins, macronutrient elements, and trace elements [2, 3]. Furthermore, it is now clear that the proportions of these constituents in breastmilk are uniquely appropriate for the human neonate at a time when growth and development are occurring at near-maximal rates, yet many of the infant's systems (such as the digestive, hepatic, immune, neural, renal, and skeletal systems) are functionally immature. In addition, breastfeeding is an integral component of the complex psychological and metabolic dependencies of the infant on its mother, with single physical functions, such as nursing, providing the stimuli of touch, balance, smell, hearing, and vision, and each having specific effects on the infant [4]. Nevertheless, the magnitude of these benefits of human lactation, by and large, has not been afforded appropriate prominence in either health-professional education or the specialist's medical literature (for example, ref. 5).

Successful lactation requires the development of fully functional mammary glands. Whereas other major organs are morphologically and functionally relatively mature at birth, the mammary gland undergoes very limited structural development *in utero*, with the most dramatic changes in women occurring during puberty, pregnancy, lactation, and weaning [6]. The latter three stages (pregnancy, lactation, and involution during and after weaning) form the phases of the lactation cycle (fig. 1). This cycle can vary greatly in length from a little over nine months

Peter Hartmann, David Cox, and Jacqueline Kent are with the Department of Biochemistry and Robyn Owens is with the Department of Computer Science at the University of Western Australia in Nedlands, Australia.

TABLE 1. Functions attributed to breastfeeding and breastmilk

Breastfeeding and the infant
a unique food
augments the infant's digestive enzymes
stimulates growth and development
may modulate behaviour
optimizes infant intelligence
protects against illness
Breastfeeding and the mother
reduces risk of breast cancer
may reduce body weight
suppresses maternal fertility

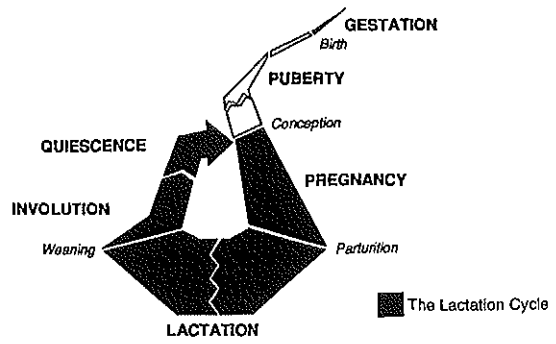

FIG. 1. Breast development and the lactation cycle

to many years, and it may be repeated many times, depending on female fecundity.

Foetal development

A comprehensive investigation of the foetal development of the human mammary gland was carried out by Dawson in 1934 [7]. It was observed that a mammary band (milk streak) appeared as a raised portion of ectoderm on either side of the midline, extending from the axilla to the groin of the human embryo by about the fourth week of intrauterine life. This band contains a narrow ribbon of raised epithelial cells known as the milk line (mammary ridge). Whereas the mammary band generally disappears, the milk line diminishes in length from its caudal end, and the cranial extremity thickens into a small nodule of ectodermal cells in the thoracic region at about 6 to 7 weeks of age. The nodule composed of epidermal cells then sinks into the underlying mesenchymal tissue to form a mammary bud. By 12 to 16 weeks, the overlying skin no longer protrudes, allowing the formation of an indentation that ultimately forms the areola and nipple. From this time to birth, the mammary gland anlage buds to form a number of solid cords, which traverse the underlying mesenchymal and subcutaneous tissue. These cords branch and become canalized to become ducts at 20 to 24 weeks after conception. At the end of gestation, Russo and Russo [6] observed the development of very primitive lobular structures composed of ducts ending in short ductules, lined by one layer of epithelial cells and one layer of myoepithelial cells. The epithelial cells had fine cytoplasmic vacuolization containing lipid droplets and apocrine secretion, which was not confined to the primitive alveolar structures.

Although the endocrine control of foetal mammary gland development is poorly understood, the higher levels of androgen in male than in female foetal rats have been associated with the suppression of mammary development in the male foetus, and the administration of steroid hormones to pregnant mice and rats can induce abnormal mammary development in their offspring (see ref. 8). These findings strongly suggest that more attention should be given to the foetal environment as a potential cause of subsequent lactation failure.

Pre-pubertal development

"Witches' milk" is one of the very few pre-scientific terms still in current use and refers to colostrum-like fluid [9, 10] that is secreted from the nipples of newborn infants. It was thought that infants secreting this "milk" were possessed by witches, and these infants were not favoured. It is now clear, however, that this is a normal transient event, as secretion can be expressed from the nipples of most infants by seven days after birth, and involution of the neonatal mammary gland is complete by eight weeks post-partum [10]. Throughout childhood, only isometric growth of the breast occurs, with limited elongation and branching of the ducts [7].

Pubertal development

In humans, unlike other mammals, extensive positive allometric growth of the breast occurs at puberty. From 10 to 12 years of age, girls enter puberty and, over time, develop to sexual maturity. Three phases of puberty have been identified: thelarche (commencement of breast development), pubarche (growth of pubic hair), and menarche (start of menstruation).

At thelarche, the ovaries of the immature female start to secrete oestrogen, which initiates positive allometric growth of the primitive mammary structures. The mammary ducts elongate and extend their epithelial lining, branching dichotomously, resulting in the formation of a branched, treelike structure that extends from the nipple into the mammary con-

nective tissue. In addition, terminal buds form on the ducts in preparation for the development of alveolar and lobular tissue structures.

During thelarche, mammary elasticity, vascularization, connective tissue volume, and fat deposition increase [6], leading to the development of the characteristic shape of the mature human breast [11]. Compared with other mammals, mammary growth in pubescent girls is far in excess of the development required for subsequent successful lactation, and therefore it has been suggested that this growth is not related to lactation but rather provides an indicator of sexual maturity.

During puberty there is accelerated growth of the nipple and development of subareolar tissue leading to the elevation of the areola and nipple. About 15 to 25 lactiferous ducts lead to each nipple from discrete lobes within the mammary parenchymatous tissue. These lactiferous ducts may merge within the nipple so that the number of ductal openings is less than the number of lactiferous ducts. The lactiferous ducts dilate at the base of the nipple to form milk sinuses, which, during lactation, accumulate milk drained from the lobes. Unlike other mammals, the lobes of the human mammary gland are separated by deposits of adipose tissue, and the proportion of adipose to secretory tissue varies between individuals. Each lobe is subdivided into lobules that, in turn, are composed of 10 to 100 alveoli. The alveoli are lined with a single layer of lactocytes (mammary secretory epithelial cells) surrounded by starlike myoepithelial cells, a basement membrane, and a network of blood capillaries [9, 12].

Under the cyclic influence of ovarian oestrogen and corpus luteal progesterone, as well as the presence of other metabolic and growth-promoting hormones [8, 12], the mammary glands are stimulated to grow. From three to four days before the onset of menstruation, women may experience swelling, tension, fullness, tightness, heaviness, and pain in their breasts [9]. Fluid retention in the connective tissue and enhanced ductular and lobulo-alveolar tissue growth increase breast volume by 30 ml [6, 9] to 100 ml [13]. Increases up to a doubling of breast size have been observed in some women. After menstruation the mammary gland is characterized by some apoptosis, with minimum breast volume occurring five to seven days post-menstrum [6]. Mammary involution following menstruation never completely returns the mammary gland back to the previous premenstrual morphology and, hence, allows the mammary parenchyma to develop, albeit gradually, during successive menstrual cycles [6] until women reach about 30 years of age. In spite of the functional responsiveness of the breast to stimulation [12], little information is available on breast development in relation to the commencement of sexual activity.

Lactation cycle

The lactation cycle begins at conception (fig. 1). During the lactation cycle, there is further growth of the breast (mammogenesis), the initiation of milk synthesis and secretion (lactogenesis 1 and lactogenesis 2), lactation (galactopoiesis), regression of the breast during and after weaning (involution), and relative quiescence during subsequent menstrual cycles.

Mammogenesis

The mammary gland develops the histologic and biochemical capacity to synthesize and secrete milk during pregnancy. Histologic studies have separated mammary development during pregnancy into two distinct phases: mammogenesis and lactogenesis 1. Mammogenesis occurs from early pregnancy and is characterized by proliferation of the distal elements of the ductal tree, creating multiple alveoli (acini) of variable size and shape [14]. Lactogenesis 1 occurs in the later stages of pregnancy and is characterized by the differentiation of resting mammary cells into lactocytes, with the potential to secrete the unique fats, carbohydrates, and proteins characteristic of milk [15].

Initially, mammary development during pregnancy appears to be an acceleration of the parenchymal hypertrophy associated with the menstrual cycle. Indeed, an increase in the sensitivity and tenderness of the breast, and nipple sensitivity in particular, is often one of the first indications of pregnancy, and this can occur within a few days of conception and before the due date of the next menstrual period. Thus, the factors initiating mammogenesis at this time must be closely related to those responsible for the mother's recognition of her pregnancy. Subsequently, the subcutaneous veins become enlarged and visible through the skin, and the areola usually enlarges and becomes more darkly pigmented [14]. Extensive lobulo-alveolar growth occurs during the first half of pregnancy, and in the third trimester there is a further increase in lobular size associated with hypertrophy of the lactocytes and the accumulation of secretion in the lumina of the alveoli [6].

Although there is little precise information on the hormonal control of mammary development in women during pregnancy, the changes in the patterns of circulating hormones are now well established. The implantation of the blastocyst in the uterine wall is associated with the secretion of human

chorionic gonadotrophin (hCG), which maintains and increases the steroidogenic activity of the corpus luteum, until hCG secretion decreases at about 8 to 10 weeks of gestation. In the later stages of pregnancy, the maternal serum concentrations of progesterone and oestrogens are increased by *de novo* synthesis in the placenta [16].

In classical studies on ovariectomized-hypophysectomized-adrenalectomized rats and mice, Lyons [17] and others have shown that ductal mammogenesis is promoted by oestrogens, growth hormone, and corticosteroids. In addition, lobulo-alveolar development occurred at maximal rates in the presence of oestrogen, progesterone, prolactin, growth hormone, corticosteroids, and placental lactogen. Studies on isolated human mammary tissue in culture suggest that insulin, cortisol, growth hormone, prolactin, oestrogens, progesterone, and epidermal growth factor (EGF) are involved in the proliferation and differentiation of human mammary cells in tissue culture [18–22]. Relaxin has been implicated in the proliferation of porcine mammary parenchyma [23]. The action of oestrogen and progesterone on mammary parenchyma leads to the secretion of EGF and transforming growth factor-α (TGF-α), both of which are potent mammary mitogens [22]. In contrast, TGF-β_1 inhibits mammary growth [22, 24, 25]. These studies imply that the development of the human mammary gland during pregnancy is controlled by a complex sequence of stimuli and inhibition similar to the hormonal mechanisms that control the growth and development of the mammary glands of common laboratory animals.

Hytten [26] used a water-displacement technique to measure the volnme of the left breast of 11 women at three months of gestation and seven days post-partum. In 10 women breast volume increased by 60 to 480 ml, and in one woman the volume decreased by 20 ml. The relationship, however, between breast volume at the end of pregnancy and the volume of the "empty" breast on the seventh post-partum day is unknown. We [27] have developed a computerized breast measnrement (CBM) system that uses video images of structured light stripes projected onto the breast to quantitate both long-term (throughout the lactation cycle) and short-term (during the day) changes in breast volume (figs. 1 and 2). Preliminary findings for breast development (fig. 3) from pre-conception until just before delivery [28] have demonstrated that significant growth can occur during the first trimester and that this growth can either continue throughout pregnancy or reach a plateau during the second trimester. The six mothers studied to date have had a successful lactation outcome irrespective of their pattern of breast growth during pregnancy.

Lactogenesis 1

The timing of lactogenesis 1 (development of potentially functional lactocytes) in women has not been precisely defined. In mid-pregnancy the true lobulo-alveolar system develops, the proliferative changes are reduced, and there is increasing cellular differentiation with the accumulation of cellular organelles and secretory products [6, 15, 29]. Lactose is the most osmotically active component of the colostrum, and hence excess lactose synthesis during pregnancy could lead to breast distension. Nevertheless, the tight junctions between the lactocytes are open during pregnancy, and thus lactose can escape across the mammary epithelium into the bloodstream and then be excreted in the urine. The concentration of lactose in the blood of pregnant women increases during mid-pregnancy [30], and this coincides with an increase in the excretion of lactose in the urine [28, 31]. These findings suggest that in women lactogenesis 1 occurs approximately halfway through pregnancy. Studies using an increase in the concentration of lactose in the blood or mammary secretion as an indicator of the occurrence of lactogenesis 1 have suggested that lactogenesis 1 occurs at different stages of pregnancy in different species. Whereas lactogenesis 1 occurs in late pregnancy in rats [32], ewes [33], and sows [34, 35], it occurs earlier in pregnancy in cows [36], goats [37], and women [30]. These species differences in the timing of lactogenesis 1 during pregnancy make it difficult to speculate on the control of the development of the functional lactocyte. A greater knowledge of the control of mammogenesis and lactogenesis 1 in women is important not only for the understanding of normal lactation, but also because early pregnancy [13] and lactation [38] have been associated with a reduced risk of breast cancer.

Lactogenesis 2

Whereas the umbilical cord couples the developing foetus to continuous life support from its mother's placenta, nursing after birth provides the growing infant with comparable but intermittent life support from its mother's breasts. Thus, it is essential for the breast to develop its unique synthetic capacity during pregnancy, so that the initiation of an adequate supply of milk accompanies the birth of the infant. The occurrence of lactogenesis 1 halfway through pregnancy in women permits lactogenesis 2 to occur, even if the infant is delivered prematurely, although the milk composition is different from that of full-term mothers, possibly because of incomplete hypertrophy of the mammary gland or incomplete exposure to prolactin and other hormones [39].

In women the control of lactogenesis 2 (the initia-

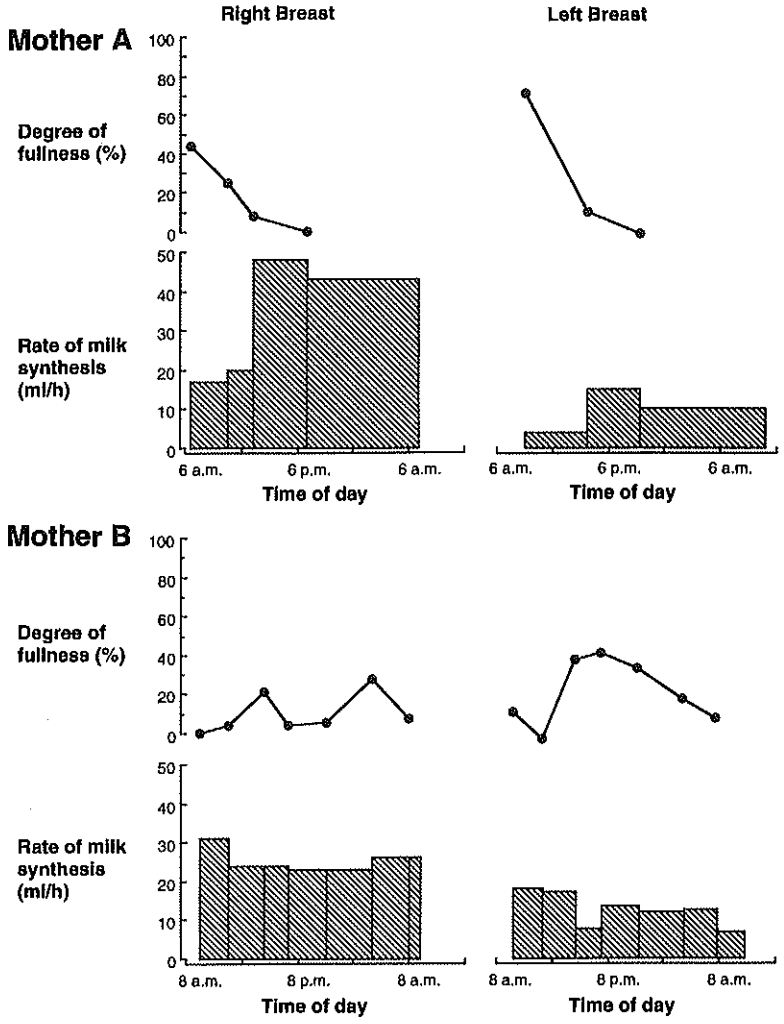

FIG. 2. Computerized breast measurement system assessment of function for right and left breasts of two mothers (A and B) over 24-hour periods. The degree of fullness is the volume of the breast at the end of a breastfeeding minus the minimum volume of the breast during the 24-hour period, divided by the storage capacity of the breast, expressed as a percentage. The rate of milk synthesis is calculated from the difference between the breast volume at the end of a breastfeeding and the breast volume just before the beginning of the next breastfeeding, divided by the time between the measurements [60]

tion of copious milk secretion) appears to be under endocrine regulation similar to that in other mammals. The pioneering work of Kuhn [40] established that progesterone withdrawal was the trigger for lactogenesis 2 in the rat, and subsequently Nicholas and Hartmann [32] established the temporal relationship between the withdrawal of progesterone approximately 24 hours before parturition and the increased rate of lactose synthesis (a measure of lactogenesis 2) coinciding with birth. This pattern appears to bc consistent for most mammals studied to date.

In women, however, progesterone withdrawal is delayed until after the delivery of the placenta; thus, there is a frame shift to the post-partum period in the close temporal relationship between the fall in progesterone and the increase in the concentration of lactose in the colostrum [41]. Lactogenesis 2 is delayed by more than a day to between 30 and 40 hours post-partum (fig. 4). Although this delay may seem inconsistent with the perceived energy requirements of the human infant, it is consistent with the acquisition of mucous membrane protection from maternal colostrum, as well as the remarkable resilience of the human neonate to nutritional abuse and the unusual weight loss in human infants after birth.

Lactogenesis 2 also occurs 30 to 40 hours after de-

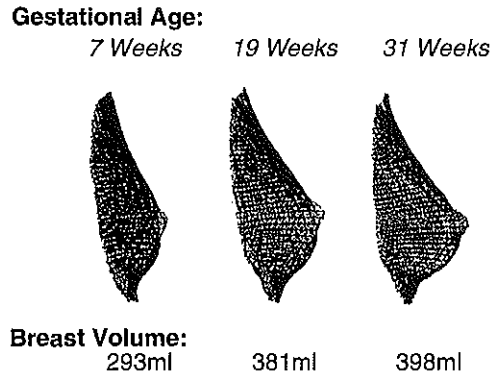

FIG. 3. The development of the left breast of one mother depicted by models generated using the computerized breast measurement system

livery in mothers who have had a Caesarean section [42], since the timing of placenta removal in relation to birth is the same as in those who delivered normally. This is fortunate for human lactation, as Caesarean section delivery in other species, such as ewes, results in a delay in lactogenesis 2 of more than a day when compared with normal delivery [33].

The involvement of the placenta in the initiation of lactation has been further substantiated by the finding that if a fragment of placenta is retained after delivery, lactogenesis 2 occurs only after its removal [43]. These observations also are consistent with progesterone withdrawal acting as the trigger for lactogenesis 2 in women, as it does in other mammals.

Although lactogenesis 2 in women does not require either the suckling stimulus or milk removal [44], it does require the presence of adequate concentrations of lactogenic hormones. The concentration of prolactin in a woman's blood is high at parturition, and suppression of prolactin secretion by the administration of bromocriptine results in the inhibition of lactogenesis 2 [44]. Nevertheless, undesirable side-effects and the potential role of prolactin in facilitating maternal behaviour have cautioned against the use of this drug for the suppression of lactation in women who choose not to breastfeed.

Close assessment of the initiation of lactation in mothers with type I diabetes shows that the increase in the concentration of lactose in the colostrum is delayed by about 24 hours compared with normal mothers [45–47]. Since this delay coincides with the reduction in insulin therapy after birth and the re-establishment of control of glucose homeostasis, permissive amounts of insulin also may be required for lactogenesis 2. Notwithstanding this delay, diabetic women with perseverance can establish successful lactation.

Milk "coming in," which is sensed by mothers as a sudden enlargement of their breasts with milk, is a post-lactogenesis 2 event occurring two to three days after delivery [42]. The physiological significance of the sensation of milk coming in is not clear, but it may represent the time when the mother's capacity to synthesize milk first exceeds the infant's appetite. That is, it may represent the transition from an endocrine-promoted lactogenesis 2 to another form of control during established lactation. Despite these considerations, severe engorgement can be associated with milk coming in, and this is a very painful event of short duration but long remembered by mothers. The risk of severe engorgement is reduced if mothers avoid timed schedules for breastfeeding and fully breastfeed their babies to appetite, day and night, from birth. The implications for lactogenesis 2 and milk coming in are important when considering the design of programmes for the early discharge of mothers from maternity hospitals [48].

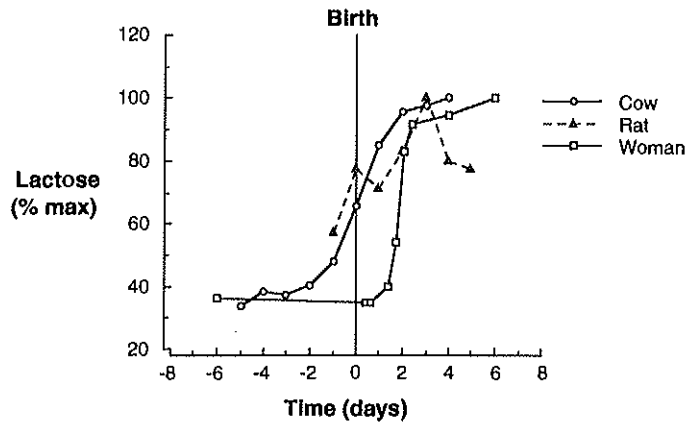

FIG. 4. Peripartum milk lactose expressed as a percentage of the maximum lactose concentration for the cow, rat, and woman

Galactopoiesis

The maintenance of galactopoiesis appears to be under a combination of endocrine, autocrine (local), and metabolic control, which varies according to the species and the stage of lactation. The relative importance of these mechanisms, however, depends on whether the species has been selected for dairy production. Nevertheless, the removal of milk from the mammary gland is of the utmost importance for the maintenance of milk secretion in all mammals. In women, frequent suckling not only stimulates the release of oxytocin and thereby elicits milk ejection, but also stimulates the release of prolactin [49] and results in the removal, inactivation, or both of local inhibitory factors [50].

The finding in the early 1970s that the sucking stimulus evoked the release of prolactin [49] provided a potential explanation for the regulation of milk synthesis. We have not, however, found any relation between the suckling-evoked release of prolactin and milk yield. Although the prolactin response decreases in later stages of lactation, there is no decrease in milk yield [28]. Therefore, the concept that demand feeding regulates the rate of milk synthesis by evoking the release of prolactin must be seriously questioned.

About 20 years ago, it was generally accepted that the nutrition of the mother was the most important determinant of milk synthesis. This assumption was based on numerous studies demonstrating the dependence of milk production on the level of nutrition in dairy cows and goats. As a result, it was concluded that feeding the malnourished mother would thereby feed the child [51]. Nevertheless, subsequent studies by Prentice et al. [52] have shown that improving the nutritional status of malnourished mothers does not increase milk production. This, together with extensive studies on milk production in women from both developing and developed countries, has led to the conclusion that maternal nutrition is not an important determinant of milk production in women (see ref. 53).

The demand-fed infant consumes irregular quantities of milk at irregular intervals during the day [53]. These feeding patterns also are consistent with mothers' awareness [54] and with recent studies that indicate that it is the baby's appetite that determines milk yield [53]. Indeed, a comprehensive consideration of the literature leads to the conclusion that ensuring that the infant has sufficient access to the breast to satisfy its appetite for milk optimizes milk production. The basic question, however, remains: How does the breast regulate milk synthesis to meet this unpredictable external demand for milk by the infant?

In 1984 Neil Matterson [55] provided a practical answer to this question: "The more he cries the less milk he drinks, so less milk is produced, so there's less for him to drink, so he cries because he didn't get a drink. Do you understand that?" Perhaps this confusing explanation of the control of milk synthesis uuderlies epidemiologic results showing that many mothers give up breastfeeding in the belief that they cannot produce enough milk for their babies [56].

A prerequisite for investigating the control of milk synthesis during galactopoiesis in any suckling mammal is to measure the rate of milk synthesis accurately. The classical means of determining the daily rate of milk synthesis in women has been the "weigh-suckle-weigh" or "test-weighing" method [57], which conventionally records the combined milk output from both breasts and sums the milk consumed during all breastfeedings over a period of 24 hours. If correction is made for evaporative water loss during each breastfeeding, test weighing is a very accurate method of determining milk transfer between the mother and her infant [58]. But neither test weighing nor alternative methods of measuring milk production [59] measure the short-term (between breastfeedings) rates of milk synthesis in individual breasts.

Our CBM system measures the short-term rates of milk synthesis in women by determining the rate of increase in breast volume between breastfeedings [27]. We installed the CBM system in the homes of seven mothers so that we could measure their milk production and changes in breast volume while they breastfed on demand in their normal environment. In addition to the short-term rate of milk synthesis, we were able to calculate two new parameters for the assessment of breast function from the progressive changes in breast volume over the 24-hour period. First, the storage capacity of the breast was calculated, that is, the demonstrated capacity of the breast to store milk that was available to the infant. This was calculated as maximum breast volume minus minimum breast volume observed over the 24-hour period [60]. Second, the degree of fullness of the breast was calculated as the volume of the breast at the end of a breastfeeding minus the minimum volume of the breast during the 24-hour period, divided by the storage capacity of the breast. Thus, the degree of fullness varied from one when the breast was full to zero when the breast was empty.

To illustrate our findings using the CBM system, the results for two of the seven mothers who participated in this study [60] are presented (table 2 and fig. 2). Mothers A and B were fully breastfeeding their babies and had similar levels of milk production: 912 and 950 g/24 hours, respectively. Nevertheless, as with most other women we have studied, this production was not divided equally between the mother's breasts, emphasizing the importance of investigating

TABLE 2. Computerized breast measurement system assessment of breast function for two mothers

Measurement	Mother A		Mother B	
Stage of lactation (mo)	4		5	
Milk yield (g/24 h)	912		950	
Storage capacity (ml)	780		190	
Relative breast size (%)				
minimum	69		92	
maximum	71		96	
Individual breasts				
Measurement	Left	Right	Left	Right
Milk yield (g/24 h)	108	804	338	612
Storage capacity (ml)	180	600	80	110
Feedings/24 h	3	4	7	7
Rate of synthesis (ml/h)				
minimum	3	17	6	23
maximum	15	49	18	31

Source: ref. 60.

TABLE 3. Observations and conclusions from computerized breast measurements of the circadian changes in breast volume in lactating women

Observation	Conclusion
The infant did not consume all available milk at a breastfeeding	The infant's appetite determines milk intake at a breastfeeding
Mothers with small breast storage capacity breastfed more frequently	The storage capacity of the mother's breasts dictates the flexibility in frequency of breastfeeding
Rates of milk synthesis varied greatly within and between breastfeedings	The short-term rate of milk synthesis is under autocrine (local) control
Rate of milk synthesis was highest when the breast contained the least milk	Autocrine control responds to the fullness of the breast
Right and left breasts differed in both milk production and size	Autocrine mechanisms may affect the number of lactocytes in the breast

the regulation of milk synthesis in individual breasts rather than in individual women.

A detailed review of the results of our investigations of human lactation over the 24-hour period using the CBM system is given by Daly and Hartmann [61], and a summary of our observations and conclusions is given in table 3. These studies clearly demonstrated that the infant's appetite determined the milk intake at a particular breastfeeding. The breast storage capacity varied greatly between women (table 2), and this factor significantly influenced the breastfeeding frequency required to maintain an adequate milk supply. In addition to these observations, we were unable to show a relation between the increase in blood prolactin at a breastfeeding and the subsequent rate of milk synthesis between breastfeedings [62]. Furthermore, the short-term rates of milk synthesis of a woman's right and left breasts often responded independently from breastfeeding to breastfeeding. For example, after the first feeding, the milk synthesis rate of the right breast could be higher than that of the left breast, but after the next feeding, the reverse could be true, with the left breast now showing the higher rate of milk synthesis.

The negative relationship between the degree of breast fullness and the short-term rate of milk synthesis (fig. 2) was of particular interest. In this respect, the right breasts of mothers A and B represent two extremes. Mother A, with a large storage capacity, had high rates of milk synthesis when her breast contained the least milk (fullness approximately zero) and low rates of milk synthesis when her breast was nearly full (fullness approximately one). In contrast, mother B, with a small breast storage capacity, achieved a high level of milk production by more frequent breastfeedings with relatively consistent short-term rates of milk synthesis, as her degree of fullness was low after each breastfeeding.

Our results for women are consistent with the autocrine theory of milk synthesis control during established lactation, which has been recently proposed for dairy goats by Peaker and Wilde [50]. These workers have isolated a protein called feedback inhibitor of lactation (FIL) that appears to suppress milk synthesis as milk accumulates in the mammary gland between breastfeedings by reversibly inhibiting the transfer of newly synthesized protein from the endoplasmic reticulum to the Golgi vesicles.

We also have shown that the difference in the fat content of breastmilk between the beginning and the end of a breastfeeding is related to the degree of fullness of the breast, rather than to whether it is either fore or hind milk [63]. Furthermore, Heesom et al. [64] have demonstrated that medium-chain-length fatty acids inhibit glucose metabolism and lipid synthesis in isolated mammary acini of rats. The presence of lipases in breastmilk and the nature of the accumulation of triacylglycerol in the alveolus suggest that autocrine control of milk fat synthesis by

free fatty acids also is mechanistically plansible in lactating women [65]. *In vitro* studies have shown that free fatty acids may act as messenger and modulator molecnles, mediating responses of the cell to extracellular signals [66].

A further interesting development arises from studies by Molenaar et al. [67]. They used ^{35}S-labelled cRNA probes to localize the sites of α-lactalbumin, α-S1-casein, and lactoferrin mRNA synthesis in sheep. Early in lactation, mammary gland expression of α-lactalbumin and α-S1-casein was high in some alveoli but not in others. Those alveoli with high expression of α-lactalbumin and α-S1-casein contained few fat globules in their cells and lumina, whereas those in which expression of these proteins was absent contained abundant fat globules. These latter alveoli also almost exclusively expressed lactoferrin. These findings suggest that milk secretion either is heterogeneous across lobules or occurs sequentially with time in the alveolus as newly secreted milk accumulates. The latter concept seems more plausible.

It is tempting to speculate that the FIL and free fatty acids may act locally to sequentially regulate the short-term rates of milk constituent synthesis, either within a mammary gland or, more likely, within lobules according to the degree of emptying of the lobules in each breast.

Involution

Stndies of lactation in village women and the few remaining hunter-gatherer societies suggest that the normal duration of lactation in women is three to four years. In these societies, and more recently in a number of developed countries, weaning is prolonged and gradual (that is, child-led weaning). The cessation of sucking results in distension of the gland with milk and atrophy of the epithelial structures. Finally, milk secretion is greatly suppressed, and the lactocytes disintegrate and desquamate. Phagocytosis of the degenerated alveoli reduces the lobuloalveolar structures, and ductal systems become predominant. It seems that the involution of the human breast occurs much more gradually than that of the mammary glands of other mammals [68], and this may explain the relative ease of relactation in women.

Acknowledgements

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Discussion of paper by Hartmann et al.

Dr. McLaren

The two women you showed us both produced more milk from the right breast than the left. Is this usual, and is it related to which breast the baby is put to first at a feeding?

Dr. Hartmann

I think that perhaps two-thirds of women are uneven in the milk production between their left and right breasts, but it doesn't necessarily mean they are consistently higher in the right breast. We found that some women changed from one lactation to the next, so most milk production in one lactation is in the right breast, and in the next it's in the left breast, so there is a fairly random distribution between breasts. Some people think it has to do with the handedness of mothers. We haven't looked at that, but certainly it can change during subsequent lactations. It seems to me to relate to a behavioural characteristic in animals, which is teat order. There is evidence from Sweden, I believe, that indicates that when babies are put on their mother's abdomen, they make their way up to the breast. They also tend to associate with the breast that they attach to first. This observation would be consistent with observations of the establishment of teat order in other mammals.

Dr. McLaren

I was particularly interested in your observation that fat content increases as the breast is emptied. Does that mean it is better for a woman to empty one breast before transferring the baby to the other?

Dr. Hartmann

This is an interesting situation, and one has to be very careful in responding, because how it is applied in practice can be quite misleading. The breast has regular mechanisms that can cope with most patterns of feeding. So far, our results indicate that it doesn't much matter how the breast is emptied; the baby will get the same amount of energy over a 24-hour period. One-sided feeding has only been recommended for women with oversupply problems. For normal feeding it is reasonable to finish one breast before offering the other.

Dr. McNeilly

Back to milk production. Presumably, in the case of twins, both breasts can operate to full capacity if they are emptied at the same rate?

Dr. Hartmann

That is correct. Our studies suggest there is additional capacity. I think mothers in Western societies have to down-regulate their physiological capacity to produce milk to their babies' requirements. We can look at the endocrine system as setting the upper limits of the mother's milk production capacity and the autocrine mechanism as then cutting it down to the actual needs of the baby. With twins the mother sustains a higher level of production that perhaps approximates the breasts' maximum capacity. We studied a woman who fully breastfed triplets for two and a half months, so the breast has enormous capacity.

Dr. McNeilly

You didn't mention the relationship of oxytocin to storage capacity. It seems that much of the milk won't come out without oxytocin release. Is that true? There is very little information on that.

Dr. Hartmann

Residual milk, in my opinion, has done more to confuse our understanding of lactation than just about

any other concept. This is because it is based on the very unnatural situation of the dairy cow. The suckling situation is totally different. Oxytocin is obviously required for milk ejection, but the amount of milk that is taken depends on the baby's appetite, not what the mother has available. So in mothers with high storage capacity, there is enormous variation between the storage capacity and the amount of milk that the baby might take at any one time.

Dr. McNeilly

But if the mother didn't release oxytocin at all, would that dramatically reduce the amount of milk the baby could get?

Dr. Hartmann

Yes, it certainly can be a problem. We don't notice it particularly in women who are breastfeeding. It is often a problem for mothers who are expressing milk. If they don't get a let-down, they can have a great decrease in milk production.

It is very important to look at milk production from individual breasts, which relates to Dr. McLaren's first question. We did an initial study in Oxford on six mothers to determine if the interval between feedings was correlated with the amount of milk the baby took. If you combine the production of both breasts, there's no relationship. If you split the intake from the left and the right breasts, there is a very tight coupling. That is, the gap between feeds determines how much the baby takes from a breast. For the other breast, there is no such relationship. It was clear women showed "breastedness" in the same way they show handedness, but it wasn't linked to handedness, because we had five "left-breasted" mothers and one "right-breasted" mother, but they were all right-handed.

So it's not clear what the relationship is. It was almost as if the control mechanisms were located in one side, as in true handedness. When we moved to Bristol, we studied 20 more mothers and found no such relationship. We found the relationship was with the first breast to be offered, which confused us somewhat. Therefore, we didn't publish the results.

Constituents of human milk

Ann Prentice

Abstract

Breastmilk contains all the nutrients required by the newborn baby. It also contains non-nutritional components that may promote infant health, growth, and development, such as antimicrobial factors, digestive enzymes, hormones, trophic factors, and growth modulators. In some situations, breastmilk may also contain harmful components, such as pollutants, drugs, allergens, and viruses. Human milk has a unique composition, which differs from that of other mammals in its ingredients and their concentrations.

Breastmilk composition is not constant and varies with stage of lactation, breastfeeding pattern, season, and parity. It also differs among individuals and among communities, for reasons that are not well understood. Maternal nutrition is an obvious candidate, but the situation is complex. Supplementation studies and cross-cultural comparisons have demonstrated that the total concentrations of fat, protein, and lactose are relatively insensitive to current dietary intake and nutritional status, whereas the fatty acid profile and the concentrations of several micronutrients, particularly water-soluble vitamins, are responsive to maternal diet.

For many infants, nutrient intake from breastmilk becomes insufficient after four to six months, and other foods should be added to the diet. Nevertheless, breastmilk can continue to be a valuable nutrient source and to provide non-nutritional factors even for older children. Consequently, breastfeeding for one to two years as part of a mixed diet has many advantages, particularly for children living in impoverished circumstances.

Introduction

Breastmilk is a complex fluid, rich in nutrients and in non-nutritional bioactive components. Knowledge of the composition of human milk and the factors that influence it has increased considerably over the past two decades. This paper briefly summarizes current understanding, drawing largely on our cross-cultural studies in the Gambia and Britain as examples. More comprehensive reviews have recently been published [1–4].

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Nutritional and non-nutritional components

Breastmilk contains all of the nutrients needed by the newborn baby during the first weeks of life. These include the metabolic fuels (fat, protein, carbohydrate), water, and the raw materials for tissue growth and development, such as fatty acids, amino acids, minerals, vitamins, and trace elements.

More than 98% of the fat in breastmilk is in the form of triglycerides, constructed within the mammary epithelial cell from medium- and long-chain fatty acids derived either from the maternal circulation (carbon chain lengths ≥ 16) or manufactured locally (carbon chain lengths ≤ 16) [5]. Short-chain fatty acids (carbon chain length ≤ 8) are only present in trace amounts. Oleic acid (18:1) and palmitic acid (16:0) are the most abundant fatty acids in breastmilk triglycerides, with comparatively high proportions of the essential fatty acids, linoleic acid (18:2ω6) and linolenic acid (18:3ω3). Comparatively high proportions of other long-chain polyunsaturated fatty acids, snch as arachidonic acid (20:4ω6) and docosahexaenoic acid (22:6ω3), are also present [5]. These long-chain fatty acids are constituents of brain and neural tissue and are needed in early life for mental and visual development [6]. At least half of the triglyceride molecules in breastmilk contain palmitic acid attached to the central carbon of the glycerol component, a property that increases digestibility, absorption, and mineral balance [5, 7]. The lipid component of breastmilk is the transport vehicle for fat-soluble micronutrients such as prostaglandins and vitamins A, D, E, and K.

Proteins account for approximately 75% of the nitrogen-containing compounds in breastmilk. Non-protein nitrogen substances include urea, nucleotides, peptides, free amino acids, and DNA. The proteins of breastmilk can be divided into two categories: micellar caseins and aqueous whey proteins, present in the ratio of about 40:60 [8]. The predominant casein of human milk is β-casein, which forms micelles of relatively small volume and produces a soft, flocculent curd in the infant's stomach. The major whey proteins are α-lactalbumin, lactoferrin, secretory IgA, and serum albumin [8], with a large number of other proteins present in smaller amounts. Secretory IgA is the principal immunoglobulin of breastmilk. It is synthesized in the mammary epithelial cell by the coupling of two IgA molecules, produced locally by lymphocytes resident in the breast tissue, with two proteins, J-chain and secretory component [8]. The specificity of breastmilk secretory IgA antibodies reflects the mother's exposure to mucosal infection and is independent of the specificity profile of blood-borne IgA [9]. Many of the proteins in breastmilk have a multitude of potential functions. Lactoferrin, for example, transports and promotes the absorption of iron, is bacteriostatic to a range of organisms, and acts as a nutritional protein, producing amino acids for absorption on digestion [8, 10].

The principal carbohydrate of human milk is lactose, a β-disaccharide manufactured in the mammary epithelial cell from glucose by a reaction involving α-lactalbumin [11]. In addition, breastmilk contains signifieant quantities of oligosaccharides, predominantly lactose-N-tetraose and its monofucosylated derivatives, representing about 10% of total milk carbohydrate. The oligosaccharide composition reflects the Lewis blood group and secretor status of the mother [12].

In addition to the nutritional components, breastmilk contains a wealth of bioactive components that may have beneficial non-nutritional functions [8, 9, 13, 14]. These include a wide range of specific and non-specific antimicrobial factors; cytokines and anti-inflammatory substances; and hormones, growth modulators, and digestive enzymes (table 1), many of whieh have multiple activities. These components may be of particular importance for young infants because of the immaturity of the host defence and digestive systems early in life. The physiological significance of many of these substances has yet to be determined, and some may be present merely as "spillover" or excretory products from metabolic processes occurring within the mammary epithelial cell. For those with established significance, the site of action may be within the mother's breast, within the infant's alimentary canal, or, after absorption, within the infant's body. Some antimicrobial components, for example, are active both within the breast, minimizing the risk of breast infection and mastitis [15], and within the baby's gastrointestinal and respiratory tracts, protecting the mucosal surfaces from infection by bacteria, viruses, and parasites [9]. By contrast, the site of action of the peptide feedback inhibitor of lacation (FIL) is within the breast, its function being the autocrine regulation of milk production [16]. On the other hand, casomorphins, opioid-like substances that may affect infant behaviour and mood in addition to a range of other functions, are produced in the baby's intestines by the degradation of breastmilk casein [17]. Many bioactive substances are also valuable nutrient sources and ultimately are digested and absorbed in the normal way. Protease inhibitors in breastmilk may afford a degree of protection from digestion for some breastmilk components [8]. A sufficient proportion of antimicrobial proteins, for example, escape digestion and emerge in the faeces, suggesting that antimicrobial activity continues throughout the length of the infant's gastrointestinal tract [10].

Breastmilk has also been shown to be an excretory route for a range of substances that might be harmful to the baby (table 1). These include viruses, such as human immunodeficiency virus (HIV) [18]; environmental and occupational pollutants, such as DDT, PCBs, and dioxins [19]; components of the mother's diet that might be toxic or allergenic, such as *trans*-fatty acids, aflatoxins, and cow's milk protein [20–22]; commonly used stimulants, such as nicotine, caffeine, and theobromine [23, 24]; and various drugs and radioactive compounds [25–27]. Where exposure to xenobioties jeopardizes infant health, difficult and often controversial decisions have to be made about whether the risks outweigh the benefits of breastfeeding [26, 28].

Comparison with animal milks

Breastmilk contains a unique combination of ingredients, differing from the milks of other mammals in both the concentration and the nature of its many components. In common with the milk of other primates, human milk has low energy and nntrient density compared with the milks of most other mammals, except for a high density of carbohydrates [4]. In addition, the daily output of the major nutrients in milk relative to the size of the mother is lower in humans than in other mammals, especially dairy and laboratory species [29].

The composition of cow's milk, the basis of most breastmilk substitutes over the centuries, is compared with that of human milk in table 2. In addition to the obvious concentration differences, the milks differ considerably in the strueture of many of the

TABLE 1. Examples of the non-nutritional components of breastmilk

Antimicrobial factors secretory IgA, IgM, IgG lactoferrin lysozyme complement C3 leucocytes bifidus factor lipids and fatty acids antiviral mucins, GAGs oligosaccharides	Growth factors epidermal (EGF) nerve (NGF) insulin-like (IGF) transforming (TGF) taurine polyamines
Cytokines and anti-inflammatory factors tumour necrosis factor interleukins interferon-γ prostaglandins α_1-antichymotrypsin α_1-antitrypsin platelet-activating factor: acetyl hydrolase	Digestive enzymes amylase bile acid-stimulating esterase bile acid-stimulating lipases lipoprotein lipase
Hormones feedback inhibitor of lactation (FIL) insulin prolactin thyroid hormones corticosteroids, ACTH oxytocin calcitonin parathyroid hormone erythropoietin	Transporters lactoferrin (Fe) folate binder cobalamin binder IgF binder thyroxine binder corticosteroid binder
Potentially harmful substances viruses (e.g., HIV) aflatoxins *trans*-fatty acids nicotine, caffeine food allergens PCBs, DDT, dioxins radioisotopes drugs	Others casomorphins δ-sleep peptides nucleotides DNA, RNA

Data compiled from references given in the text.

milk fractions [30]. For example, in cow's milk the major proteins are α-casein and β-lactoglobulin; the ratio of casein to whey protein is 80:20; the casein micellar volume is double that of human milk, and the curd formed is hard; the principal milk immunoglobulin is IgG; and lactoferrin and lysozyme are present only in small amounts [30]. Cow's milk triglycerides contain a higher proportion of short-chain fatty acids and a lower proportion of long-chain and polyunsaturated fatty acids; furthermore, the positional distribution of fatty acids on the glycerol molecule is different [30]. In addition, many of the non-nutritional factors found in human milk are absent from cow's milk or are present only in trace amounts. For the human baby, these differences affect the digestibility and absorption of nutrients, the bioavailability of micronutrients, and the potential benefits from non-nutritional factors.

Variations in breastmilk composition

The composition of breastmilk is not uniform, and the concentrations of many of its constituents change during the lactation period and differ between individual mothers. As variations in concentration are not necessarily inversely related to breastmilk volume, differences in breastmilk composition affect the daily intakes of milk components by the breastfed child. There are several factors that are known to influence the concentration of breastmilk constituents in predictable ways [31]. These include stage of lacta-

TABLE 2. Typical contents of human and cow's milk

Contents	Human milk	Cow's milk
Fat		
total (g/100 ml)	4.2	3.8
fatty acids ≤8C (%)	trace	6
polyunsaturated fatty acids (%)	14	3
Protein (g/100 ml)		
total	1.1	3.3
casein	0.4	2.5
α-lactalbumin	0.3	0.1
lactoferrin	0.2	trace
IgA	0.1	0.003
IgG	0.001	0.06
lysozyme	0.05	trace
serum albumin	0.05	0.03
β-lactoglobulin	—	0.3
Carbohydrate (g/100 ml)		
lactose	7.0	4.8
oligosaccharides	0.5	0.005
Minerals (g/100 ml)		
calcium	0.030	0.125
phosphorus	0.014	0.093
sodium	0.015	0.047
potassium	0.055	0.155
chlorine	0.043	0.103

Data compiled from references given in the text.

TABLE 3. Typical contents of 100 ml breastmilk produced on days 1–5 (colostrum) and more than 15 days (mature milk) post-partum

Contents	Colostrum	Mature milk	C:M%[a]
Metabolizable energy (kcal)	55	67	82
Fat (g)	2.9	4.2	69
Lactose (g)	5.3	7.0	76
Protein (g)			
total	2.0[b]	1.1	182[b]
secretory IgA	0.5[b]	0.1	500[b]
lactoferrin	0.5	0.2	250
casein	0.5	0.4	125
Calcium (mg)	28	30	93
Sodium (mg)	48	15	320
Vitamin A (μg retinol equivalents)	151	75	201
Vitamin B_1 (μg)	2	14	14
Vitamin B_2 (μg)	30	40	75
Vitamin C (μg)	6	5	120

Data compiled from references given in the text.

a. Percentage ratio of concentrations in colostrum and mature milk.
b. Considerably higher on days 1–3.

tion; breastfeeding routine; parity, age, and other maternal characteristics; regional differences; and, in some situations, season of the year and maternal diet. These are discussed in detail below.

Stage of lactation

Human lactation can be divided into four phases that differ in the composition and volume of milk produced: colostral, transitional, mature, and involutional. Colostrum is secreted for the first three to five days after delivery, transitional milk until the end of the second week, mature milk during full lactation, and involutional milk at the end of lactation. These definitions are arbitrary; the timing varies from one mother to another, and composition does not change abruptly. Typical concentrations of selected milk constituents are shown in table 3 [29, 32–35]. Notably, colostrum is rich in secretory IgA, lactoferrin, vitamin A, and sodium compared with mature milk but has relatively low concentrations of fat, lactose, and vitamin B_1. Involutional milk is characterized by low lactose content and high concentrations of protein, fat, and sodium [11, 36]. Because milk volume is low during the colostral phase, rising slowly during the first week to the higher levels of established lactation [37–39], the daily intake of most milk components by breastfed babies increases after birth, reaching a peak after several weeks (table 4). The exception is secretory IgA and, hence, total protein intake, which is maximal in the first week (table 4).

Mature breastmilk composition also changes during the course of lactation, although not as markedly as in the early weeks [31, 36, 40]. Many nutrients show a gradual decrease in concentration of around 10% to 30% during the first year of lactation, often reaching a low plateau thereafter. A greater decrease occurs for some components, such as zinc [41]. Some components show little change, especially those involved in osmoregulation, including lactose and sodium, whereas a few, notably lysozyme, increase.

Breastfeeding routine

Breastmilk composition can vary during the day and from the beginning to the end of a feeding. This is most pronounced for fat and fat-soluble components

TABLE 4. Typical daily intakes (g) of selected breastmilk constituents

Age	Protein			Fat	Lactose	Calcium
	Total	Secretory IgA	Other			
Day 1	5.0	4.8	0.2	<1	1	0.01
Day 3	12.0	5.0	7.0	5	12	0.06
Day 8	9.0	1.8	7.2	22	40	0.19
3 mo	7.5	0.7	6.8	29	52	0.22

Calculated intakes assume the following daily milk volumes: day 1 (0–24 h), 40 ml; day 3 (48–72 h), 200 ml; day 8, 600 ml; 3 months, 750 ml [1, 38, 52]. Concentration data from table 3 and other references in the text.

such as vitamin A and zinc [5, 42]. The fat content of breastmilk can change by as much as fivefold during the course of a feeding [42]. The fat concentration is influenced by the breastfeeding routine of the mother, and short-term variations are related to the volume of milk produced per feeding and the time interval between feedings [42]. Differences in breastfeeding routine can affect the diurnal variation in fat concentration. In the Gambia, for example, where mothers feed on demand and sleep with their infants who suckle during the night, the highest breastmilk fat concentration tends to occur in the early morning, whereas in Western societies, with different feeding schedules, the early morning is associated with the lowest fat concentration of the day [42]. Other constituents, such as protein, may show small but consistent changes from the beginning to the end of a feeding and during the day [36, 43], whereas others, such as calcium, are unaffected [44].

Maternal parity and age

Breastmilk composition may be influenced by the parity and age of the mother. In the Gambia young, primiparous mothers have higher concentrations of several constituents, especially fat, total protein, and immunoproteins, whereas older mothers of very high parity (nine or more children) tend to produce milk with reduced quality [45–48]. Other components, such as calcium, do not change with parity [44]. Similar observations have been made in some studies elsewhere [36], but not in others, and the mechanisms involved remain elusive.

Season

The season can influence breastmilk composition. In sub-Sahelian Africa, where food availability, infection rates, farm work, and child-care patterns vary between seasons, variations in the concentrations of some constituents, such as fat, immunoproteins, and water-soluble vitamins, have been observed [45, 49, 50]. The changes may be related, in part, to alterations in the mother's diet or breastfeeding behaviour. Milk ascorbate level, for example, closely parallels maternal plasma ascorbate concentration and vitamin C intake, and is high during the season when mangoes are plentiful but low for the rest of the year [50].

Region

Differences in breastmilk composition have been reported between urban and rural populations, and between different socio-economic, geographic, and ethnic groups. Failure to consider differences in duration of lactation, breastfeeding practices, maternal parity and age, sampling protocols, and assay techniques may have contributed to the impression of marked regional differences. A recent evaluation of the available data suggests that the similarities between regions are more striking than the differences, particularly with respect to the major nutrients [31]. Nevertheless, some distinct regional differences are evident, particularly in the concentrations of certain protein components, minerals, vitamins, and trace elements [31, 44, 51]. The reasons are largely unknown but may be related, in part, to the maternal diet and the local environment.

Maternal diet and nutritional status

In the past it was commonly believed that poorly nourished mothers had reduced lactational performance, in both the amount and the quality of breastmilk produced. This view has now been shown to be largely incorrect [4]. A recent examination of the world literature could not demonstrate any convincing relationships between maternal nutritional

status, as indicated by body mass index (BMI), defined as weight/height^2, and either breastmilk output or energy content [52], even in very thin mothers (BMI < 18.5 kg/m^2).

Direct dietary supplementation studies mostly support this view. In a Gambian study, where poorly nourished lactating mothers were given a high-energy, nutritionally balanced supplement that provided a net energy gain of 3 MJ/day, there was no impact on breastmilk volume [4, 37]. Breastmilk fat and protein concentrations were increased slightly by the supplement, but lactose levels fell, resulting in only a marginal effect on total breastmilk energy. A review of other intervention studies concluded that there was no persuasive evidence for the positive effects of diet on breastmilk energy output [53]. Although breastmilk fat concentration has been correlated with various aspects of maternal fatness in a number of studies [4, 36], including those in the Gambia [45], this observation is not universal; in some populations negative relationships have been reported [4].

Lactation, therefore, appears to be relatively robust in the face of poor nutrition. Maternal diet can, however, affect the breastmilk concentrations of many minor constituents, particularly long-chain polyunsaturated fatty acids, some vitamins, zinc, selenium, iodine, and fluorine [51]. The profile of fatty acids in the mother's diet and adipose tissue stores is reflected in the fatty acids of breastmilk [5, 47]. The concentrations of two water-soluble vitamins, riboflavin (vitamin B_2) and ascorbic acid (vitamin C), show rapid, dose-related responses to maternal supplementation [4, 50]. The fat-soluble vitamins A, D, E, and K are less responsive to diet because of the buffering action of maternal stores and carrier proteins, but large supplements can result in increased breastmilk concentrations, occasionally to potentially toxic levels [51]. Maternal zinc supplementation may slow the decline in breastmilk zinc concentration during lactation, although the magnitude of this effect and its significance for the breastfed child are still uncertain [41, 54].

Worldwide variations in breastmilk composition have suggested that poor maternal calcium intake may be a factor in determining breastmilk calcium concentration [55]. Mothers in the Gambia, for example, where the diet contains little calcium, have an average breastmilk calcium concentration more than 20% lower than that of British women [44, 56]. A recent supplementation study, however, which tripled the calcium intake of Gambian women for the first year of lactation, had no impact on breastmilk calcium concentration [56]. Intriguingly, a possible link with calcium intake during the preceding pregnancy emerged during this study, an observation that deserves further investigation [57].

Differences between mothers

Even when these various influences are taken into consideration, breastmilk composition varies considerably from one mother to another in the same population. Typically, major constituents such as fat, protein, and calcium can differ by two- to threefold between mothers at the same stage of lactation [44], and the concentrations and activities of some of the minor constituents can be highly variable [48]. At the same stage of lactation, breastmilk volume also varies between mothers [37]. In general, between-mother differences in composition and volume are maintained throughout lactation and are not necessarily related to each other [36, 37, 45, 48, 53, 58]. As a consequence, the intakes of breastmilk components are also highly variable, and some infants consistently receive substantially more or less from breastmilk than others of the same age. It is, therefore, important, when assessing the adequacy of breastfeeding for individual children, that measurements be made of both breastmilk intake and breastmilk composition.

Contribution of breastmilk to infant nutrition

Breastfeeding will normally provide all the nutrient requirements of a baby for the first four to six months of life [59]. After this time some nutrients may become limiting, including not only dietary energy, but also essential minerals such as zinc and iron. Current recommendations are that solid foods are unlikely to be necessary before four months, but a mixed diet should be offered by six months [59].

Moreover, breastmilk can continue to make substantial contributions to infant nutrition for many months after the introduction of weaning foods [40, 60]. This is especially true in communities where weaning and adult foods are of poor quality. In the Gambia, for example, older, partially breastfed children obtain more than two-thirds of their vitamin A and fat from breastmilk [60]. When breastfeeding stops, the intake of these nutrients drops dramatically. A similar effect is seen in Dutch children weaned onto macrobiotic diets [61]. The contribution of breastmilk to vitamin A nutrition may be the reason why prolonged breastfeeding protects against xerophthalmia and eye disorders in regions where vitamin A deficiency is common [60]. In addition, significant quantities of many of the non-nutritional factors continue to be ingested by the partially breastfed older child, which may be especially important for children living in impoverished and unsanitary environments [60]. In affluent societies, where high-quality weaning foods and health care are read-

ily available, the benefits of partial breastfeeding beyond six months are less apparent [60]. For children in poorer societies, however, the many beneficial effects of prolonged breastfeeding on nutrition, health, birth spacing, and the family economy [60] strongly suggest that breastfeeding for one to two years should be encouraged as part of a mixed diet.

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Discussion of paper by Prentice

Dr. Garza

Dr. Prentice, I also am intrigued by the calcium data. If you look at casein levels, are they comparable between the Gambia and Britain, or is the casein just not saturated? (I know that is not an appropriate term.)

Dr. Prentice

Clemens Kunz of the University of Dortmund in Germany measured the casein levels for us not long ago, and they seem to be very similar in American and Gambian mothers. In human milk, however, the main vehicle for calcium is citrate, not casein, and we are concentrating on the citrate levels first before going for the casein, as we are not expecting to see any major differences there.

Dr. McNeilly

Dr. Prentice, I have learned a lot. Could you tell me if nutrition might affect the rate of milk synthesis, or is that not shiftable?

Dr. Prentice

Dr. Hartmann could probably answer that question better than I. The only information we have is from our Gambian supplementation study, in which both unsupplemented and supplemented women produced the same amount of milk per day, but the supplemented women fed fewer times per day. So we think that it quite possibly has something to do with the mother's nutritional state, not necessarily with substrate supply affecting the storage capacity, as Dr. Hartmann said. Perhaps the unsupplemented women had smaller storage capacity and had to feed much more frequently during the day to produce the same volume. This is speculation, because we have not done any work on it. Have you any comment, Dr. Hartmann?

Dr. Hartmann

Yes, I think that when substrate supply is limited, the babies have to feed very frequently, regardless of the storage capacity, to keep the rate of synthesis at the maximum. Providing the mothers with more energy from the diet somewhat increases their ability to produce milk. Then the baby might not suckle as frequently to get the volume of milk that it requires, so I don't think it is inconsistent.

Dr. Rasmussen

I would like to contribute the results from a supplementation trial in Guatemala that have been presented at meetings but haven't yet been published. We selected women at the end of pregnancy and the beginning of lactation based on mid-calf circumference, not on body-mass index (BMI), because BMI has the properties that you mentioned. In that supplementation trial, we gave mothers either a low-energy or a high-energy supplement; we didn't have a no-treatment group, because we didn't consider it ethical, given the state of the population. The women in the high-energy group produced more milk, and—of particular importance to this meeting—they exclusively breastfed their babies for a longer period. We were not in the field long enough to ask if there was an effect on fertility in these women (in other words, on the length of their amenorrhoea), but I think there were clearly changes in the way the women breastfed as a result of changes in their milk volume. So I think there may be important effects of supplementation that we may not have seen in the trials that we have had today.

Dr. Prentice

I don't want to detract from that at all, but I still feel that we may be talking about two different things: the biological limits on lactation and the whole area of the mother's well-being—the social factors that

affect the way she and the baby interact to increase milk volume. It seems from the work we have been doing that most women can produce reasonable volumes of milk, and if they don't, there are other factors that are probably affecting it other than the capacity of the breast in most instances. I wanted to ask you if you had any macronutrient content data from the breastmilk—that was my brief this morning. Does it affect the composition of the milk?

Dr. Rasmussen

The only component we have looked at is energy. There are compensatory changes in energy, such that women who produce more milk have less energy-dense milk. The effects ou iufant growth are expected to be minimal. But our statistical power was not calculated on measuring infant growth.

Dr. Prentice

I think I would have predicted that. In our supplementation studies we found that if we gave women essentially a higher-fat diet, there was more fat in the breastmilk, but lactose was reduced. This has been seen in quite a lot of other studies as well. Thus, the mother's breastmilk fat concentrations may well be responsive either to her own diet or to her adipose tissue stores. We have seen it, other people have seen it, but some other studies have not, and so it is still relatively controversial. But whatever happens, total milk energy seems to stay remarkably similar.

Dr. Hartmann

Could I add that we looked at some immunologic factors in the same material, and lactoferrin remained the same in both groups.

Dr. Garza

What was the content of fat in the Gambian diet?

Dr. Prentice

It's about 20% to 25%.

Dr. Garza

In studies done with Salvador Villalpando and Nancy Butte in Mexican women consuming diets of lower fat content, we found much lower levels of fat in human milk that were not fully compensated for by changes in lactose.

Dr. Prentice

That were *not* compensated for?

Dr. Garza

That's right. We saw the same directional changes you did, but the reduction in fat was much greater than the increase in lactose, so that in populations with very low levels of fat (in the 10% to 12% range), the breastmilk fat content may be influenced dramatically.

Dr. Prentice

I certainly could believe that fat intakes might be limiting at that very low level. Did you find a difference in the shift between the mauufactured fatty acids and the dietary fatty acids?

Dr. Garza

We didn't look at fat composition. Dr. Villalpando, has fat composition been examined since those earlier results were available?

Dr. Villalpando

We are looking at those data now. We see an increase in the medium-chain-length fatty acids, but the milk energy increase was not that impressive.

Dr. Prentice

Mike Crawford long ago suggested the same thing from Tanzanian studies, but there the total fat tended to stay the same but with larger amounts of medium-chain-length fatty acids.

Professor Howie

I apologize that this question is a little lateral to what you have been talking about, but I want to ask about the concept that breastfeeding mothers may not have to increase their own diet in proportion to the amount of milk they are giving the baby. In other words, if a mother is breastfeeding, the total energy cost to the community is less than if she were feeding herself and her baby by artificial means. That concept was discussed quite a bit a year or two ago, and I wonder if you have any comments on that and on its potential importance for nutrient provision.

Dr. Prentice

I think I would still say the same thing. There do appear to be women who are not able to increase their food intake, that is, their energy intake, and there do seem to be relatively simple compensations that can occur: a reduction in activity, for example. We are still not really sure that in lactation there is much in

the way of changes in costs like basal metabolic rate and so on, although there may well be in pregnancy, but fairly minor adjustments may be satisfactory to enhance efficiency. These include accessing energy from fat stores; many, but not all, women in that situation will lose some of their fat stores while they are lactating. Certainly, in the Gambia some women put on weight during lactation at the time of year when food is in good supply. But they are obviously eating enough for both weight gain and milk production. So, yes, I think we would still be saying the same, that there are compensations for the energy needs of lactation.

Problems of establishing lactation

Michael W. Woolridge

Abstract

The problems associated with the establishment of lactation can be viewed primarily from the mother's perspective but should also be viewed from that of the caregiver supporting her and the maternity facility providing her with care.

Factors intrinsic to the mother

The first time a mother puts her baby to her breast, she is doing something for which nothing will have adequately prepared her. Childbirth and breastfeeding are comparable in this respect; unfortunately, anticipation of the former may prevent her from giving adequate consideration to the latter, particularly to practical issues. Clinical experience suggests that ensuring that practical issues are correct can be vital to a successful outcome for breastfeeding, yet it rarely proves possible to address them adequately antenatally. The result is that the mother and her newborn, both novices to the process, go through an extremely rapid learning curve that can run completely smoothly or may be fraught with difficulties. Much will depend upon whether the mother encounters problems, and her perseverance and determination in overcoming them. Cultural factors during her upbringing and the expectations of society are likely to influence her persistence, but for individual women little direct influence can probably be exerted over these.

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Factors extrinsic to the mother

The pathway to success is not solely determined by factors intrinsic to the mother (or her baby) but also by the quality of care she receives both antenatally in preparation for breastfeeding and post-natally. Several extrinsic factors can therefore be proposed that are likely to have a beneficial impact on the individual mother's chances of success:

» good antenatal education and preparation
» optimal post-natal support, delivered by appropriately trained health-care professionals
» continued community support from a social network (partner, peers, and relatives, lay helpers or counselors, and health-care workers)

Despite the potential impact of individual-specific factors, it is imperative for the health-care system to offer well-structured support, ensuring the mother's access to well-trained and motivated staff, to offer all women the best chance of success.

For convenience, the factors leading either to a successful or to an unsuccessful establishment of lactation will be addressed under three broad headings:

» cultural influences on breastfeeding
» perinatal practices in hospital
» individual-specific influences

Before addressing these issues, I would like to focus on the physiological constraints on the establishment of lactation, looking at the factors that regulate both milk synthesis and effective milk transfer from mother to baby.

How long does it take to establish breastfeeding?

This key question can be addressed by reconsideration of classical physiology. Technically, the new mother must acquire the practical skills for handling her baby and positioning and fixing her baby on the breast. This may take from several days to a few weeks. The more fundamental physiological ques-

tion is "How long does it take for a mother's milk supply to match her baby's needs?" This question has largely been overlooked, although the evidence has been available for some time.

What triggers the onset of milk production?

At one time the view was current that early *and* frequent breastfeeding was instrumental in the early establishment of milk supply [1]. The data, however, only support a benefit of frequent suckling: early initiation, *per se*, has been shown to be without impact [1, 2]. This is because separation and delivery of the placenta, not early suckling, acts as the primary trigger for lactogenesis (the onset of milk production). During pregnancy the breasts have been primed for milk production by a "cocktail" of maternal hormones, some intrinsic to the mother (prolactin, growth hormone, insulin, thyroid hormone) and others originating from the placenta (oestrogen, progesterone, placental lactogen, chorionic gonadotrophin). At birth the placenta is delivered, thus removing a significant source of the steroid hormones (oestrogen and progesterone) that have blocked the action of circulating prolactin upon breast tissue. Lactogenesis then begins, and measurable increases in milk output are detected between 30 and 72 hours after delivery [3, 4]. It is important to appreciate this fact, as *retained placental products* can be one of the few physiological constraints on the establishment of milk production. Any remaining placental tissne can secrete sufficient steroid hormones and thus continue to suppress the onset of milk synthesis [5].

Variability in lactogenesis

There are dramatic differences between women in both the initial changes in the rate of milk synthesis and the initial level of milk production. There can be a fivefold difference in the initial level of milk output, with infant intakes of between 200 and 900 g/24 hours on the fifth day post-partum [6]. This initial level is unrelated to birthweight; only at four to six weeks of age does infant weight predict intake [7–9]. Thus, production rates more likely reflect intrinsic variability between women. Physiological factors likely to affect this include variation in the amount of secretory tissue, in circulating hormone levels, and in the sensitivity of response to these hormones, a function of the hormone receptors associated with the secretory tissue.

One implication, however, is that *milk production* (triggered by placental delivery) *is established without clear reference to the baby's size*; it is only as a result of the interplay between the mother and her infant that the broad limits on milk output become refined to match the baby's needs. This, in effect, is a "calibration" process, which will involve up-regulation of milk supply in the majority of women, whose initial milk output is low, but occasionally down-regulation of supply in women for whom it is initially excessive.

The crucial point is that breastmilk production (supply), which has been initiated "blind," must be progressively fine-tuned (calibrated) to meet the baby's needs (demand). If during this time the baby were offered calories from another source (for example, artificial formula), the blunting of appetite so caused might lead the mother's breasts to underestimate her baby's true needs, with the resultant danger that milk output might be calibrated at an inappropriately low level.

There is clinical evidence (personal observation, author's clinic) that in some women this process of down-regulation may be *irreversible*. So, if milk output fails to be optimized in the early weeks because of poor management, or if appetite is depressed because of competing calories from an alternative source, then once milk output has been set below the baby's *overall* needs, it may not be possible to reverse the process. For this reason, the avoidance of complementary milk feedings or "top-up" bottles of formula is essential, as they are highly likely to interfere with the *establishment* of an adequate milk supply.

They can have a further non-physiological effect by undermining the mother's confidence in her milk supply, causing her to feed less frequently. In addition, an artificial bottle teat can represent a gratifying oral stimulus, in simple tactile terms, causing the infant to shift its preference from the breast to the bottle teat (this is discussed at greater length below). Pacifiers and nipple shields can pose a similar threat to the successful establishment of breastfeeding.

How long does this calibration process take?

Published data indicate that milk production continues to rise from birth to around four to six weeks, at which point it tends to reach a plateau [3]. A recent study has placed the population average for peak milk output at just short of five weeks [10], although this underplays the considerable variation that exists between women (five days and six months were the most discrepant points in a small sample of 30 women [6].

Nonetheless, evidence from a compilation of data (cross-sectional) from 16 studies of exclusively

breastfed infants [3] indicates that milk output rises sharply until four to six weeks, then levels off at an average of 750 g/day for a singleton. (If a mother has twins, her milk output will continue to climb beyond 750 g/day to around 1,500 g/day, indicating that there is no absolute constraint on an individual woman's milk output, simply that 750 g/day represents the normal level at which milk output stabilizes for a singleton.) When the introduction of weaning foods is delayed, milk output is held at this level for weeks or months [11], until the introduction of solids causes fewer breastfeedings to be offered and milk supply to decline. In many cultures, however, weaning foods are introduced early. In Thailand, for instance, they are invariably introduced by one month of age. In such circumstances, there is a suggestion that they compete calorically with breastmilk, driving milk output down, rather than truly supplementing intake [10].

Factors affecting the establishment of lactation

Cultural influences on breastfeeding

Breastfeeding fails far more commonly for cultural reasons than for biological reasons. There are few physiological constraints on a successful outcome for breastfeeding. In contrast, the wealth of factors impacting upon the individual woman from family, friends, health-care workers, and the world at large exerts an enormous influence on her. Just as these factors are acknowledged to influence the probability of her initiating breastfeeding, so, too, they are likely to exert an influence over her tendency to continue once she has started.

It is axiomatic to a successful outcome that women should want to breastfeed; women who encounter and overcome breastfeeding problems usually attribute their success to their own perseverance and determination. How do health-care workers inspire in women the desire to breastfeed, and how do they influence their motivation to succeed?

Women's attitudes and beliefs are shaped by their own experience but are also fashioned by cultural pressures, and it may be difficult for health-care workers to exert much influence over these. Nonetheless, epidemiologic research continues to identify the widespread health benefits of breastfeeding to both the mother and her infant [12–14]. If women are to make a truly informed choice on how to feed their infants, then health-care workers have an obligation to provide mothers antenatally with all relevant information about these benefits and about the hazards associated with artificial feeding, irrespective of any pre-existing choice the mother may have.

The role of health-care workers

In the past, a supportive environment for the new mother would have been provided by the extended family, whose members would have undertaken most of the routine tasks that would otherwise fall to the mother. In traditional rural communities of the developing world, cultural taboos on undertaking household tasks may apply for four to six weeks after delivery [15], the time taken for the milk supply to become established. The absence of the extended family in industrialized cultures suggests that motherhood generally is undervalued. In many cultures, particularly those in transition, family ties have been eroded and the extended family has become so fragmented that new parents may have little contact with relatives who would traditionally have provided help and support. Furthermore, in those cultures where bottle-feeding has predominated over the past decades, a vast cultural expertise on breastfeeding has been lost. Under such circumstances, one would hope that health-care workers (midwives and the primary health-care team in the community) would be in a position to make up these deficiencies by providing a collective professional expertise. In practice, however, such an idealized picture does not exist. Little emphasis is given to the management of breastfeeding in professional training, and health-care workers commonly lack both the breadth of knowledge and the core practical skills to enable them to manage lactation effectively. This situation should be rectified as soon as is practicably achievable, by including lactation management in the core training curriculum of every health-care worker whose designated role includes management of the nursing couple (midwives, for example). The emphasis should be on the acquisition of key skills through the mentor–apprentice system, and the combination of knowledge and skills is essential if women are to receive the expert support they need from health-care staff.

Perinatal practices that affect the establishment of breastfeeding

It is legitimate to view the factors that either help or hinder the establishment of breastfeeding from the perspective of the maternity facility providing health care. Although largely unpredictable events can shape an individual mother's chances of establishing breastfeeding, there is enormous scope for hospital practices and staff attitudes to impact upon breastfeeding success.

In general, these factors can be grouped as follows:

» antenatal parent education
» quality of professional training in knowledge and skills

» hospital policy on key practices
» extended post-natal support, including both routine community support and specialist clinical support

The quality of support in each of these areas can be set through policy formulation and implementation by the maternity facility.

The impact of maternity care practices

The expectation is of a supportive health-care system, but the reality may be even worse than indicated above. Too often, medical practices in hospital have impeded or hindered the successful establishment of lactation. Historically, separation of the mother and baby immediately after birth was rationalized without empirical justification [16]; such a policy necessitated nurseries for the care of the newborn, which further encouraged the routine giving of supplementary fluids, including formula. Abolishing nurseries as a concept and encouraging the mother to be the primary caretaker with responsibility for her infant through routine "rooming-in" is fundamental to reversing these outmoded practices.

A global campaign, the Baby-Friendly Hospital Initiative, sponsored by international health agencies (WHO and UNICEF) and supported by national governments, is now in place to reverse this situation, by ensuring that hospital practices are designed to protect and promote breastfeeding.

Under this initiative, hospitals are encouraged to match standards of post-natal care set out in the WHO/UNICEF "Ten Steps to Successful Breastfeeding" (table 1) and to seek external assessment against these criteria. If they are successful in demonstrating compliance with the global criteria, they can be designated as a "Baby-Friendly Hospital," in effect, a global charter mark in recognition that they have made a policy commitment to making the mother and her baby the focus of a supportive, caring environment in which breastfeeding can flourish. The core practices of the Ten Steps are as follows:

Policy formulation. To minimize the tendency for new mothers to be given conflicting advice, it is vital for all health-care staff to adhere to the same set of practices. The best way to do this is for the maternity facility to establish a clear policy for the management of the new mother and her infant, training all health-care staff to a level where they understand the need to comply with this policy and are able to implement it with confidence. Monitoring staff compliance, breastfeeding intention, and outcome should then become a routine part of the audit cycle. Policies can be refined only if they are strictly implemented, followed by routine monitoring of specific clinical outcomes. Only then can the policy be modified to reduce any adverse outcomes.

Professional training. This requires a commitment to increasing the knowledge and skill base of hospital staff. Eighteen hours of training in lactation management, including at least three hours of supervised clinical practice, is urged by WHO/UNICEF as the minimum necessary for any member of the health-care staff (previously untrained in lactation management) who has contact with the breastfeeding mother and her infant. Nonetheless, if routine training (a midwife, for example, might receive prequalification) combined with post-qualification skill development enable nursing staff to overcome routine problems of breastfeeding, these can be deemed both adequate and appropriate, whatever the duration.

Antenatal education. The quality of antenatal education, including whether the proposed method of feeding receives adequate discussion, is highly influential in determining whether women make a truly informed choice on how to feed their infants. It is also to be hoped that all potentially breastfeeding women receive sufficient preparation to avoid or overcome several common initial breastfeeding problems.

Early contact between mother and baby. Early initiation of skin-to-skin contact between the mother and infant, leading spontaneously to the first breastfeeding, is likely to be of fundamental importance in establishing close affectionate ties between them. In the immediate post-partum period, the mother is regarded as passing through a "sensitive period" [18], and the baby shows raised alertness at this time [19]. Although early skin-to-skin contact with the

TABLE 1. Ten steps to successful breastfeeding

1. Have a written breastfeeding policy that is routinely communicated to all health-care staff
2. Train all health-care staff in skills necessary to implement this policy
3. Inform all pregnant women about the benefits and management of breastfeeding
4. Help mothers initiate breastfeeding within half an hour of birth
5. Show mothers how to breastfeed and how to maintain lactation even if they should be separated from their infants
6. Give newborn infants no food or drink other than breastmilk unless medically indicated
7. Practise "rooming-in"—allow mother and baby to remain together 24 hours a day
8. Encourage breastfeeding on demand
9. Give no artificial teats or pacifiers (also called dummies or soothers) to breastfeeding infants
10. Foster the establishment of breastfeeding support groups and refer mothers to them on discharge from the hospital or clinic

Source: ref. 7.

mother will undoubtedly help to reinforce the newborn's ability to seek and locate the breast [19, 20] and to facilitate recognition of the newborn [21, 22], there is little functional need for the altricial human newborn to "imprint" on its mother. For the human infant, it is more important to secure the mother's sustained emotional attachment, so that she continues to provide vital warmth, nourishment, comfort, and protection.

Therefore, early mother–infant contact serves the infant primarily by securing maternal attachment [23] and, as such, it is a biological imperative. Ensuring prolonged high-quality contact in the immediate post-partum period, therefore, deserves to be a core practice of intrapartum care, irrespective of how the mother subsequently chooses to feed her infant.

Although there is some empirical support for a maternal sensitive period, there remains the question of whether giving high-quality skin-to-skin contact at a later stage may not also be capable of facilitating the development of emotional attachment, or, conversely, whether subsequent unrewarding or fractured breastfeedings may undo any initial benefits. Of the many studies conducted to evaluate the impact of enhanced early access of the mother to her infant, only one [18] has considered whether there are any deficits if the enhanced contact (45 minutes private, skin-to-skin) is provided at a later stage (12 hours after delivery) compared with immediately after delivery. It showed a non-significant reduction in affectionate behaviour. A significant graded reduction in affectionate behaviour was observed, compared with a control group of mothers permitted only visual contact with their babies after delivery. Therefore, the evidence is rather slight to contest the possibility that prolonged, high-quality, skin-to-skin contact offered at any subsequent time might be capable of matching some, if not all, of the benefits of early mother–infant contact. If the mother has been deprived of early contact because of intrapartum medication or surgical procedures, high-quality contact should be encouraged with as much enthusiasm at a later stage. Furthermore, professional care should always be available during early breastfeedings and should strive to ensure they are as rewarding and problem-free as possible.

Further key practices. Although practices such as rooming-in and demand feeding may be regarded as essential to breastfeeding success, at a more general level they may be regarded simply as extending the newborn infant the courtesy of being regarded as an individual in its own right, rather than as an imperfectly formed automaton to be directed as we see fit. This change in philosophy in the way we view the human newborn is essential if we are to recognize that the newborn has much right to choice as the mother, although there is an obvious practical constraint on this choice being "informed." If the infants were in a position to make an informed choice on how they would be fed, on health grounds they would undoubtedly choose to be breastfed. It is difficult to see what cultural objections they might raise! So, we must learn to set their rights alongside the mother's and the father's in reaching a decision about the method of feeding. Although it is possible to constrain the infant's pattern of feeding to conform to a Western "idealized" cultural norm—as Pinilla and Birch [24] have shown for night feedings—there is no evidence that this benefits long-term habit formation in the child, whereas it may prove detrimental to the infant's emotional development [25].

Avoiding bottles and teats. We have already dealt with the physiological reasons for avoiding unnecessary supplementation and the use of artificial teats and pacifiers. Each of the WHO/UNICEF Ten Steps is research-based, and although this step (step 9) is perhaps the least well supported, it can be defended by arguing both from first principles and from clinical experience. It is important to re-emphasize at this point that we are considering events during the critical period of the establishment of lactation. It is acknowledged that different rules may apply during established lactation, when we accept that the occasional offering of bottles for social reasons (preferably of the mother's own expressed breastmilk) is unlikely to disrupt breastfeeding success.

Evidence from a study in Brazil indicates that the use of pacifiers is associated with a shorter duration of breastfeeding [26], as predicted. Clinical experience also suggests that pacifiers can impede the successful establishment of breastfeeding. Although the mechanism is not clear, certain lines of evidence can be considered.

First, ultrasound studies [27, 28] indicate that during suckling the mother's breast distorts and conforms to the internal geometry of the baby's mouth. Milk removal is achieved by the baby's compressing the base of the teatlike shape formed from the breast and nipple between his gums, and expressing milk from the sinuses lying within the "teat bulb" with a peristaltic wavelike action of the tongue. On a bottle teat, the infant attempts to achieve the same action, but because the artificial teat is more rigid, there is, instead, a tendency for the soft tissues of the baby's mouth to deform to accommodate to the geometry of the teat. Expressing milk from the teat bulb may be resisted by the less compliant material from which the artificial teat is constructed, with the result that the baby adapts by a shift towards extracting milk more by suction than by peristaltic expression. If the baby develops a reliance on one method of milk extraction over the other, he may not adapt well when offered both breast and bottle or when shift-

ing between the two. To date, no specific carry-over effect has been scientifically demonstrated; it has only been inferred from clinical observation.

Additionally, artificial teats may constitute a "supernormal" sign stimulus [29, 30], causing greater tactile stimulation of the baby's mouth than the more compliant breast. Whereas the breast naturally retracts elastically, the artificial teat remains in place, requiring little effort from the baby to hold it in his mouth. The supernormal stimulus, represented by the artificial teat, can compete for attention with the natural stimulus of the breast, and the baby, if exposed to it at an early stage, may be unable to ignore it. The outcome is that the baby may develop a preference for the artificial over the natural (nipple shields can be comparable in this respect). The term *nipple confusion* has been coined for the behaviour of the baby who refuses the breast in favour of the bottle or pacifier, but such a term may be insufficiently descriptive. The term *acquired teat preference* may be more accurate and would still embrace the established breastfeeder who refuses the bottle.

Another possibility is that bottle-feeding bypasses the triggering of the baby's natural adaptive reflexes for feeding and the maturation of the natural repertoire of responses necessitated by breastfeeding (rooting, gaping, drawing elastic breast tissue into the mouth, and suckling) [31]. There may also be a critical window during which the infant's natural response repertoire matures, so that time spent sucking on an artificial teat may represent both a lost opportunity and enhancement of an aberrant response repertoire.

Finally, the excessive use of soothers can mean that the baby is put to the breast either too infrequently or for too short a time, with the result that the baby does not secure sufficient nutrition. Not only can this adversely affect the infant's nutritional status, it will also disrupt the mechanism of supply and demand. At older ages, we have seen infants who are growing inadequately or are failing to thrive simply because pacifiers have been introduced. This appears to be due largely to the net reduction in suckling time and its effect on both immediate intake and future supply, which is only reversed when the mother makes active efforts to withhold the pacifier.

The use of pacifiers can also cause the earlier return of fertility, resulting in closer child spacing. In many cultures this may have an adverse impact on maternal as well as infant health [14, 32].

Cup-feeding. One way around the problem of giving additional fluids, where they are medically indicated, is to give them by cup or spoon [33]. In many centres, cup-feeding has been successfully re-embraced and appears to be associated with a greater success rate for establishing breastfeeding. A multicentre trial has been initiated in the United Kingdom to formally test such a view.

Individual-specific influences during the establishment of lactation

Practices that can either promote or impede breastfeeding success for the individual mother and her newborn can be broadly grouped into the following categories:

- obstetric procedures intrapartum and use of analgesia
- paediatric medical interventions necessitating admission to the neonatal intensive-care unit or step-down care nursery
- maternal pathophysiology of milk production
- routine post-natal practices affecting mother and infant care
- quality of post-natal care and support

For the individual mother, there may be unexpected predisposing factors that militate against the successful establishment of breastfeeding.

In rare circumstances, the baby may be born with an oral anomaly that will require a specialist's attention, or the nature of the baby's birth (for example, pre-term, small for gestational age, or congenital abnormality) may require separation from the mother for medical care. Although medical services should be able to tackle many of the clinical problems with relative ease, the role of the mother at this time can often be overlooked. The one significant thing the mother may be able to do for her infant under these circumstances is to express her breastmilk, yet too few centres recognize the need to attach equal significance to this non-acute aspect of clinical care.

Excluding such medical crises, however, the baby may be sleepy or lethargic as a result of intrapartum analgesia (as from pethidine) [20] or may be irritable following an instrumental delivery. The resulting behaviour, either a lack of response by the baby or signs of discomfort when the baby is handled, may make it very difficult for the novice mother to handle her baby positively and with confidence, and she may feel her efforts to breastfeed are being rejected. Concern should also be raised over increasing reports that modern epidurals and gastric suctioning, either alone or in combination, adversely affect the initiation of breastfeeding; their impact should be evaluated epidemiologically.

The foetus may have had access to its thumb, fingers, or hand in the womb (often observed during antenatal ultrasound examination) and may have had the opportunity to acquire an artificial sucking style. If the foetus has become used to sucking on a discrete, relatively rigid object for several weeks, the infant may find the elastic, retractile tissue of the nip-

ple and areola less attractive in tactile terms and thus may be reluctant to adapt to sucking at the breast. This theory could be readily evaluated by independent assessment of ultrasound scans and early sucking behaviour.

The main reason for raising this theoretical possibility is that it represents a potential individual-specific predisposing factor. We cannot yet predict which babies will or will not find the offering of artificial teats counter-productive to the establishment of breastfeeding, but simple adherence to the policy recommendation in step 9 of the Ten Steps should avert such a problem. It is explicit that this policy relates to the management of the normal full-term infant and that there are permissible clinical circumstances for departing from it.

Caution should be exercised, however, to protect against two harmful inferences: that because a baby has been observed on ultrasound to be thumbsucking *in utero*, problems will automatically arise with breastfeeding; or that difficulties of fixing and attachment in the early days are due to antenatal thumbsucking, so that no remedial efforts will be made. Neither of these inferences is defensible. Rather, the issue is raised because awareness of the possibility may help caregivers provide appropriate support rather than leaving the mother on her own to come to terms with an unrewarding infant who refuses to feed from the breast. It may be necessary for this baby to relearn how to suck correctly in the context of breastfeeding, in which case the offering of bottles, pacifiers, or finger foods will only perpetuate the artificial oral preference. A baby's early tendency to refuse the breast will undermine the learning experience for the new mother, whereas acknowledgement of her predicament and the offering of appropriate help and support will be encouraging and empowering.

Successful achievement of the technical aspects of breastfeeding will also be militated against if the mother is given inexpert help in attaching her baby at the breast in the early days [34]. Forcing her baby to the breast, or holding him there against his will, is likely to frustrate the woman's own efforts and can lead to many common complaints. The baby may also find these efforts aversive and develop a behavioural coping strategy that presents itself as breast refusal or rejection; once developed, this behaviour can be very distressing to both mother and infant and is often difficult to reverse.

Finally, research conducted with professional referrals to a clinical support service for breastfeeding women [6] has identified several classes of problems, all of which may be perceived as breastmilk insufficiency. While 98% of professional referrals to the clinical service were for reliable symptoms (for example, inadequate weight gain, unsettled infant behaviour, and sensations of reduced supply), up to 85% of them could be reversed by straightforward practical steps that included:

» technical improvements to physical aspects of the breastfeeding process
» optimizing feeding management (feeding frequency and duration, pattern of breast usage)
» providing support and encouragement

Four demonstrable causes of insufficiency were identified. Genuine pathophysiologies of milk production represented only 2% of clinical referrals. Another category (5% of referrals) represented physiologically low milk output, while the remaining two (8% of referrals) would normally be regarded as lactation failure of maternal origin, but were in fact acquired conditions owing to suboptimal management of the nursing couple (for more detailed discussion, see ref. 6).

Conclusions

The factors most likely to contribute to a mother's initial success with breastfeeding are support and encouragement provided by health-care workers who are skilled and knowledgeable in managing lactation. These professionals must work within a system that is similarly caring and supportive, the policy of which recognizes the intrinsic rights of both the mother and the baby, allowing them unrestricted access to each other (as would be the case if the mother delivered at home). More proactively, the health-care system and its staff should positively encourage those practices that have been shown to have a beneficial impact on the establishment of breastfeeding, while eradicating all practical hindrances. Finally, it is to be hoped that the mother will have a relatively trouble-free breastfeeding experience, or at least that her motivation and persistence with breastfeeding will be sufficient for her to overcome any problems she may encounter. A sensitive and supportive attitude from health-care staff will be highly valued by women and can contribute significantly to their success by boosting their confidence in their ability to breastfeed.

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Discussion of paper by Woolridge

Dr. Valdés

I have a question regarding the group of women with an irreversible decline in milk output. You can use lactation in adopted mothers as a comparison. It takes longer, and the production doesn't increase as in the first month. It steadily increases throughout the first six months. Why doesn't that happen in a biological mother?

Dr. Woolridge

Our finding is disconcerting, especially when one hears about grandmothers in Africa who are able to re-establish lactation simply through suckling. Some of our interventions to boost these mothers' supplies have been quite aggressive, to see if there was any way of improving output. We would not diagnose the mothers who responded either to increased suckling or to pharmacotherapy. Where there has been substantial down-regulation, it is often difficult to shift back up. Where there has been up-regulation from birth, the potential to carry on up-regulation is retained. Down-regulation, if it is excessive, can be a harmful process. Clearly there are other factors, particularly psychosocial factors in women in industrialized countries, that seem to exert a block over and above the motivation to feed. But in physiological terms, this down-regulation could be a critical factor.

Dr. Rasmussen

I am wondering if any of the babies in what you call the behavioural category, contented failure to thrive, are the oues who were rejecting the breast. Is there any indication that they are responding to the taste of the milk? That is, are mothers eating things that the infants are allergic to or just dou't prefer?

Dr. Woolridge

There is no evidence of anything long-term. Certainly there is evidence that the baby will refuse or reject the breast for a brief period, either with the return of the menstrual cycle or from a particular food that the mother includes in her diet. But we haven't seen any long-term cases of breast refusal. I will cite two anecdotes, however. One is a mother who had a severe case of thrush, and she had been given a whole set of pharmacological preparations by her general practitioner. She was putting Timodene, which is for athlete's foot, on her nipples, and the baby was going to the breast but pulling back. She also smoked, and we weren't sure if it was the taste of the nicotine or tar products in her milk. While chatting with her, I squeezed some of this Timodene out onto my finger and tasted it, and it was quite revolting. Clearly, the Timodene was responsible for this baby's reluctance to go to the breast, and that had been going on for eight weeks.

The next example is also quite disconcerting. Recently we saw two babies whose first breastfeedings after delivery had been interrupted to give oral vitamin K. The babies grimaced at being given the vitamin and then refused to breastfeed for the next five days. Now, if you want to teach a baby what is harmful and bad, you give it a feeding and then follow it with a distasteful flavour, a perfect case of one-trial learning. You have to be very careful about when oral preparations are given to the baby, and not give them in association with the first or subsequent breastfeedings.

Dr. Prentice

I wish to continue with the discussion about irreversibility, because certainly in our Gambian experience it is difficult to see how that fits in. Certainly, we see women whose breastmilk volume goes way down in the wet season, possibly because they have become very anorexic with various iufections. Then their

breastmilk volume will come back up again, will double, and they will be well past the six weeks of lactation at that stage.

Dr. Woolridge

If one accepts that the calibration process takes four to six weeks, the results of down-regulation may differ if the weaning process invades that critical period or comes after it.

Dr. Prentice

What we see is at a later stage. This makes me wonder about the underlying physiology: for example, the role of the number of lactation cells, and what affects their longevity. Are we observing down-regulation? Is the process truly irreversible? What proportion of your subjects producing less than 450 ml of milk were in the irreversible group? Could those you were calling lazy children get used to being down-regulated? Would those mothers respond by increasing milk volume?

Dr. Woolridge

There is some overlap between the groups in about 4% of the clinical population. So I am not suggesting that we should suddenly recalibrate our views, but it is a possibility to be aware of; that is, the process of down-regulation can create clinical dilemmas.

Dr. Victora

I have a question about one of the Ten Steps to Successful Breastfeeding, which relates to the use of pacifiers or dummies. We looked into the literature a couple of years ago and found virtually nothing. Since then, we have done a couple of studies in Brazil that showed that children who had a pacifier introduced in the first month of life were three times more likely to be weaned in the subsequent three to four months than children who were not using a pacifier. The magnitude of this effect was about as large as that of introducing a bottle with artificial milk, so we were quite impressed by our finding. Obviously, we can't know whether this is a cause–effect association, or if pacifier introduction is a maternal strategy for weaning the child. I wonder if you have any data on that, and also if you could let us know if you have had any success in the United Kingdom in preventing mothers from introducing the pacifier?

Dr. Woolridge

We did try to discourage the use of pacifiers up to the time Ed Mitchell found that pacifiers might be protective against sudden infant death syndrome. We are still quite anxious to find out what the explanation for that particular finding is. It is an area where there is huge reluctance, as many women in the United Kingdom use pacifiers quite extensively. Here is one scenario of how these behavioural problems come about. Let's say you have a baby who has had access to his thumb or fist *in utero* and has become used to sucking on a small, rigid, discrete object. Suddenly the object is no longer available. The baby is encouraged to go the breast, but it doesn't find the breast as physically discrete in terms of its tactile qualities. The baby initially refuses the breast, but the midwife is rather heavy-handed and insists that the baby go to the breast. The baby starts to fight and refuses the breast, and after about three days of this, someone eventually gives in and gives the baby a bottle. The baby thinks, "Wonderful, this is what I have been missing out on," as this is closer to the thing that the baby has been used to. There is some evidence in some babies that, if you like, some antenatal preconditioning changes their expectation of what they should get afterwards. I will show you one last slide. There is much talk about "nipple confusion," which is an expression I don't like. Having trained as a zoologist, I thought I would bring you a piece of Dutch ethology. This is a slide showing how you can fool an oystercatcher into incubating the wrong clutch of eggs. If you give it a clutch of eggs that is larger than its normal clutch, it will incubate those in preference to its own clutch. If you give it a football that is painted to look like its eggs, it will try to incubate that. This is what is called a supernormal stimulus. It's so good at switching on the animal that it can't be refused. Nature didn't expect scientists to come along and paint footballs the colour of eggs. I do think that bottle teats and pacifiers represent supernormal stimuli for the baby. If you like, they stimulate the mouth with a greater tactile strength. For some babies, if breastfeeding is unsatisfactory, they will actually refuse the breast in favour of this more tactile object.

Professor Hanson

You made a comparison between lactating mothers in the United Kingdom and in Thailand. I would like to ask if you could qualify that a bit. Does this mean you are comparing British mothers who are exclusively breastfeeding with mothers in a traditional society, where I am convinced they rarely breastfeed exclusively? For instance, on the Indian subcontinent, a number of traditional foods that are introduced early to the infant are heavily contaminated and may have severe consequences for the infant's future life. A number of severe infections originate from this feeding practice. Once they start other

foods, exclusive breastfeeding is rare. Could you speak about this?

Dr. Woolridge

I think the boundaries are very blurred. In Thailand some women initiate weaning foods purely on an experimental basis, introducing very low levels of supplement from, say, one month to three months of age. It's only at about four months that they start to give those weaning foods in substantial amounts, but I agree about the potential contamination. What is intriguing in Thailand is that many of the traditional methods of preparing weaning foods make the food sterile. They will steam rice in a vine leaf, which removes the pathogen load. In the United Kingdom very few mothers actually exclusively breastfeed. The specific recommendation of the Department of Health is to delay the onset of weaning until three months, but when you survey women, you find that most of them have offered their babies something by 10 weeks of age. So in fact there is not quite the discrepancy you might expect between these two cultures.

Professor Hanson

I will not be using the term weaning food in the same way that you do, because from the start of breastfeeding, the whole family—for instance, in Pakistani societies—will participate in feeding the baby and will put all kinds of food in the baby's mouth. This certainly brings the risk of infectiou and doesn't bring much energy or useful food to them. It is a risk that I think is often disregarded. You would need someone to stay with the family to find this out. What has been called exclusive breastfeeding has often not been.

Dr. Hartmann

I would like to go back to the relationship between socio-economic class and breastfeeding. The same sort of thing happens in Perth, Australia. In the high socio-economic class about 80% of mothers breastfeed to six months of age. But this is a very recent behaviour. I think the problem is that we haven't successfully reached the lower socio-economic classes with the breastfeeding message, and that is why breastfeeding rates have reached a plateau.

Dr. Woolridge

I agree, and unfortunately that group is often also very difficult to target in many other respects, such as in relation to the discontinuation of smoking and the way in which they use their financial resources.

Dr. Rasmussen

I want to come back to the comment on the pacifiers and offer you an alternative theory from the maternal perspective. A hungry breastfeeding infant is a vigorous young person who may make the mother's nipples quite sore. The introduction of a pacifier can have what I call the "nipple-saving effect" on breastfeeding continuation in women who might otherwise discontinue. Now in that case you may have women whose breastfeeding is already very adequate, and the pacifier has no effect whatsoever. It may be superior to giving the baby other foods, or it might not be.

Dr. Woolridge

Clinically, our objective when we are counselling women with distressed, unsettled infants is based on the premise that the infant has an appetite-control mechanism and that the most likely regulator of that control is fat intake. We try strategies that maximize the efficiency of milk delivery, so that she can help her baby achieve a state of satiety. You are quite correct that, even when she has an ample supply of milk, if the baby is unsettled, she is likely to resort to a pacifier to find some other way of settling the baby, rather than have her nipple traumatized in the process. Clinically, we focus on the primary target of ensuring delivery of synthesized milk, and then we address colic and other concerns as secondary matters.

Dr. Valdés

One thing I was surprised to see was the differences between economic classes. In the developing countries it is just the other way around: our lower-economic-level mothers nurse much more than those at higher levels. At the same time, we feel that mothers in the lower economic groups are easier to reach. We are much more successful in addressing and changing their behaviours.

Dr. Woolridge

Certainly, there are ways in which it is quite inappropriate to compare an industrial country with Thailand. In the United Kingdom in 1940, the picture is reversed. What is surprising is how difficult we are finding it to target women in the promotion of such a recently acquired practice. Artificial formula was quite appropriately developed as an emergency backup option, but the trouble is that it has become the first choice of too many people.

Dr. Valdés

I have some comments related to pacifier use. I can't understand why the mother would have sore nipples.

Dr. Rasmussen

Poor positioning would do it.

Dr. Valdés

If the mother correctly positions the infant when she breastfeeds, for whatever time, she won't have sore nipples. But what we observe, in waiting rooms for example, are mothers who naturally put the baby to the breast when the baby cries. There, yon have short feedings. The mother who uses a pacifier instead of putting the baby to the breast loses an opportunity to feed.

Dr. Pollitt

Just a short comment in connection with this issue of "nipple coufusion." We have to remember that sucking on a pacifier is different from sucking on a breast. With the pacifier there is no negative pressure, and the activity of the tongue differs.

Dr. Woolridge

There is also no fluid delivered, so there is no need for phase-locked sucking, swallowing, and breathing, whereas on the breast these different activities have to be phase-locked. On a pacifier breathing is carried out independently from sucking.

Professor Hanson

I'd like to come back to the point of motivating women in poor countries to breastfeed exclusively. We were impressed to find that a motivation campaign in very traditional areas—villages, sub-slums, and city slums—results in substantial increases in this practice. Even traditional societies can be approached very successfully.

Social and biological determinants of lactation

Salvador Villalpando, Samuel Flores-Huerta, Mardia López-Alarcón, and Ignacia Cisneros-Silva

Abstract

During the last decades breastfeeding rates have fallen to such a level that at least one million infant deaths annually have been attributed to the replacement of breastfeeding by formula-feeding. After the recent World Summit for Children, unprecedented efforts were targeted to reverse this trend. The evolution of breastfeeding patterns and related practices in Mexico is presented as a case study. Before the Baby-Friendly Hospital Initiative, the rate of breastfeeding initiation and the average breastfeeding duration in Mexico were among the lowest in developing countries. The use of formula in hospitals was common. Knowledge about breastfeeding and awareness of its advantages were low among the public and health professionals. The International Code related to breastmilk substitutes became law, and the Baby-Friendly Hospital Initiative was included in the National Plan for Health in 1991. Formula manufacturers decided voluntarily to stop advertising their products. After five years, several surveys show noticeable changes in hospital policies and practices regarding breastfeeding promotion and improvement in the rate of breastfeeding initiation and exclusivity. Total duration of breastfeeding, public awareness, and mothers' knowledge about the basics of breastfeeding are increasing. Despite continued inadequate post-partum support and counselling, and an inconsistent effectiveness in conveying to the public the benefits of breastfeeding, progress has been made in the last five years and will be reflected in improved infant health in the near future.

Introduction

Humans are the only mammals whose offspring survives without natnral lactation. This has been made possible on a worldwide scale by technological developments for modifying and preserving milk from other species [1]. As a result, the breastfeeding rate in developed countries has fallen dramatically. In the mid-1940s, about 50% of infants were breastfed up to three months in England and Australia; by 1971, only 25% of American babies were breastfed. Concerns regarding the negative effects of artificial feeding of infants resulted in the active promotion of breastfeeding as a healthier feeding mode. Currently, up to 80% or more of mothers breastfeed up to six months in some countries, although rates are highly variable [2].

A similar decline in the rate of breastfeeding has occurred in developing countries. It started 20 to 30 years later than in their affluent counterparts. The deadly consequences of such a decline are eloquently summarized by Stephen [3] in his report as a representative of the United States Government to the 34th World Health Assembly. He pointed out that at least one million infant deaths in developing countries are due to diarrhoea and malnutrition associated with formula-feeding. As part of the multinational agreement signed during the World Summit for Children, important national and international efforts were directed towards curbing and reversing the prevalence of formula-feeding in developing countries.

Mexico: A case study

To address the social and biological determinants of lactation establishment, I will present the case study of Mexico as an example, because Mexico lags behind many Latin American countries in improving the frequency and duration of breastfeeding [4]. The social determinants will be classified as (1) the general framework represented by the economy and the pertinent national policies, (2) the organizations acting as health-care purveyors, (3) the training and commitment of health-care professionals,

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and (4) the individuals participating in the process of lactation.

The magnitude of the problem in Mexico

Before the Baby-Friendly Hospital Initiative started its operation in Mexico in 1991, the frequency of breastfeeding was highly variable in rural, urban, and metropolitan communities. Recently, Pérez-Escamilla reviewed the studies reporting the prevalence of breastfeeding in Mexico from 1953 to 1988 [5]. In these studies the percentage of women initiating breastfeeding ranged between 84% and 99% in rural and urban populations. For the purpose of this article, the data originally categorized as urban by Pérez-Escamilla were separated into urban and metropolitan, defining metropolitan as cities of more than one million inhabitants during the year the studies were conducted. This distinction is relevant because of differences in rural-to-urban migration rates and in the availability and accessibility of health-care services. As seen in table 1, breastfeeding prevalences at birth varied widely among rural (73% to 99%), urban (79% to 94%), and metropolitan (59% to 86%) populations. Urban and metropolitan populations tended to have lower prevalences of breastfeeding. The prevalence was progressively lower at three and six months post-partum in the three categories. The most notable reduction occurred in the urban and metropolitan groups. The wide variability in the prevalence might be attributed to differences in the operational definitions of breastfeeding, differences in sampling procedures, and the extreme differences in the sample sizes of the referred series (median, 105 subjects; range, 50 to 5,011).

A more reliable picture might be obtained from three nationwide studies [6–8]. The proportion of never-breastfed infants in the 1986 National Health Survey in the 32 Mexican states [6] ranged from 5% to 34% (median, 21%). Another study, representing all geographic regions and both urban and rural populations, found an overall prevalence of breastfeeding in the first months post-partum varying from 60% among the urban elite to 89% in rural populations [7]. These figures dropped to 18% and 54%, respectively, at six months. The National Nutrition Survey of 1988, based on a probabilistic sample, reported that 13.8% of infants younger than four months never received breastmilk, while 60% were fed breastmilk for at least four months, but only 11.5% were exclusively breastfed for this period. They found significant regional differences in the prevalence of breastfeeding and determined in a hazard analysis that better living conditions (a proxy for socio-economic situation), higher levels of maternal education, introduction of other milks, and living in urban municipalities were detrimental to breastfeeding. Data about exclusive breastfeeding, defined as being fed breastmilk but no other milks or liquids, were available in only two series [7–9]. The prevalence of these feeding categories at one month post-partum was 19% (7) and 23% (8, 9), and at three months, 0% and 3%.

Surveys conducted after the Baby-Friendly Hospital Initiative was launched indicate that the prevalences of breastfeeding and exclusive breastfeeding are increasing. In metropolitan Mexico City, the initiation of breastfeeding was reported as universal [10]. Within the first month post-partum, breastfeeding prevalence was 76%, with an 11% rate of exclusive breastfeeding; at four months post-partum, the rates fell to 57% and 4%, respectively. Preliminary data from a larger study conducted in 36 public and private hospitals in 1994 and 1995 showed that before hospital discharge, the overall prevalence of breastfeeding was 87%, and the prevalence of exclusive breastfeeding was 70% (E. Rios, personal communication, 1995). Another study combining data

TABLE 1. Median (range) prevalence of breastfeeding according to residence and age of child in the series reviewed by Pérez-Escamilla and Dewey [5][a]

	Rural		Urban		Metropolitan	
Age	No. series	% breast-feeding	No. series	% breast-feeding	No. series	% breast-feeding
Birth	13	91 (73–99)	9	85 (79–94)	5	66 (59–86)
3 mo	2	73.5 (63–84)	6	55 (33–78)	6	54 (19–80)
6 mo	9	77 (47–99)	4	52 (33–52)	6	36 (12–52)

a. The series represent samples or subsamples from individual geographic localities defined by the authors in each article.

from mother–infant pairs participating in a breastfeeding-promotion programme and data from controls reported a 93% prevalence of breastfeeding at one month post-partum, falling to 74% at four months post-partum. No data on exclusive breastfeeding were available [11].

Economics and national policies of breastfeeding

The manufacturers of infant formulas are frequently international enterprises. Their market interests go beyond formulas and even beyond specialized products for infants and children. In Mexico one manufacturer controls more than 75% of the infant formula produced within the country and more than 97% of the powdered formula. This almost monopolistic control gives manufacturers a great influence on market regulation [12, 13].

The International Code for Marketing Breastmilk Substitutes was adopted by the Mexican health authorities in 1989. Two years later, the Mexican Congress enacted the code into law. The Ministry of Health included the Baby-Friendly Hospital Initiative in the National Plan for Health [14]. As a result, by the end of 1994, 15% of the 532 qualified hospitals in the country were awarded the title of Baby-Friendly Hospitals [15]. Before the Baby-Friendly Hospital Initiative was implemented in Mexico, formula and baby foods were advertised extensively and promoted heavily by hospitals, paediatricians, and nurses. A very high percentage of hospitals received free or reduced-price formula from manufacturers. Only 7 of 59 hospitals purchased all their formula, and only 2 paid full price [12]. Usually, hospitals were supplied by more than one manufacturer. In the majority of cases, hospital officers stated that such donations were unsolicited. In addition, manufacturers were allowed to distribute samples of formula to mothers at the time of hospital discharge. Mothers were approached outside the hospital premises in most cases, thus relieving hospitals from legal responsibility.

In 1993 all companies selling infant formulas in Mexico signed a voluntary landmark agreement committing themselves to stopping these practices. As a result, the report of the US Agency for International Development/Latin American and Caribbean Health and Nutrition Sustainability (USAID/LACHNS) [16] found that distribution of free samples or gifts to mothers by formula companies almost vanished from the two hospitals surveyed. In a subsequent study of 36 hospitals conducted by Rios et al. (E. Rios, personal communication, 1995), officers from seven hospitals acknowledged accepting free or low-priced formula supplies.

Health-care institutions

Perhaps the most contradictory aspect of Mexican health-care institution policy related to maternal and infant health is the mandate by labour laws to provide mothers of infants a free six-month supply of a breastmilk substitute. In the past, conflicts within hospitals between the declared norm and the practice were frequent. In a survey of 59 hospitals in 1991, administrators claimed to have installed facilities and to have adopted routines favourable for breastfeeding. Nevertheless, investigators observed significant deviations from their claims [17]. For instance, none of the hospitals practised early mother–infant contact. Although most claimed to have facilities for rooming-in, only 5% practised it systematically. Most hospitals kept newborns in nurseries and provided mothers with portable cribs for the infants during the daily visits of the infants to the mothers' rooms. Infants were fed formula in the nurseries, having very few occasions to suckle at the breast. Only 4% of the hospitals allowed exclusive breastfeeding during the day; almost 16% did so during the night. The hospital schedules for breastfeeding were related more to staff shortages than to intentional policies. About half of the hospitals surveyed provided new mothers with written information about how to feed their babies at discharge. Although material encouraging breastfeeding predominated, it was astonishing to find that 20% of the hospitals provided information encouraging bottle-feeding [17].

Preliminary data obtained by the follow-up study in 36 hospitals by the Nestlé Infant Formula Audit Commission conducted by Rios from 1994 to 1995 (E. Rios, personal communication, 1995) provide evidence of a substantial improvement in those policies and practices. About half the mothers suckled their babies in their own beds, though only a small percentage were allowed to suckle within the first 30 minutes post-partum. About 80% of breastfeeding women had proper facilities in the hospital that enabled them to feed their infants throughout the day. At discharge 40% of the mothers reported they had participated in educational activities about breastfeeding, and 4% had received information exclusively about formula-feeding. The USAID/LACHNS report [16] found that elimination of infant formula from hospitals was a widespread practice, probably because breastfeeding is less time-consuming and produces substantial savings. In contrast, the implementation of other policies had less success. In two hospitals with full rooming-in, 40% to 60% of the infants were fed before the initiation of breastfeeding, most of them with oral glucose solutions. The funding for educational activities and counselling

was low, and the intended educational messages were not conveyed efficiently.

A recent survey compared the performances of 14 public hospitals in Mexico City. Half were certified as Baby-Friendly Hospitals [18]. The evaluation was based on interviews with mothers on discharge from the hospital. The questionnaires explored the hospitals' policies related to the "Ten Steps to Successful Breastfeeding" [19]. Certified hospitals scored significantly better than non-certified hospitals in many areas: pre- and post-partum instructions on infant feeding, the numbers of infants suckled within the first 30 minutes of life, rooming-in, exclusive breastfeeding, non-use of feeding bottles, and availability of support groups. Encouragement from the health team to breastfeed was similar in both types of hospitals. Formula was prescribed for a negligible proportion of mothers. It must be underlined that despite the differences described, the non-certified hospitals have had a good level of compliance with the policies of the Baby-Friendly Hospital Initiative. The effect of rooming-in on the initiation of breastfeeding was compared in a cohort of 15,574 mother–infant pairs [20]. Sixty-eight per cent of the infants in the rooming-in programme breastfed within six hours after birth, and all were breastfeeding at discharge. None of the infants in the traditional wards did so. In spite of the shortcomings described, active breastfeeding programmes have a clear and positive impact on breastfeeding prevalence.

Another problem is the high proportion of Caesarean deliveries, which might interfere with the decision of women to breastfeed. A longitudinal study by our group [11] found that almost 30% of the women in a cohort delivered by Caesarean section. These figures are consistent with many other reports. Although women giving birth vaginally breastfed more frequently than those delivering by Caesarean section, breastfeeding rate differences vanished by 60 days post-partum, making it evident that rooming-in stimulates the initiation but does not lengthen the duration of breastfeeding.

Health professionals

There is a general notion that physicians and allied professionals in Mexico lack adequate skills to advise lactating women about initiating and sustaining lactation. Such a notion is based on the evidence that their knowledge of nutrition is very superficial [21]. Nutrition is not included in the curricula of medical schools as an individual discipline. The principles of infant feeding are taught in courses of paediatrics. The most popular textbooks of paediatrics have 3 to 6 pages of information on human lactation and 9 to 25 pages of information on artificial feeding, and comparable amounts of classroom time are devoted to these topics.

In a recent study more than 500 medical students and more than 170 residents from different Mexican universities answered a questionnaire exploring their knowledge of the basics of nutrition [22]. The critical grade for an appropriate level of knowledge was 4.3, which was higher than the average grade of the medical students and residents. In 1992 the National Centre for Maternal Lactation launched a programme to train health professionals in infant nutrition and breastfeeding. The Centre produced educational materials to support the future educational activities of those graduating from the Centre. There has been no published evaluation of this programme.

Individual beliefs

The multiple social factors that are important to the establishment of lactation vary among cultures. In Mexico regional differences often encompass significant cultural diversity. Such differences will be illustrated by data gathered from two independent cohorts of 346 urban and 216 rural mother–infant pairs.

Communities studied

The rural setting is the Otomi Indian village of San Mateo Capulhuac north-west of Mexico City ($n = 216$). The 5,000 inhabitants live mostly from subsistence agriculture, with maize the main staple. There is little consumption of animal products. The diet of lactating women is marginal in energy and protein and low in fat. The level of physical activity is high [23].

The urban setting is represented by two neighbourhoods of Mexico City: Iztapalapa in the south-east ($n = 170$) and Tizapan in the south-west ($n = 176$). Both are densely populated by families of low-income workers living in small apartments. The diet of urban lactating women is closer to the Recommended Dietary Allowances [24] in energy and protein than that of rural women. Their lifestyle tends to be sedentary.

Besides the geographie differences, the two groups have significant differences in level of poverty, education, and accessibility to a paying job. There are also differences in sanitary facilities in the home. Although piped water was available in most rural households, it was not chlorinated, and fecal contamination was the norm (table 2).

In the rural community, 99% of the infants were predominantly breastfed in the first two weeks (other liquids could be provided except for non-

TABLE 2. Socio-economic characteristics of the communities

Characteristic	Rural ($n = 216$)	Urban ($n = 346$)
Poverty level of the community[a]	4	2
Household characteristics		
piped water	93%	92%
flush toilet	6%	87%
dirt floor	64%	11%
refrigerator	5%	60%
crowding[b]	91%	80%
Maternal characteristics		
education, median years (range)	3 (0–6)	9 (2–14)
living with partner	98%	87%
working outside home	2%	32%

a. 1 = mildest, 5 = worst (see ref. 24 for explanation of scale).
b. Three or more persons per room.

human milk). These high rates prevailed up to six months (table 3). None of the mothers failed to breastfeed their previous children, and all mothers reported being breastfed as infants. Formula was not commercially available in the village at the time of the study, although feeding bottles were present. The price of one can of formula in the nearest town was equivalent to one day's salary. The high prevalence of breastfeeding seems to have very strong cultural support, while formula-feeding was not practised for economic reasons. The breastfeeding rate was also high (93%) immediately after delivery in the urban group. It declined progressively in the post-partum period. By the third month fewer than three-quarters of the women were providing any breastmilk to their infants, and only 40% of the mothers were predominantly breastfeeding. At the end of the sixth month, 52% of the mothers were feeding their infants any breastmilk, and only 25% were feeding breastmilk without additional non-human milk (table 3).

Breast- or bottle-feeding: Who decides?

In the case of rural mothers, the high and protracted prevalence of lactation implies that such a decision was made from a very limited set of options. The decision process in the case of urban mothers is more complicated. They often have a weaker tradition of breastfeeding. In addition, formula is readily available, and one day's average salary of a low-income worker can buy three cans of formula. Further, about 60% of those workers are entitled to the Social Security benefit of a free supply of formula.

We first asked, "Who decides the feeding mode of a given infant?" The vast majority of a cohort of breastfeeding mothers interviewed two weeks after parturition claimed they themselves made the decision to breastfeed. They claimed that the decision to use formula was the responsibility of a family member or of members of the health-care team [10].

During a follow-up visit at about four months, after infants were switched to formula, the mothers were asked who procured the first can of formula. In almost 40% of the cases, the mother obtained the first can of formula without any professional advice. In 20% of the cases, the first formula was provided or prescribed by a physician or nurse. Overall, deci-

TABLE 3. Prevalence of breastfeeding according to residence and age of child

Age (mo)	Rural ($n = 216$)			Urban ($n = 346$)		
	% predom. breast[a]	% breast + formula	Total	% predom. breast[a]	% breast + formula	Total
0.5	99	0	99	75	18	93
1	98	0	98	67	21	88
2				49	29	78
3	98	0	98	40	31	71
4				38	26	64
5				30	27	57
6	94	0	94	25	27	52

a. Predominantly breast: no other milk, but solid food and other liquids provided.

sions were taken by mothers in 64% of the cases and by health-care professionals in 31% of the cases. These results support the idea that in this group mothers play the leading role in deciding whether the infant is breastfed or bottle-fed.

In response to a questionnaire, 60% of women who discontinued breastfeeding gave "insufficient milk" as the reason. Thirteen per cent stated that the infant refnsed to suckle. Surprisingly, only 9% indicated that the free supply of formula was the reason to stop breastfeeding. These results suggest that in most cases mothers switched to formula spontaneously because they perceived their lactation performance as inadequate.

Other social factors influencing the establishment of lactation

For this part of the study, four weeks of continuous breastfeeding was defined as the successful establishment of breastfeeding. The success rate tended to be higher in better-educated mothers, but the trend was not statistically significant. Working mothers were as successful as those staying at home, probably because labour regulations allow mothers a postpartum leave of absence of 90 days. The level of family income was positively correlated with success. It is important to note that family income covaried with years of education and level of knowledge of breastfeeding. Women living in the same house with their partners were more successful in establishing lactation than single mothers. None of the women in the last category lived alone; they almost always lived with relatives (table 4).

Pérez-Escamilla et al. [10] found no relationship between returning to work and successful breastfeeding, usually because mothers had already discontinued lactation. As in our study, the advice of close friends was one of the most frequent reasons given for introducing formula. Poor socio-economic level and the presence of a partner negatively influenced breastfeeding.

TABLE 4. Relation between maternal socio-economic factors and the establishment of breastfeeding in the urban cohort

Factor	% successful breastfeeding	χ^2
Years of education		
0–6	65	
7–12	81	
>12	72	NS
Employment status outside home		
employed	81	
not employed	68	NS
Monthly household income (US$105)		
1	65	
2	71	
3	85	$p < .05$
Marital status		
married	83	
single	55	$p < .02$

NS, Not significant.

Biological determinants of lactation establishment

The evaluation of lactation performance is critical, because data presented above suggest that concerns about lactation performance may induce mothers to stop breastfeeding. The following data come from a study of 30 mother–infant pairs. Ten were recruited in the rural community of San Mateo Capulhuac, and 20 in the urban community of Iztapalapa. Exclusively breastfed infants weighing more than 2,500 g at birth were followed for the first month of life. The growth of the infants and the output and composition of the milk were recorded.

Growth of Infants

Urban newborns were 100 g heavier than rural newborns on the average, but the difference was not significant. Both rural and urban infants lost weight within 48 hours after birth; urban infants lost significantly more weight than rural infants (197 $\pm$ 74 g vs 122 $\pm$ 30 g; $p < .01$). By 74 hours after birth, all had regained their birthweight. This recovery was followed by a period of fast growth (45 g/day) up to day 30. The mean body weight of both groups was comparable at day 30 to the mean body weight of breastfed infants in the United States.

Maternal milk production and daily nutrient intake of infants

At day 3 milk production (a little more than 360 ml/day) and energy (65 kcal [272 kJ]/kg/day) and lipid (3.4 g/kg/day) intakes of infants per kilogram body weight were similar in the rural and urban groups (table 5). The energy intake was below the energy requirements determined by Lucas [26], using the double-labelled water technique in infants of similar age.

By day 15 milk production had increased to almost 550 ml/day in both groups and energy intake to 97 kcal (406 kJ)/kg/day for urban infants and 88 kcal (369 kJ)/kg/day for rural infants. The differences between groups were not significant, and the absolute

TABLE 5. Energy and macronutrient intakes (mean ± SD) in relation to age and residence of infants

Age/ residence	Energy (kcal/kg/d)	Protein (g/kg/d)	Lactose (g/kg/d)	Lipid (g/kg/d)
Day 3				
rural	65.3 ± 16.7	1.5 ± 0.4	7.1 ± 1.7	3.4 ± 1.4
urban	65.7 ± 23.2	1.8 ± 0.7	6.9 ± 2.5	3.4 ± 1.3
Day 15				
rural	87.9 ± 20.3	1.4 ± 0.4	9.8 ± 2.6	4.8 ± 1.7
urban	97.3 ± 29.7	1.5 ± 0.4	9.9 ± 2.1	5.7 ± 2.6

values were closer to the values published by Lucas [26]. The daily energy and protein intakes at day 3 were negatively correlated with the magnitude of weight loss within the first few days. Such a loss likely indicates a negative energy balance because of insufficient energy intake. We speculate that the infant's hunger might be expressed as insistent suckling and uneasiness during the first stages of lactation. Mothers may have interpreted this as an inability to meet the nutritional demands of infants and therefore discontinued lactation.

On days 3 and 15, the number of suckling episodes per day was similar in both groups. On day 3 the average time the baby spent attached to the breast was about 198 minutes in both rural and urban groups. On day 15, however, rural infants suckled almost 30 minutes per day longer than urban infants. This finding suggests that a stronger stimulus was necessary to maintain milk production.

Although the maternal nutritional status was different in the two groups, the milk volume and energy output were similar. This finding suggests that maternal nutritional status had little impact on the lactation performance at these planes of nutrition.

Conclusions

We have presented evidence that before the Baby-Friendly Hospital Initiative was implemented in Mexico, the proportion of urban mothers commencing breastfeeding was low, exclusive breastfeeding was rare, and the average total duration of breastfeeding was three months. In addition, the marketing practices of formula manufacturers and the practices and policies of both public and private hospitals were detrimental to breastfeeding. All of these measures improved after the Baby-Friendly Hospital Initiative was introduced. This substantial improvement is seen as a consequence of national and international efforts.

Mothers are the chief decision makers in choosing the mode of infant feeding. A lack of adequate support and appropriate advice seems to be responsible, in part, for the short duration of breastfeeding. The energy intake of exclusively breastfed infants is below reported requirements during the first days postpartum. It is associated with a loss of body weight, which might be misinterpreted by mothers as an inability to fulfil their infants' needs, leading them to stop lactation or to introduce some formula feedings.

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Discussion of paper by Villalpando et al.

Professor Hanson

May I just comment on history? The first described case of artificial feeding was by one of the Assyrian kings. Also, in archaeological investigations of cultures along the Indus, many spoons and feeding utensils that were obviously used for artificial feeding have been found. So all through history this has been common. In Sweden in 70 and 150 A.D. there were areas where there was no breastfeeding at all; nobody knows why. And there was a law in Norway from 1040 that mothers should breastfeed, obviously, because of the fact that many didn't, so this is an old thing.

Dr. Prentice

I would like to explore a little more with you and Dr. Woolridge the issue of women feeling that they have insufficient milk. This seems to come out of every culture that we've heard about today, and, certainly, my experience in Africa is similar. Women will say that they are worried that they don't have enough milk. Where formula or other foods are available, they'll move on to either. What is it that women expect of a baby that makes them feel that they don't have enough milk? Dr. Woolridge showed that a lot of perceived milk insufficiency is found in women with milk volume in the normal range. From my own experience, having breastfed in the United Kingdom and in Africa, British women expect children to stay asleep for long periods at night. The family expects it even if the mother doesn't, which puts a lot of pressure on women to somehow make the child not feed at such frequent intervals. I just wondered if similar sorts of cultural problems would be underlying your women's responses as well?

Dr. Villalpando

I think the infant's behaviour often raises the question of whether milk production is sufficient. It is not the same in rural areas, where the infants probably cry as much as urban infants, but they don't have any other option.

Dr. Valdés

Our rural mothers may breastfeed 20 times a day. In the waiting room, they feed once, twice, or three times. When you ask them how many times they have breastfed today, they say maybe one, two, or five times, but they don't have this notion that taking the baby to the breast often is a bother. But for mothers from higher socio-economic groups, if the baby is not quiet for four hours, which was what they were used to when the babies were bottle-fed, they feel they don't have milk.

Dr. Woolridge

I think there is a total difference in outlook between a mother in the United Kingdom and a mother in Thailand. As we have just heard, the mothers in Thailand have no expectation of failing. They just assume it is the only option, and they will do it successfully. Intriguingly, they still report perceptions of insufficient milk, but it doesn't cause them to discontinue breastfeeding. It is a common cultural concern, even in that sort of society. I agree that in the United Kingdom there is an expectation that a baby should sleep for long stretches to fit in with the adult lifestyle. It's an inappropriate expectation, and much of it has been derived from formula-feeding.

Dr. McNeilly

Mary Houston investigated this question of insufficient milk. She concluded that for many women it was a legitimate reason for giving up breastfeeding. If a woman says she doesn't have enough milk, she shouldn't carry on, because it's going to damage the child. Some women were certainly using that as a legitimate excuse to stop breastfeeding.

Dr. Villalpando

I think that is true for our urban group. As you could see, the individual who most often bought the first can of formula without any advice was the mother. She was really legitimizing her decision to stop breastfeeding by saying that she had insufficient milk production.

Dr. Van Esterik

If I may comment on the Thai example, different methods produce very different pictures. I was doing ethnographic work in another part of Thailaud, and the discussions about insufficient milk were quite different. Of course, they are not phrased that way, but I came across two things quite regularly, not in questioning but from observation. First, women were becoming concerned that their breasts were too small, that there was something wrong with their shape. There are pictures on calendars in every tiny hut, and a woman would be very strongly influenced to think about whether or not her breasts were adequate to this task. That's something that I think is changing quite rapidly. The second is a fundamental approach, strongly linked with Theravada Buddhism, that the capacity to nurture well is a result of merit stored from former lives. This means that women talk ahout themselves as being someone who is either a good nurser or not a good nurser, almost as if we would say that this is a characteristic that they would expect to see in themselves. It is also very interesting to think about how women classify themselves as both mothers and women. I know it doesn't fit with the kind of work you were doing, but at least it suggests perhaps another way to look at cultural factors.

Professor Howie

May I make a point about almost a war of commuuication that seems to be a common factor in developed and developing countries? I think one of your slides made the point how clever formula manufacturers are at getting their message across. In fact, they target health professionals even more than they target the patients themselves, and how successful that campaign is! We have seen literature distributed by the mauufacturers who now have an obligation to state the advantages of breastfeeding. They give one page on the benefits of breastfeeding and maybe five pages about cracked nipples, tiredness, and breast abscess. In fact, the section that is supposed to encourage breastfeeding mothers is targeted so cleverly that it has exactly the opposite effect. What do you feel about making a systematic attempt to get better education that is not dominated by the formula manufacturers, so that some misunderstandings about breastfeeding can be overcome? We recently asked mothers who were breastfeeding if they knew that the baby would lose weight in the first few days after birth, and the number who knew this was about 5%. We are simply not getting hasic information over to our mothers, and I suspect from what you are saying that there is a failure in Mexico, the United Kingdom, and many other countries.

Dr. Woolridge

There are two sides to this problem. One is to attack the problem of medical education by working with assistant professors of paediatrics who are lecturing to students, inviting them to seminars about lactation and so forth. This is a huge task. The other is the lack of a strong network of people promoting breastfeeding awareness to hospitals, physicians, and the general public to counteract the propaganda from formula manufacturers, because most literature handed to mothers is prepared by those companies.

Dr. Pérez

What is more comfortable for a working mother three months after the child's birth, breastfeeding or bottle-feeding, and why?

Unidentified speaker

I would say breastfeeding. The situation, though, is that we put so many obstacles against mothers breastfeeding successfully that we have this notion that the mother and baby have to be changed to fit the circumstances of work and so forth. We shouldn't be changing human behaviour, we should be changing working conditions to fit breastfeeding.

Dr. Villalpando

Many years ago the labour laws in Mexico supported long post-partum leaves of absence intended to aid breastfeeding. However, fewer than half of the mothers breastfed for such a long period, so the outcome was the reverse of what many expected.

Dr. Rasmussen

Let me put it another way, that convenience is in the eye of the beholder. If you do a survey in the United States, upper-economic-class women will tell you that breastfeeding is by far the most convenient, for all of the reasons we know. If you ask lower-economic-class women the same question, you don't get the same answer. Their lives are chaotic, they're

on the bus, they're embarrassed to breastfeed on the bus. The last thing in the world they consider breastfeeding to be is convenient for them. The answer to Dr. Pérez's question depends on a woman's life circumstances, and whether breastfeeding works for her. It's wonderful to have labour laws to say you're entitled to a maternity leave, and if you have a job or are protected by these laws, that may be wonderful in other ways. The United States is in the embarrassing position of not even having such laws, so I can hardly cast any stones. What about women who work in the informal sector for whom there is no protection whatsoever? Their labour is just as valuable to their families, the interference of their work conditions with breastfeeding may be as great or greater, yet they have no protection at all. In their case, convenience, again, may be an issue.

Dr. Valdés

We are researching that area. We have a study on working women, and one aspect we are concerned about is women's satisfaction with breastfeeding. We were surprised that the mothers in the control group who did not breastfeed were very satisfied, and the mothers who exclusively breastfed or human-milk-fed for six months, even while working, were equally satisfied.

Professor Hanson

I use the Swedish example, where it is rare for mothers not to breastfeed. They are entitled to 18 months off, most of that period with full pay, so it works.

Dr. Valdés

To go back to the issue of insufficient milk and mothers' perceptions, I think many women don't understand lactation well. They are encouraged to think that their milk will come in and their breasts will feel very full. But at about four to six weeks the breast physiologically adapts, so that they have less fullness and enlargement. Some women interpret the change in sensation to mean that they have less milk. They really need to understand that lactation is an adaptive process, and even though the breasts are quite soft, they still produce milk.

Professor Hanson

One issue I don't think is covered much in connection with the insufficient-milk syndrome is the contribution that the infant makes to the mother's perception about insufficieut milk. We have to remember that the infant regulates its intake by many different aspects of its sucking behaviour. To a large extent, this is accomplished by differences in sucking amplitude or frequency. The infant has some degree of control over what actually takes place. We seldom look at the contribution the infant makes to the mother's decisions regarding feeding.

This also extends to another comment I want to make in connection with the determinants of milk production. There is an enormous variability in birthweight in different populations in the world. In Sweden, for example, the average is approximately 3,500 g. In Santa Maria Cauque, Guatemala, the average is approximately 2,600 g, a 900-g difference. There is likely a relation between an infant's birthweight and its sucking behaviour. The degree of breastfeeding success in different populations is also determined, in part, by other infant characteristics. Yet in general, there tends to be a greater emphasis placed on the mother as the one who will make the final decisions on what is going to happen, and not enough attention is given to the infant's roles.

Dr. Garza

Let me go back to the role the infant plays, because I think it is an important one. In studies we did about 10 years ago, we were interested in understanding whether infants were hungry whenever they demonstrated behaviours that the mother interpreted as hunger. We followed women longitudinally for four months beginning at about the third month postpartum. Women who were planning to breastfeed for 6 to 12 months were recruited. At the point they introduced solid foods, we asked why they were doing this. I think 100% of them said it was because the child was either fussy or not sleeping. They were interpreting this as evidence that the child was hungry and, therefore, that they were unable to sustain or increase milk production sufficiently to satisfy the infant.

The remarkable thing, however, was that when we measured the energy consumption of infants before and after the introduction of solid foods, we found no difference. Thus, I think children give certain cues that women interpret as hunger but that are, in fact, driven behaviourally by other needs. The child likely has reached the point where it wants to put something else in its mouth, and mothers tend to interpret those cues as hunger. Because the infant's behavioural response to other foods is often positive, their mistaken interpretations are reinforced. In fact, those responses appear to have nothing to do with physiological hunger defined in the usual terms. There are inappropriate periods in early infancy to introduce other foods. The physiological timing of complementary foods determined by

behaviours other than hunger is dependent on a number of conditions that relate to the infant's surroundings.

Dr. Villalpando

Studies have investigated infant intake by 24-hour test weighings. Fewer than 50% of suckling episodes result in the intake of more than 50 g of milk. The remainder result in the intake of as little as 5 or 10 g of milk. This suggests that the infant is not really hungry. It's just sucking for the joy of sucking.

Unidentified speaker

I would like to return to the determinants of a woman's preference, because I cannot understand why generally in Latin America, fewer than 20% of women are fully breastfeeding at six months post-partum? We need to find an answer to that.

Unidentified speaker

I haven't heard anybody talk about the same woman with different babies in successive births. Is past behaviour predictive of future behaviour?

Dr. Victora

We did research on that. Some mothers who tended to breastfeed one child for a long time were likely to do the same with the next child. If mothers breastfed a very short time, the results were about the same in subsequent pregnancies. There was, however, a gray area when mothers breastfed from one to six or seven months. They were very unpredictable. One could not predict what would happen with the next baby.

I would like to go back to a point raised earlier. I think babies have very strong personalities. When we did our pacifier study, the main factor influencing pacifier use was the infant. Some babies just refuse them, and those are the babies who tend to breastfeed longest.

Dr. Prentice

To add a caveat to that, in our African experience, where 100% of women were breastfeeding for 18 months or so, women in successive lactations tended to show a characteristic breastmilk volume and breastmilk composition. Thus, it's a mixture of culture, maternal feelings, and the way a mother's breasts work.

Breastfeeding and the suppression of fertility

Alan S. McNeilly

Abstract

Breastfeeding suppresses fertility for a variable length of time, but when certain criteria are applied, it can be a reliable contraceptive. The individual variation in duration of infertility is directly related to suckling activity. As suckling declines, follicle growth resumes and ovulation may occur. Infertility is maintained by suckling-induced disruption of the normal pattern of pulsatile luteinizing hormone release and is related to an increased sensitivity of the hypothalamus to the negative feedback effects of oestradiol. Even if ovulation does resume, the corpus luteum function is often insufficient to maintain pregnancy. Attempts to alter suckling activity to prolong lactational infertility are not successful, but maintenance of reasonable suckling frequencies of normal duration can protect women from pregnancy for a prolonged period postpartum.

Introduction

It is quite clear that breastfeeding results in a suppression of fertility for a prolonged period of time, depending on the pattern of suckling behaviour [1–3]. Stimulation of the nipple during suckling results in three responses: first, the release of oxytocin from the posterior pituitary to allow release of the milk present in the breast to the baby; second, the release of prolactin, which is essential for milk production for the subsequent feeding; and third, the suppression of gonadotrophin secretion, which results in suppression of ovarian activity. When established, the pattern of suckling varies considerably, and this is dependent on the mother and child and is not necessarily controllable. Throughout lactation, the duration of lactation and the duration of infertility are directly related to the suckling pattern. Attempts to increase suckling frequency to maintain longer durations of amenorrhoea have not been successful, because the mother and the baby interact so that the amount of nutrition received by the baby remains fairly constant [4]. As suckling frequency is artificially increased above that established in lactation, there is a concomitant decrease in suckling duration at each feeding. Thus, the overall duration and intensity of suckling remain the same, and there is no overall effect on the duration of infertility. It is, therefore, important to understand all the different components of suckling that relate to the suppression of fertility, and these have been reviewed in detail recently [2, 3, 5]. This article briefly reviews the present state of knowledge regarding the principal mechanisms involved in suckling-induced infertility.

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Ovarian activity and the interbirth interval

The components of the interbirth interval are important to understand before any discussion of the control of gonadotrophin secretion during lactation. The interbirth interval consists of four periods: (1) the recovery from pregnancy; (2) a period of amenorrhoea during breastfeeding; (3) the resumption of the ovulatory cycles (which may not take place if a new conception occurs); and (4) finally, a new pregnancy. Over a number of years, we have investigated the interactions between the suckling pattern and the resumption of ovarian activity in relation to the pattern of gonadotrophin secretion. In some women, where suckling is maintained at a high level, ovarian steroid secretion can be suppressed for a number of months and even years, even in well-nourished Western societies [1]. In other women, where suckling frequency is lower, ovarian activity will resume earlier. In Edinburgh it was shown that if the frequency of suckling is maintained above five times a day and the duration is maintained above 65 minutes a day, amenorrhoea will often be the consequence [6]. Al-

though the exact frequency and duration of suckling required to maintain infertility vary among societies, it is usually possible to establish a guide for the suckling required [7].

During the period of lactational amenorrhoea, the plasma concentrations of oestradiol secreted by the dominant follicle(s) remain minimal, in contrast to the normal increase seen during the follicular phase of the normal menstrual cycle [2, 3]. These results suggest that there is minimal ovarian activity, as follicle development during the normal menstrual cycle is always associated with an increase in oestrogen secretion. During early lactation (up to 12 weeks post-partum), ultrasound visualization of the ovary confirmed the absence of follicle development [8]. At later stages in lactational amenorrhoea, however, although oestrogen secretion remained minimal, follicles up to pre-ovulatory size (around 20 mm diameter) were detected by ultrasound [9]. The reason for the presence of follicles that secrete low amounts of oestrogen relates to the effect of suckling on the secretion of the gonadotrophins luteinizing hormone (LH) and follicle-stimulating hormone (FSH). The low steroid-secreting activity of these follicles presumably relates to a reduced input of gonadotrophin, particularly of LH. This possibility will now be discussed.

Changes in FSH and LH

During the menstrual cycle, a rise in plasma FSH at the beginning of the cycle stimulates the growth of a cohort of follicles, which increase to around 10 mm in diameter by the mid-follicular phase. At this stage, a single follicle continues to grow up to around 20 mm in diameter, becoming the pre-ovulatory follicle that will ovulate. The selection of this dominant follicle is dependent on a fall in the plasma concentration of FSH occurring about days 6 to 8 of the follicular phase. As the follicle grows, it acquires the ability to secrete oestradiol by conversion of androgen from the outer thecal layer of the follicle to oestradiol by the granulosa cells within the follicle. Only LH, released in pulses, stimulates thecal androgen production. FSH alone does not stimulate steroid secretion from the ovary. The increase in plasma oestradiol secreted by the developing pre-ovulatory follicle leads to positive feedback and the discharge of the pre-ovulatory surge of LH. This induces ovulation, luteinization of the follicle, and formation of the corpus luteum, which secretes progesterone in response to a slow pulsatile secretion of LH. The progesterone and oestradiol released by the corpus luteum decrease the pulse frequency of release of gonadotrophin-releasing hormone (GnRH) from the hypothalamus, which drives the pulsatile release of LH from the pituitary. The decline in GnRH pulsatile stimulation, together with inhibin A released from the corpus luteum, leads to a major suppression of release of FSH and an inhibition of follicle development during the luteal phase. If conception does not occur, the corpus luteum regresses and the resulting drop in steroid and inhibin concentrations results in an increase in FSH that initiates the next wave of follicle development. These events are all closely coordinated and regulated by the rate of pulsatile secretion of GnRH from the hypothalamus, which stimulates the pulsatile release of LH. During the follicular phase of the normal menstrual cycle, the GnRH/LH pulse frequency increases to around one pulse per hour, and any disruption or slowing in the pulsatile release of GnRH/LH prevents normal follicle development and reduces steroid secretion by the developing follicle.

During breastfeeding the plasma concentrations of FSH increase rapidly after birth. By four weeks post-partum, they are within the normal early follicular range, whether or not breastfeeding occurs [10]. These levels of FSH are maintained throughout the duration of lactational amenorrhoea and are substantially higher than those seen during the luteal phase of normal cycles. Thus, any apparent absence of follicular development associated with low oestrogen secretion cannot be due to lack of FSH. Indeed, it is probable that this maintained high level of FSH is the cause of the observed growth of follicles up to the pre-ovulatory level. The low steroid secretion must relate to the difference in pattern of LH secretion.

The pattern of 24-hour profiles of LH secretion at four weeks post-partum is very variable. Most women show no evidence of pulsatile secretion of LH, whereas in some there is a resumption of LH pulsatile secretion. But this occurs at random and at a slow frequency [11]. In some women with slow pulsatile LH secretion, pulsatile release of FSH is also seen, a rare occurrence in the normal menstrual cycle that is related to the very low levels of oestrogen and inhibin released from the inactive ovary. As the pulse frequency of LH secretion increases, the pulsatile release of FSH is lost, and a natural pattern of FSH secretion similar to that in the normal cycle resumes. Thus, FSH pulses may occur, but only when the negative feedback from the ovary is suppressed. After four weeks there is a gradual increase in the frequency of pulses of LH, but for many weeks, particularly during lactational amenorrhoea, the pulse frequency remains erratic and below the normal follicular phase frequency required to stimulate normal oestradiol secretion from any developing follicle. Thus, although the plasma levels of FSH are sufficient to stimulate follicle development as seen by ultrasound, the suckling stimulus prevents the resump-

tion of a normal frequency of pulsatile LH secretion, and the follicles make only limited amounts of oestradiol. The rate of return of normal pulsatile secretion is very variable among women, and it is this variation that causes the variation in the resumption of fertility. It is presumed that the variability is due to the differences in the patterns and intensity of suckling, and that this is why it is difficult to control.

The disturbance in the pattern of pulsatile LH release is almost certainly the cause of the lack of oestrogen secretion by follicles, resulting in a lack of ovulation. In a study in which GnRH pulses were replaced at the normal follicular phase frequency of once per 60 minutes in breastfeeding women at six weeks post-partum, at a time when ovarian activity was completely suppressed as indicated both by oestrogen and by ultrasound, normal pre-ovulatory follicle growth and oestrogen secretion were induced without a problem [8]. Ovulation occurred, although this was followed by an inadequate corpus luteum. When the pump was turned off and GnRH infusion stopped, ovarian activity was suppressed for at least 10 weeks in most women. Thus, restoring a natural, follicular-phase pattern of pulsatile GnRH secretion in breastfeeding women will induce the growth of normal pre-ovulatory follicles, indicating that the aberrant pattern of LH secretion during lactational amenorrhoea causes the failure of normal oestrogen secretion. Therefore, no pre-ovulatory LH surge would be induced, owing to the lack of oestrogen-positive feedback, and ovulation would not occur. Prolactin and suckling remained high throughout the period of GnRH pulsatile infusion between 6 and 10 weeks post-partum, showing that there was no direct interference of prolactin with gonadotrophin action at the ovarian level.

The mechanism by which suckling interferes with the normal pattern of GnRH release is unclear. The potential role for endorphins acting in the hypothalamus has been discussed elsewhere [3, 12]. Infusion of the opiate antagonist naloxone failed to increase the secretion of LH and FSH in a significant manner in normal breastfeeding women [13]. Nevertheless, in women receiving the progesterone-only birth control pill, a small increase in LH and FSH release did occur. This could be expected, as the negative feedback effect of progesterone on GnRH pulsatile secretion during the luteal phase of the menstrual cycle is thought to be mediated by an increase in opiate tone within the hypothalamus. One interesting observation was that treatment with an opiate antagonist increased the amount of LH and FSH released in response to GnRH. At the present time, there is no explanation for this effect, because no opiate receptors have been described in the pituitary gland. It may be that the opiate tone is so high in the hypothalamus that we are unable to give sufficient opiate blocker to affect the system. Because of passage of the blockers to the infant through the breastmilk, however, it would be unethical to use higher doses than we originally used. Thus, a role for endorphins in the suckling-induced disruption of GnRH release remains unproven in women.

There is one final aspect of the control of GnRH release, and hence of LH and FSH release, which is very important. Treating breastfeeding and bottle-feeding women with oestrogen at different times during the return of fertility during lactation showed clearly that there was an increase in sensitivity to the negative feedback effects of oestrogen on LH and FSH secretion and a failure of positive feedback, leading to a failure of oestrogen to induce the pre-ovulatory surge of LH [14]. We have now shown that breastfeeding women are hypersensitive to oestrogen: the use of transdermal patches to increase plasma concentrations of oestradiol to early follicular phase levels results in a rapid inhibition of further pulsatile release of LH, attributable to an inhibition of GnRH release from the hypothalamus [15]. This could be crucial in our understanding of how suckling suppresses fertility, although the mechanisms are unknown. The increased sensitivity to oestrogen must be induced by suckling, because in breastfeeding women who wean their babies, there is an early return to the normal feedback sensitivity to oestrogen. The implications are that when the levels of FSH are sufficient to initiate and maintain the growth of large follicles, the slow pulse frequency of LH caused by the suckling stimulus is only sufficient to allow these follicles to release small amounts of oestradiol. However, the increase in sensitivity of the GnRH pulse generator to oestradiol means that the small amount of oestradiol released from the follicle will be sufficient to switch off further GnRH/LH release, and the follicle will stop making oestradiol. Thus, no pre-ovulatory LH surge will be generated, and ovulation will not occur. If suckling was rapidly cut down around this time, then the increased sensitivity of the GnRH pulse generator would disappear, a pre-ovulatory LH surge could be induced, and ovulation and pregnancy could occur without any major warning during lactational amenorrhoea. This is rare but does occur [6].

Prolactin

Plasma concentrations of prolactin decline during lactation, even though suckling is maintained. The amount of prolactin released during suckling declines with time, but each suckling episode is associated with an increase in prolactin, even though this may be small. The amount of prolactin released

during the afternoon appears to be greater than in the morning, and this has recently being confirmed by 24-hour profiles of prolactin release [11, 16]. It is quite clear that early in breastfeeding, by four weeks post-partum, the normal increase in prolactin associated with sleep that occurs during the normal menstrual cycle resumes, and superimposed upon this is the prolactin response to suckling. The amount of prolactin released during suckling at night appears to be greater than that released during the day, but the pattern is very variable. By eight weeks, the amount of prolactin released over the 24-hour period has declined, but every suckling episode still releases prolactin. The pattern of prolactin release is entirely dependent on suckling. In a woman feeding six to eight times a day, each suckling episode is normally associated with an increase in prolactin, followed by a decline almost down to baseline, provided the next suckling episode does not occur within two hours. If, however, suckling is very frequent, then prolactin levels do not decline between suckling episodes and high levels of prolactin are maintained. Only when suckling is stopped (for instance, during sleep) does the prolactin concentration decline, but as soon as suckling recurs at a high frequency, prolactin levels increase and are maintained high. The release of prolactin in response to suckling does not appear to be related to opiates, because infusion of the opiate receptor blocker naloxone does not influence the amount of prolactin released in response to suckling. In contrast, dopamine clearly suppresses prolactin release, even during lactation when prolactin levels are high. The dopamine receptor blocker metaclopramide causes a huge release of prolactin, 10- to 70-fold higher than that induced by suckling, showing that during lactation, dopamine still maintains a tight control on prolactin release.

Whether the high plasma concentrations of prolactin maintained throughout lactation are part of the mechanism through which suckling suppresses GnRH/LH release is unclear. Dopamine is the principal regulator of prolactin secretion, acting directly on the pituitary lactotrophs to suppress prolactin release. It has been shown in a few species that prolactin can regulate its own secretion by directly increasing dopaminergic tone and dopamine release from the hypothalamus, and dopamine can suppress GnRH release [3]. Nevertheless, blocking dopamine receptors with the dopamine antagonist metaclopramide at 12 weeks post-partum in fully breastfeeding women did not affect LH or FSH secretion or the pituitary responsiveness to GnRH, even though the treatment caused a massive release of prolactin, indicating that it was indeed active [17]. Thus, it appears that dopamine itself does not directly control the pattern of pulsatile GnRH release.

The interaction between prolactin and GnRH release is clearly important, because patients with pathological hyperprolactinaemia often have amenorrhoea and a disrupted pattern of LH/GnRH release [13]. Thus, it is tempting to assume that the high levels of prolactin associated with lactation suppress LH and FSH release, presumably by affecting GnRH release. Previous studies have indicated a reasonably close association between the number of subjects with high levels of prolactin and the duration of lactational amenorrhoea [for example, 18–20]. Indeed, one study showed that women who have an increased release of prolactin in response to suckling have a longer duration of amenorrhoea [21, 22]. Nevertheless, in our own studies over a number of years, we have been unable to show any close association between the amount of prolactin released, the pattern of prolactin release, and gonadotrophin secretion. Indeed, over a 24-hour period, pulsatile secretion of LH often coincides with times of maximum prolactin secretion during suckling, particularly when the prolactin response to suckling is highest at night [16, 17]. Equally, it is clear that the pattern of return of GnRH pulsatile release is not like that in puberty, when maximum pulsatile release of LH occurs during sleep. It is possible that the effect of prolactin is very snbtle and relies on the plasma concentrations of prolactin remaining above an inhibitory threshold, which would suppress the normal pattern of GnRH release. It is not clear how this threshold could be assessed, but in previous studies it was observed that women had variable basal plasma concentrations of prolactin during normal menstrual cycles after weaning (Howie PW, McNeilly AS, unpublished observations, 1983). These prolactin levels could differ by np to fourfold. During lactational amenorrhoea in these women, the level of prolactin below which ovarian activity resumed related directly to the level of prolactin during the menstrual cycle in the individual woman. More work is required to determine whether prolactin plays a major role in suppressing GnRH output, but it is clear that the pattern of prolactin secretion is directly related to the pattern of suckling. How suckling influences GnRH and, hence, gonadotrophin secretion remains unclear [3].

Conception during lactation

The foregoing discussion has made it clear that suckling is the key to the suppression of fertility. The variable return of ovarian activity is related to the variable pattern of suckling input and how fast the baby feeds. It is known that conception rates in women who are still breastfeeding but have resumed menstrual cycles are lower than those in women who have resumed menstruation after stopping contra-

ception. The reason for this has now become clear. When ovulation occurs during lactation, it is often associated with reduced or inadequate corpus luteum function, resulting in reduced progesterone secretion [23–25]. The implication is that conception in a number of cycles can occur, but inadequate luteal function prevents continuation of the pregnancy. In some women menstruation does not resume before the return of full fertility. The first ovulation is normal, and pregnancy may occur without a preceding menstrual period. This, however, is rare and in our experience is related to a rapid reduction in suckling input. The cause of this inadequate corpus luteum function is still not absolutely clear. In bottle-feeding women, the first menstrual cycle is often associated with inadequate luteal function, and this has been related to a reduction in the amount of LH released during the pre-ovulatory LH surge [24]. A similar situation may occur during breastfeeding, and as luteal function improves during subsequent ovulations, the amount of LH released during the pre-ovulatory surge also increases [6].

Summary

Suckling interferes with GnRH secretion early in lactation by disrupting the pattern of GnRH release, so that it does not occur at a constant rate of once every 60 to 90 minutes, the normal pattern seen during the follicular phase of the cycle. FSH levels are high, so follicles can develop, but oestrogen secretion is compromised by this inadequate LH input. As suckling declines, the pattern of GnRH release becomes more constant, and this relates to the increase in oestrogen secretion seen during the later part of lactation. Nevertheless, when this follicle discharges an LH surge to induce ovulation, the following luteal function may not be normal. This may be related to a decrease in the amount of GnRH released during the pre-ovulatory LH surge and the altered sensitivity to positive feedback caused by oestrogen. Only when weaning is almost complete does one normally see the resumption of normal ovarian activity in ovulatory cycles.

Conclusion

Suckling is the interaction between the baby and the mother, and this interaction is crucial to the suppression of fertility. The suppression of fertility is associated not with a complete suppression, but with a disrupted pattern, of GnRH pulsatile secretion. Whether prolactin is involved remains unresolved. Although the exact mechanisms by which breastfeeding suppresses fertility are not known, it is clear that suckling activity is the major controller of the duration of infertility.

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Discussion of paper by McNeilly

Dr. McLaren

Thank you for a very clear exposition of a very complex subject. I was particularly interested to learn about that double-assurance system that is nature's way of suppressing fertility, emphasizing the importance of this mechanism for spacing births.

Dr. Pérez

You mention that the key is suckling, but what is the mechanism? How could one reproduce that?

Dr. McNeilly

We do not know how to mimic the effect of suckling. If you increase prolactin by drug treatments, that has some effect on LH pulse generation, perhaps by an effect on GnRH rather than by a direct effect of prolactin. The bottom line is still that lactational infertility is driven by a change in GnRH pulse output, and we don't know how to regulate that.

Professor Hanson

Would a mother of a premature baby who is pumping or extracting her milk be able to stimulate her nipples to the extent that she would be able to induce infertility?

Dr. McNeilly

Induced lactators make milk, but no one has really looked properly at reproductive performance, so there is no published literature. There are anecdotes that suggest that there is an effect on the resumption of menstruation when they express milk by hand but not with breast pumps, so I do not think it is just emptying the breast. I think it is actually nipple stimulation.

Professor Howie

I don't think that the situation in the pre-term infant has been studied systematically as it has been with term babies. Because pre-term babies will not be suckling with the same regularity or strength, their suckling might not have the same effect as that produced by the full-term baby.

Dr. Garza

There are some very limited data showing that use of the breast pump does not result in the same prolactin surges as direct suckling, probably not only because of the lack of physical stimulation, but also because of the lack of a psychosomatic component. It may be that the neural pathways do not respond in the same way. In the normal-term infant, do you know if anyone has compared the effects of nutritive and non-nutritive suckling on maternal endocrinology? The pattern of suckling is so different that there may be reason to suspect that one or another is more effective in sustaining the hormonal changes that lead to amenorrhoea.

Dr. McNeilly

The problem is that when you look at the world literature, nobody uses the same definition. Now that a single definition has been developed, it should be used to describe suckling. In Thailand, with Dr. Sodsai Tovanbutra, we counted the number of sucks per suckling episode to determine if it was related to prolactin release. There was no relationship at all. So the idea that prolactin is one of the monitors of the suckling stimulus and GnRH pulse generation doesn't work. There was one defect. We just counted the number of sucks. We did not have a recorder, so we could not work out the intersuck interval. The problem is that we do not really know how to monitor suckling activity.

Dr. Woolridge

The data on pump use and prolactin are ambiguous. Professor Howie, I think that your study is the only one that shows the complete absence of a prolactin response during the use of an electric breast pump, but there are at least four published studies that show a reasonable prolactin surge. We have just completed a study with women who have established milk production with an electric pump, and they have been doing repeated within-measures studies. On every occasion, 24 women had a prolactin surge every time they used an electric pump. Maybe one of the reasons why non-nutritive sucking is effective is that the endocrine system may be more sensitive to particular types of sucking, such as that associated with low milk release. We have a pump that operates at twice the normal rate, and we are anxious to look at the prolactin surge.

Dr. McNeilly

Is the pump a suction pump, or is it actually a proper milking pump?

Dr. Woolridge

We have just compared single and double pumping with and without one of the Silastic inserts that give it a more physiological style of action. We were unable to show any impact of the Silastic inserts on prolactin release.

Professor Hanson

The effectiveness of suckling is especially important in poor countries, where 20% to 30% of newborns may be of low birthweight. Is the spacing between pre-term, low-birthweight children shorter than that between full-term children?

Dr. Prentice

We have to remember that many low-birthweight babies in the third world are actually term babies. They are small for dates, but they are not premature, so we should not get confused.

Dr. Pollitt

There are large and significant differences between the sucking patterns of pre-term and term babies on the bottle. I do not know about the breast. But almost any parameter that you can think of or identify in the term baby is going to be different from that of the pre-term baby. In other words, the amplitude, the frequency, the duration of the burst, the length of the period without sucking, and so forth are all different. What is particularly interesting in the pre-term baby is that there is continuous sucking. There are no bursts, but instead there are continuous, varied, small-amplitude sucks.

Dr. McNeilly

It is very difficult to know exactly what part of the suckling stimulus is important. We have seen women who suckled 25 times a day and women who suckled 5 times a day, each with a total suckling duration of 60 minutes per day. They have the same patterns of gonadotrophin secretion and ovarian function, so clearly the brain is very adaptable at reading a signal coming from the nipple. I would not be surprised if there was an interaction between the baby and the mother as well, helping to amplify this stimulus. In Chile, Dr. Diaz* increased the suckling frequency in breastfeeding women in an attempt to switch off ovarian activity after it had resumed. The attempt failed, because although the number of suckling episodes was increased, the babies reduced the duration of each feeding so that the overall apparent suckling input was the same and the increased number of episodes had no effect whatsoever. The problem is that the system is so adaptable. To say you need so much suckling to maintain infertility is very difficult. What we should try to do is to determine the minimal parameters for each particular society, parameters that we can actually measure. In Edinburgh we chose frequency and duration of each feeding to see if that would give a guide to maintaining infertility. It worked in our particular group of women.

Dr. Prentice

Could you bring us up to date on the thinking about the mother's nutritional status? Our supplementation studies in lactating women suggested that feeding the women more resulted in their ovarian activity returning earlier, and we put that down at the time to the lower prolactin levels. Do you think that it is sucking frequency only, or does the mother's nutritional status have some impact?

Dr. McNeilly

If you look at situations involving acute weight loss or chronic weight loss, you actually have to lose a lot of weight to switch off ovarian activity. Andrew

* Diaz SP, Miranda P, Brandeis A, Cardenas H, Croxatto HB. A study on the feasibility of suppressing ovarian activity following the end of postpartum amenorrhea by increasing the frequency of suckling. Clin Endocrinol 1988;28:525–35.

Loudon, John Milne, and I** compared red deer on a restricted diet and on a full diet. We showed that on a restricted diet, the rate of milk secretion was much lower, so the calves kept going back more often. The supplements in your study may have subtly altered the suckling activity, perhaps the strength of sucking at each episode, without a change in the number of suckling episodes.

Dr. Prentice

In the context of the meeting, what you appear to be saying then is that if a well-nourished mother has a high suckling frequency, she is likely to have just as long a period of fertility as an undernourished mother. The common perception is that for women in the third world, breastfeeding as a contraceptive is all right, but for women in developed countries, it's not a particularly good method of contraception.

Dr. Rasmussen

My question relates to night feeding. We were all very intrigued by your previous night-feeding findings. They seemed to justify feeding our babies at night. Your comments now seem to have wiped out that justification. Can you tell us more about what you now know that makes you think night feeding is not important?

Dr. McNeilly

Our early studies suggested that a woman who was breastfeeding at night was likely to remain amenorrheic longer. As we accumulated more data, it became apparent that it was not necessarily the night feeds that were important. It now seems that if women feed six times a day, it can be between eight in the morning and six at night, and that will maintain the infertility.

** Loudon ASI, McNeilly AS, Milne JA. Nutrition and lactational control of fertility in red deer. Nature 1983; 302:145–7.

Dr. Rasmussen

So it is just the number of times a day or the total minutes of suckling, not when in the 24-hour period it occurs. Earlier, you hypothesized that it was interfering with the LH surge at ovulation.

Dr. McNeilly

Yes, that's right, because at that time (10 years ago), that was our state of knowledge. But I think now, having accumulated more information, that the night feeding is not necessarily as important as we assumed. It is the suckling input during the 24-hour period that matters. In Keith Gordon's*** studies in monkeys, which have patterns similar to the human in resuming ovarian activity (pulsatile LH secretion and so forth), restricting suckling to either daytime or night-time has made no difference to gonadotrophin secretion, provided the suckling frequency remains the same. Furthermore, the anecdotal reports that we have from women who are working during the day and feeding only at night suggest that infertility is maintained, provided suckling is continued.

Dr. Valdés

If a working mother breastfed more frequently at night but kept the same number of daily feedings, would that be enough to maintain amenorrhoea?

Dr. McNeilly

I thiuk it probably would, but I would not like to be held responsible for that practice being adopted aud then failing. It requires specific investigation.

*** Gordon K, Hodgen GD, Richardson DW. Postpartum lactational anovulation in a non-human primate [*Macaca fascicularis*]: endogenous opiate mediation of suckling-induced hyperprolactinaemia. J Clin Endocrinol Metab 1992;75:56–7.

Demographic effects of breastfeeding: Fertility, mortality, and population growth

Jane Menken and Randall Kuhn

Abstract

This article reviews the demographic effects of breastfeeding on fertility and child survival and, ultimately, on population growth. Extended breastfeeding both reduces fertility by prolonging birth intervals and increases child survival through improved nutrition, especially where adequate substitutes are not available. The results presented show, however, that although breastfeeding is a major determinant of fertility in the absence of other means of fertility control, prolonged breastfeeding alone cannot reduce fertility to levels consonant with slow or zero population growth. The benefits, at least for the first year of life, demonstrate the need for policies that promote breastfeeding and encourage compatibility between breastfeeding and other aspects of women's lives. In particular, policies are needed that permit women to breastfeed their children while, at the same time, improving their socio-economic circumstances through participation in the labour force.

Introduction

Breastfeeding is known to reduce fertility and increase child survival. It affects fertility by prolonging the interval between births. It increases child survival both directly, through the provision of beneficial nutrition to the child, and indirectly, through improved child spacing. In this article we review evidence that leads to these conclusions and consider two questions that relate the findings on breastfeeding to population growth:

» Can long breastfeeding patterns reduce fertility to levels compatible with slow population growth under conditions of low mortality?

» Can shorter breastfeeding patterns, which lead to both higher fertility and higher infant mortality, also lead to higher population growth rates? This outcome would require the fertility-enhancing effect of early weaning to overwhelm its negative effect on child survival.

We first consider how low fertility must be, when combined with the low mortality even the poorest countries have achieved in recent years, to lead, ultimately, to either very slow or no population growth. We next offer illustrative data on recent levels of fertility and mortality around the world. This section is followed by a discussion of the factors that determine levels of fertility, including breastfeeding, and then by an examination of the evidence relating breastfeeding to infant and child survival. We end with a set of policy recommendations.

Population growth

During the 1960s and 1970s, there were many assessments of the world population situation. Some were by alarmists who wrote of the "population explosion" and credited population growth with responsibility for many, if not all, of the afflictions of the developing world. Others, taking a more judicious view, still concluded that rapid growth, on balance, had consequences sufficiently detrimental to prospects for improving conditions in much of the world to warrant efforts to slow the increase in population by reducing fertility. Indeed, this has been the primary rationale for family planning programmes.

In 1974 the United Nations sponsored an International Conference on Population in Bucharest, Romania. Although some countries urged the adoption of policies aimed at slowing growth, primarily through family planning, out of that conference instead came the dictum that "development is the best contraceptive." However, this dictum was not followed by even its most fervent supporters in the developing world. Instead, developing countries in-

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creasingly turned to population policy and family planning programmes aimed at reducing fertility.

One of the major challenges to the received wisdom on population questions came in 1981 with the publication of Julian Simon's book *The Ultimate Resource* [1]. Simon, while not opposed to the principle that individuals should be able to control the number of children they have if they so choose, contested the view that rapid growth had deleterious effects. He argued that population growth is a significant and effective long-term stimulus to economic development, exerting its influence by, among other means, increasing the tempo of innovation. His views profoundly influenced the US Government's stance at the 1984 United Nations International Conference on Population [2].

Ten years later, the 1994 United Nations Conference on Population and Development was held in Cairo. The US position, like those of many other countries, had changed, with concern for human rights, the status of women, maternal and child health, and the environment being discussed in preparatory meetings around the world as well as at the conference itself.

Any discussion of breastfeeding aud population must take place against the backdrop of these concerns. It must also take into account the fact that population growth, continued indefinitely into the future, will ultimately outstrip space on earth. There have been any number of demographers who have amused themselves (if no one else) with calculations of how long it would take for the population to reach numbers so large that each person had only one square foot of earth to occupy, or until the numbers represented mass equal to that of the earth, and so on. At an annual growth rate of 2%, it takes about 35 years for a population to double, at 3% it takes only 23 years, and at 4% it takes about 17 years. (The doubling time is about equal to 69/annual growth rate.) The non-trivial point of these calculations is that ultimately birth and death rates must again come into balance. In the past they were balanced at high levels of both fertility and mortality. The issue is whether they can be brought into balance for the world, as well as the currently developed nations, at low levels of mortality, which require correspondingly low levels of fertility.

Some mathematical relations

If fertility and mortality rates are constant over time, the mathematics of population growth lead to some important relationships that are useful in this discussion [3, 4]. The growth rate r is related to the average number of children a woman bears and to the survival of those children so they can contribute progeny to the subsequent generation. The net reproduction rate (NRR) is a measure that summarizes both fertility and child survival. It is defined as the average number of daughters a girl born today will contribute to the next generation. If birth and death rates are unchanging over time, results from mathematical demography show that r is related to NRR through the average age at which women bear their children. Thus, if that average age is 28 (as is characteristic of a wide range of populations) and r is expressed as a proportion (for example, if growth is 2% annually, then $r = 0.02$), then a powerful result of the mathematics of population growth [3, 4] is that

$$\ln (\mathrm{NRR}) \sim 28r$$

so that

$$\mathrm{NRR} \sim e^{28r}.$$

NRR itself can be estimated from two other measures related to fertility and survival. The total fertility rate (TFR) is the average number of children borne by a woman who survives her entire reproductive span, in other words, to age 50. The number of daughters is about equal to TFR × .488, where .488 is roughly the fraction of children who are girls. The proportion of girls born today who may contribute children to the next generation can be approximated by the proportion surviving to the average age of child-bearing, for which we are using $p(28)$. With these assumptions,

$$\mathrm{NRR} \sim \mathrm{TFR} \times .488 \times p(28).$$

Using this approximation, table 1 shows the NRR needed for growth rates ranging from 0% to 4% per year and, for TFR ranging from two to nine children, the $p(28)$ that would lead to these growth rates. For example, an annual growth rate of 1% can be achieved with TFRs from three to nine, but the corresponding survival probability that would maintain this growth goes down sharply as the average number of children increases. Table 2 shows the $p(28)$ values corresponding to life expectancies at birth that range from 20 to 80 years, taken from the West Model Life tables developed by Coale and Demeny [5]. The values that correspond to life expectancies of 50 years or more are in bold type in table 1. They clearly indicate that TFRs of five or more are associated with growth rates of at least 2.5% per year and doubling times of less than 28 years.

Recent fertility, life expectancy, and growth rates in the developing world

Table 3 is included here to give some concrete background to our discussion. The data are for 33 coun-

TABLE 1. Combinations of the probability of surviving to age 28 [$p(28)$] and total fertility rate (TFR) that lead to a specified growth rate (r) and corresponding net reproduction rate (NRR). Boldface numbers correspond to life expectancy of at least 50 years

Probability of surviving to age 28 that produces given NRR when:									
r (%)	NRR	TFR 2	TFR 3	TFR 4	TFR 5	TFR 6	TFR 7	TFR 8	TFR 9
0.0	1.00	**1.00**[a]	.68	.51	.41	.34	.29	.26	.23
0.5	1.15		**.79**	.59	.47	.39	.34	.29	.26
1.0	1.32		**.90**	.68	.54	.45	.39	.34	.30
1.5	1.52			**.78**	.62	.52	.45	.39	.35
2.0	1.75			**.90**	.71	.60	.51	.45	.40
2.5	2.01				**.83**	.69	.59	.52	.46
3.0	2.31				**.95**	**.79**	.68	.59	.53
3.5	2.66					**.91**	**.78**	.68	.61
4.0	3.06						**.90**	**.79**	.70

TFR = total fertility rate = average number of children born to a woman who lives to age 50.
NRR = net reproduction rate = average number of daughters a girl born today will contribute to the next generation $\sim e^{28r/100} \sim$ TFR (.488) $p(28)$.
.488 ~ proportion of babies that are girls.
$p(28)$ = probability a girl will survive to age 28 (the mean age of the fertility schedule); see table 2 for relationship between $p(28)$ and life expectancy.

a. Because the calculated value for this cell was greater than one and, therefore, outside the possible range, it was replaced by the maximum possible value.

TABLE 2. Relationship between expectation of life at birth and proportion of women surviving to exact age 28 [$p(28)$]

Life expectancy (yr)	$p(28)$
20	.32
30	.47
40	.61
50	.73
60	.83
70	.94
80	.99

Source: ref. 5.

tries in which Demographic and Health Surveys were taken between 1985 and 1992. The information on life expectancies and growth rates comes from the Population Reference Bureau [6] and that on TFRs from Muhuri et al. [7]. Nearly all (30 of the 33) of these countries have life expectancies over 50, and only 5 have lowered their growth rates to under 2% per year. The TFRs are for the five years prior to the survey date and are highly variable.

In addition to showing the great variation in overall fertility, the table shows the general trend of declining fertility with increased socio-economic status, here measured by education of the woman. For most countries with low fertility, that level has been achieved through the use of methods of fertility control, although for some parts of Africa, unusually high rates of sterility are believed to be important determinants of reproduction. When combined with the life expectancies also shown in table 3, these fertility rates lead to the substantial growth rates seen there. By contrast, the countries of the West all have growth rates under 1.5%.

Reproduction in the absence of fertility control

Populations that offer evidence of few or no practices intended to limit the number of children a woman bears over the course of her lifetime have reproductive patterns that have been termed *natural fertility*. Wood [8] reports that 70 such populations have been identified; their average total fertility was 6.1 children per woman, and the standard deviation was 1.2. Thns, the variation in fertility, *even without deliberate control*, is substantial. The great French demographer Louis Henry earlier estimated total marital fertility for nine populations that did not limit fertility. If all women married at age 15 and survived the reproductive years, the average number of children per woman would vary from 8.5 to 14.1 [9]. Yet there is substantial consistency. Henry noted that there is a common age pattern to the fertility of married women in such populations; fertility remains high until the mid-thirties and then declines in a fashion that produces a concave curve. This curve was later codified in the Coale and Trussell [10] set of

TABLE 3. Life expectancy (e_0^0), growth rate (r), and total fertility rate (TFR) for all women aged 15–44 according to education in 33 countries in which there were demographic and health surveys between 1985 and 1992

Country	e_0^0	r (%)	TFR for: All women	No schooling	Did not complete primary school	Completed primary school	Secondary school or higher
Sub-Saharan Africa							
Botswana	55	2.7	4.80	5.59	5.20	(4.58)	(3.33)
Burundi	50	3.2	6.54	6.52	6.89		*
Cameroon	54	3.2	5.84	6.29	6.31		(4.68)
Ghana	52	3.2	6.10	6.77	6.27		(3.55)
Kenya	59	3.7	6.52	7.02	7.30	(6.63)	(4.86)
Liberia	53	3.2	6.29	6.44	6.96		(4.73)
Mali	43	3.0	6.74	6.82	*	*	*
Nigeria	48	3.0	5.94	6.34	7.04	5.99	(4.20)
Senegal	47	2.8	6.42	6.80	5.50		*
Sudan	52	3.1	4.84	5.73	4.96		(3.26)
Togo	53	3.7	6.21	6.82	5.75		*
Uganda	50	3.7	7.12	7.54	6.99		*
Zambia	51	3.8	6.18	6.83	6.58	(6.05)	(5.02)
Zimbabwe	58	3.1	5.53	6.94	6.44	(5.22)	(3.84)
Near East and North Africa							
Egypt	58	2.4	4.67	5.74	5.08	(3.93)	3.32
Jordan	69	3.4	5.75	7.13	6.19	5.72	5.01
Morocco	62	2.4	4.04	4.83	(2.68)	(2.33)	(2.06)
Tunisia	65	2.1	4.34	5.00	(4.32)	(3.31)	(2.66)
Asia							
Indonesia	58	1.7	3.04	3.36	3.51	3.10	2.52
Pakistan	56	3.1	4.67	4.90	4.52		3.64
Sri Lanka	68	1.5	2.77				
Thailand	64	1.4	2.32	3.33	2.46		1.49
Latin America							
Bolivia	58	2.7	4.95	6.14	5.96	4.72	3.20
Brazil	62	1.9	3.71	6.66	4.06	(2.99)	(2.18)
Colombia	68	2.0	2.84	4.93	3.99	3.07	2.18

TABLE 3—*Continued*

Country	e_0^0	r (%)	TFR for: All women	No schooling	Did not complete primary school	Completed primary school	Secondary school or higher
Dominican Republic	66	2.3	3.25	(5.67)	3.84	3.17	2.71
Ecuador	65	2.4	4.22	6.31	6.01	4.19	2.83
El Salvador	61	2.9	4.37	5.96	4.47	(3.14)	(2.45)
Guatemala	60	3.1	5.61	6.94	5.44	(3.92)	(2.70)
Mexico	66	2.3	4.08	6.39	5.72	3.59	2.51
Paraguay	65	2.7	4.69	(6.60)	6.24	4.47	3.28
Peru	60	2.2	3.68	7.11	5.42	4.25	2.66
Trinidad and Tobago	67	1.4	3.14	(2.28)	3.67	3.69	2.95

Sources: e_0^0 and r from ref. 6; TFR from ref. 7.

* <50 women-years of exposure in at least one of the age groups.
Numbers in parentheses: 50–199 women-years of exposure in at least one of the age groups.

schedules of fertility, in which all populations with natural fertility were described by a standard schedule that represented the age pattern and a multiplier, a parameter that represented the relative level of fertility in a particular population compared with a standard reference population. In other words, if marital fertility in a particular population was about 90% of the reference at age 20, they found it was about 90% as high at all other ages. They went further and found that populations that control their fertility have age patterns that could be described well with the addition to their equation of a second parameter that represents the degree of fertility control. Their work in developing this model of fertility and demonstrating that it fits a wide range of populations well permits us to conclude that although there is a great deal of variation to be explained in worldwide patterns of reproduction, in populations that do not practise deliberate methods of control, there are common patterns that are of great interest.

The proximate determinants framework

To understand the causes of these common patterns and of variation in natural fertility and in controlled fertility, and the magnitude of the effects of various factors on reproduction, demographers usually consider the proximate determinants of fertility. The proximate determinants can be divided, as shown in figure 1, into those that affect the reproductive span and those that influence the rate of births within that span [11].

Reproductive span

A woman's potential reproductive span begins when she first ovulates, an event that is usually roughly measured by first menses. It ends when she becomes sterile or dies, whichever comes first. Yet rarely, if ever, is all of this potential reproductive span devoted to reproduction. Most societies have practices that limit the *effective reproductive span* to less than its maximum, by postponing marriage (or unions) until some time after menarche or through permanent abstinence or dissolution of marriages. In many traditional societies in the past, marriage took place very close to menarche, so the mean age at first marriage was often under 20 years for women. In contrast, the mean age at marriage in a number of European countries is in the mid-twenties or later, thus substantially reducing the time available for reproduction. Therefore, the effective reproductive span starts at menarche or marriage, whichever is later, and ends at marital dissolution, sterility, the start of permanent abstinence, or death, whichever is earliest. The effective reproductive span can be thought of as the period when a woman is *exposed to the risk of child-bearing*. Of course, in many societies there are also intermittent "time-outs" when the woman is not exposed to this risk, either because the

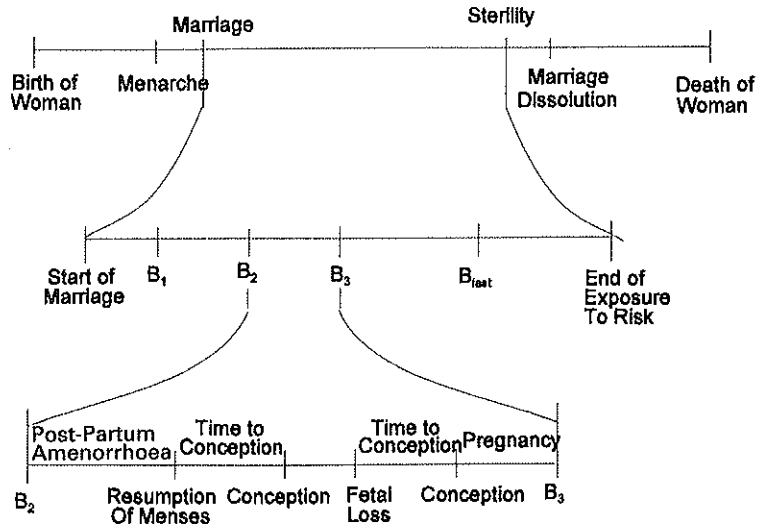

FIG. 1. Reproductive span and birth intervals

marriage has dissolved or beeause of temporary spousal separation.

Birth interval dynamics

Within the effective reproductive span, the pace of child-bearing is determined by the lengths of the intervals between successive births. These intervals themselves can be divided into their component parts: (1) the *post-partum period*, whieh follows each birth and is the time from the birth until both ovulation and sexual relations are resumed; (2) the *time to next live-birth conception*, which is made up of the time to coneeption and, if there are any foetal losses, an interval *for each foetal loss* comprising the pregnancy and post-partum period associated with that foetal loss, plus another time-to-conception interval; and (3) the *pregnancy* that leads to the next live birth.

The first birth interval (between the start of the effective reproductive span and the first birth) differs from later birth intervals only in that it docs not contain the post-partum period that starts the later intervals.

The *time to next live birth* is determined by *fecundability*, the monthly probability that a woman will conceive, and by the likelihood that fertilization of the ovum will not lead to a live birth (and the length of the pregnancy and the post-partum period associated with the end of that pregnancy). Fecundability itself is determined by the frequency and pattern of intercourse, the length of the ovarian cycle, whether or not the cycle is ovulatory, and the probability that a single act of intercourse will lead to a live birth (see references 12 and 13 for the most recent modelling of fecundability).

Table 4 lists a number of factors affecting the effective reproductive span and the pace of ehildbearing within that span and, for each factor, an indication of whether it is primarily biologically or socially determined. It can be argued that all of these factors are determined both biologically and socially. For example, menarche occurs as part of normal biological development. It is well known, however, that it is strongly related to nutrition, and the feeding of girls is determined both by social norms regarding appropriate food distribution within the family and by the availability of food. The latter is a result of the ability to obtain food, whieh is itself dependent on the supply of food in markets or through ownership of land and access to that supply.

Breastfeeding exerts its effect on fertility in two ways. The first and by far the stronger effect comes through prolongation of post-partum amenorrhoea, the time from the birth until a woman resumes ovulation or menstruation. The second effect occurs after the end of the post-partum period, when breastfeeding can reduce the probability that the next ovulation will result in conception. In the first case the frequency and extent of breastfeeding are primarily socially determined—and that very social determination has led to this conference. Its effect on amenorrhoea is, of course, biological. Women who do not breastfeed resume ovulation within a very short time (about six weeks) after a live birth [14]. By contrast, the very long breastfeeding periods in rural Bangladesh around 1970 led to a median time until resumption of menses of about 18 months [15]. Although this mode of breastfeeding action has been well known for many years, more recently it has been found that breastfeeding beyond the resump-

TABLE 4. Factors affecting the effective reproductive span and birth intervals

Features that are affected	Affecting factors
Effective reproductive span	
Start	
menarche	biological and social
marriage or regular sexual union	social
End	
sterility (which may be earlier than menopause)	biological and social
widowhood	biological and social
divorce	social
death	biological and social
Birth intervals	
Post-partum period	
amenorrhoea	biological
breastfeeding	social
resumption of sexual relations	social
Fecundability	
frequency and pattern of intercourse	social
proportions of cycles that are ovulatory	biological
breastfeeding	social
duration of the fertility period	biological
probability that conception will follow a single act of intercourse	biological
contraception	social
Probability of foetal loss	
spontaneous	biological
induced	social
Length of non-susceptible period associated with foetal loss	
spontaneous	biological
induced	biological and social
Gestation leading to live birth	biological and social

tion of menses serves to reduce fecundability [16–19]. These effects will be considered in greater detail below, following a discussion of methods for assessing the impact of various fertility determinants on the average number of children women bear.

An aggregate fertility model

Bongaarts [20–22] developed a model that took into account marriage, post-partum infecundity, and fertility limitation through contraceptive use and through induced abortion as determinants of TFR. It takes as its starting point total fecundity (TF), the number of children women would have if they reproduced at the maximum, which would occur if (1) no woman ever breastfed, (2) no woman used contraception or had an induced abortion, and (3) all women were married throughout the biological reproductive span, from ages 15 to 50. Bongaarts estimated that TF is just over 15 children. He then developed four indices to be estimated for each population of interest:

C_i = *index of post-partum infecundity*. The index varies from 0 to 1 and represents the proportion of potential fertility, TF, remaining when the average post-partum period of the population of interest has been taken into account. Therefore, $C_i = 1$ if the population does not breastfeed at all. Because of our interest in breastfeeding, the equation for estimating C_i is given in the next section. The fertility-reducing effect of post-partum infecundity is $(1 - C_i)$.

C_A = *index of abortion* = proportion of TF, *after post-partum infecundity has been first taken into account*, remaining when the effect of induced abortion in reducing live births has been taken into account. Spontaneous abortions are included in the original estimate of TF, since they are treated as a purely biological occurrence. Note that few countries have sufficient information available on abortion to make reasonable estimates of C_A [23].

C_C = *index of contraception* = proportion of TF, after the effects of post-partum infecundity and induced abortion have been taken into account, remaining after contraceptive use has been considered.

C_m = *index of marriage* = proportion of TF, after the first three factors have been considered, remaining when the particular marriage pattern has been taken into account. C_m actually represents the number of years a woman is married, relative to the maximum possible, but it is a *weighted* number, in that a year of marriage during the part of the reproductive span when women are most fecund is counted more than a year of marriage towards the end of the reproductive span, when many women are already sterile or subfecund.

Thus, in the Bongaarts decomposition,

$$\text{TFR} = \text{TF} \times C_i \times C_A \times C_C \times C_m.$$

Because the emphasis in this article is on breastfeeding, calculation of the indices other than C_i will not be discussed.

Estimating the index C_i

The estimation procedure is based on the prolongation of the birth interval when the post-partum

period extends beyond the biological minimum, and there is no use of contraception or induced abortion. If there is no breastfeeding, a rough estimate of the birth interval is about 20 months, based on 1.5 months of anovulation, 7.5 months waiting time to conception, 2 months added by spontaneous abortion, and 9 months of pregnancy leading to a full-term live birth. The birth interval, divided into the effective reproductive span, gives an estimate of the number of children a woman could bear. The index C_i asks how much this birth interval is increased by a longer post-partum period before both ovulation and sexual relations are resumed. Without either lactation or delayed sexual relations, this birth interval averages 18.5 months. It lasts $18.5 + i$, where i is the average duration of the post-partum period, extended either by breastfeeding or by post-partum abstinence. The index becomes the ratio of the birth interval without breastfeeding or post-partum abstinence (20 months) to the birth interval with either or both:

$$C_i = 20/(18.5 + i).$$

The duration of post-partum abstinence is usually estimated from data collected for that purpose. But frequently the average duration of post-partum amenorrhoea is estimated from the time until first menses post-partum, which is itself estimated from women's reports on the length of breastfeeding. Bongaarts [22] developed an equation from an analysis of all data available at the time on observations of both the duration of breastfeeding and the time to first post-partum menses that then permits rough estimation of the duration of amenorrhoea from data on how long women breastfeed. Usually i, the post-partum period, is assumed to be equal to the estimated period of post-partum amenorrhoea. The exception is for those populations in which couples abstain even after amenorrhoea ends. In those cases i is estimated as the length of post-partum abstinence.

The impact of breastfeeding on fertility

Table 5 offers Bongaarts' estimates [22] of these indices, except for C_A, which is assumed to be one, for a number of populations around 1970 and for several historical populations. The major impact of

TABLE 5. Estimates of total fertility rate and Bongaart's proximate determinants indices[a]

Country and date	TFR	C_i	C_m	C_C	Country and date	TFR	C_i	C_m	C_C
Developing countries					Developed countries				
Bangladesh, 1975	6.34	.54	.85	.90	Denmark, 1970	1.78	.93	.55	.23
Colombia, 1976	4.57	.84	.58	.61	Finland, 1971	1.61	.93	.51	.22
Costa Rica, 1976	3.69	.90	.57	.47	France, 1972	2.21	.93	.52	.30
Dominican Republic, 1975	5.85	.61	.60	1.0	Hungary, 1966	1.80	.93	.62	.21
Guatemala, 1972	7.05	.61	.72	1.0	Poland, 1972	2.09	.93	.44	.34
Hong Kong, 1978	2.26	.93	.88	.18	United Kingdom, 1967	2.38	.93	.61	.27
Indonesia, 1976	4.69	.58	.71	.75	United States, 1967	2.34	.93	.63	.26
Jamaica, 1976	4.32	.88	.54	.59	Yugoslavia, 1970	2.11	.93	.57	.26
Jordan, 1976	7.41	.80	.74	.81	Historical populations				
Kenya, 1976	8.02	.67	.77	1.0					
Korea, 1970	3.97	.66	.58	.68	Bavarian villages, 1700–1850	4.45	.85	.37	.91
Lebanon, 1976	4.77	.78	.58	.69	Crulai, 1674–1742	5.60	.67	.57	.96
Malaysia, 1974	4.76	.90	.61	.57	Grafenhausen, 1700–1850	4.74	.67	.44	1.0
Mexico, 1976	5.73	.84	.61	.73	Hutterites	9.50	.82	.73	1.0
Nepal, 1976	6.37	.55	.85	.89	Ile de France, 1740–1779	6.10	.71	.50	1.0
Pakistan, 1975	7.02	.64	.79	.91	Oschelbron, 1700–1850	5.06	.73	.48	.95
Panama, 1976	4.57	.88	.62	.55	Quebec, 1700–1730	8.00	.81	.63	1.0
Peru, 1977	5.11	.76	.57	.77	Tourouvre-le-Perche, 1665–1714	6.00	.75	.59	.89
Philippines, 1976	5.01	.76	.61	.70	Waldeck villages, 1700–1850	4.41	.68	.44	.96
Sri Lanka, 1975	3.53	.61	.51	.74	Werdum, 1700–1850	3.78	.64	.40	.96
Syria, 1973	7.00	.73	.73	.86					
Thailand, 1975	4.70	.66	.63	.74					
Turkey, 1968	5.60	.73	.76	.66					

Estimates based on table 4.2 in ref. 22.
TFR = total fertility rate; C_i = index of post-partum infecundity; C_m = index of marriage; C_C = index of contraception.

a. Each index represents the proportion of potential fertility remaining after the particular factor has been taken into account in this order: post-partum infecundity, marriage, contraceptive use.

breastfeeding can be seen through the values of the index C_i in countries that, at the period in question, did not limit their fertility through contraception or abortion. Whereas in Western Europe the demographic transition to low levels of fertility was caused, to a great extent, by the adoption of a pattern of very late marriage and a relatively high degree of nonmarriage, much of the developing world is characterized by high proportions of the population being married throughout the reproductive span. In these cases the overall level of fertility has been determined, to a great extent, by post-partum infecundity. Although in some societies post-partum taboos set the length of the post-partum period, in most it is breastfeeding that determines when a woman again becomes capable of conceiving after the birth of an infant. Yet the maximum reduction in TF, the potential fertility, is about half; if breastfeeding is the only way fertility is reduced, the numbers of children remain quite high.

Breastfeeding, as already mentioned, has another substantial effect on fecundability. When continued beyond the post-partum anovulatory period, breastfeeding reduces the likelihood of conception. This effect does not enter into the Bongaarts model but can be thought of as reducing the C_i levels slightly below those presented in table 5.

Three conclusions can be reached thus far:

» The longest breastfeeding that we know of reduces fertility to about half its potential maximum. This is a substantial effect and, for much of the world, is likely to be the major determinant of overall fertility levels.
» In no case is the breastfeeding effect sufficient to reduce fertility to levels that are compatible with slow population growth under circumstances of low mortality.
» Reducing breastfeeding has the potential to increase fertility.

This last statement, although true, must be discussed in the context of adoption of means of fertility control. Although there have been fears, over the years, that populations would experience massive fertility increases as, over the course of development, women reduced both the intensity and the duration of their breastfeeding, these fears have not been realized. In every country for which there are data, the most educated women, who breastfeed the least, also have the lowest fertility (see table 3). Although our models say that if breastfeeding declines, holding all other factors constant, fertility will rise, in the real world it is rare that all those other factors remain constant. The same processes of social change that affect women's attitudes and practices concerning breastfeeding also affect their attitudes towards and practice of fertility control. There may be lags, so that over the short term following a decline in breastfeeding, fertility might increase, but the general pattern has been one of sufficient compensation, through adoption of family limitation, that the expected rise in fertility has not taken place.

There is a countervailing effect, however. To the extent that reduced breastfeeding increases infant and child mortality, the effect on growth rates is muted. Growth rates depend on NRR, whereas our discussion thus far has been limited to TFR. We therefore turn next to a consideration of the effect of breastfeeding on survival.

Mortality

Although the proximate determinants of fertility have been systematized and to some extent quantified, we are not yet able to set out the determinants of child mortality in such a neat manner. Mosley and Chen [24], in one attempt at developing such a framework, attributed child mortality to five sets of factors: (1) maternal factors, (2) environmental contamination, (3) nutrient deficiency, (4) injury, and (5) personal illness control. They also refer to a negative synergy by which sickness and malnutrition amplify each other's effects and lead to childhood mortality; sickness leads to malnutrition, malnutrition leads to sickness. Therefore, relatively few child deaths are attributed directly to malnutrition, because most malnourished children are recorded as dying of an illness to which their malnourishment has left them susceptible.

Of these five groups of determinants of child mortality, three are profoundly influenced by breastfeeding: maternal factors, environmental contamination, and nutrient deficiency.

The maternal factors include child spacing, which is directly influenced by the effects of breastfeeding. Longer breastfeeding lengthens the birth interval when there is little or no use of contraception. This longer birth interval generally leads to decreased mortality, mostly due to lessened competition for maternal and household resources. With longer birth intervals, there will be fewer children in the family, and perhaps more importantly, it is less likely that the family will have two or more very young children at the same time. Therefore, parental efforts to obtain medical care and provide adequate nutrition and an environment that limits disease transmission can be focused on one child at a time in their period of greatest vulnerability, rather than spreading these efforts thinly across several children simultaneously. This effect may be especially important for daughters, who may be disadvantaged when they must compete with their brothers for familial resources.

Breastfeeding directly influences infant and child

health by providing a better food supply when the child is quite young. Until quite recently we would have had no potential negative effects to report. The spectre of AIDS and HIV has cast a shadow over this issue, sometimes invalidating this conclusion. Recent studies have shown that HIV-infected mothers may transmit the infection to their children through their breastmilk, especially in the colostrum in the first few days following the birth [25]. The risk of transmission is difficult to assess, since few large-scale studies have been conducted, and it is difficult to distinguish transmission of HIV through breastmilk from earlier transmission. Dunn et al. [26] estimated the risk of transmitting HIV-1 through breastmilk to be 14% to 29%, depending upon whether the mother was infected before or after the birth of the child. The risk of transmission of HIV-2 seems to be much lower [27]. In most developing world environments, the risk of HIV is not as great as the threat of mortality owing to infections from water used in infant formula and from poor nutrition [28]. Therefore, the World Health Organization [29, see also 30] recommends that breastfeeding be promoted in all developing countries, even where there is a high prevalence of HIV infection. It further recommends that "Where infectious diseases and malnutrition are the main causes of infant deaths and the infant mortality rate is high, breastfeeding should be the usual advice to pregnant women, including those who are HIV-infected." Only where mortality is low and there are safe alternatives to breastfeeding should mothers infected with HIV be advised to use these alternatives [29].

Vanlandingham et al. [31] reviewed studies that attempted to quantify the effect of breastfeeding on child survival. They report Holland's [32] finding that in Malaysia breastfeeding was significantly related to infant mortality in the first six months. Infants who never breastfed were 12 times more likely to die in the first two months of life than those who had at least some breastfeeding. Holland divided infants who survived the first two months into those breastfed at least one month, those breastfed less than one month, and those never breastfed. There was a clear gradient in survival over the next two months; those breastfed longest had the greatest chance of surviving to the age of four months. Similarly, among those who survived the first four months, those breastfed longest again had the highest chance of surviving the next two months (until age six months). According to Vanlandingham et al. [31]:

> Holland's work is characterized by a careful attempt to eliminate reverse causation—infants may be too sick to suckle, so that death 'causes' weaning rather than the reverse—but this thorny problem probably cannot be entirely overcome. The problem is minimized in the case of infants in age groups after one to two months, because the analysis is conditioned on breastfeeding behavior prior to the start of the interval.

In the demographic research by Montgomery et al. [33], a variety of methods were used to control for the child's health status at birth and to make corrections for selection bias; the same conclusion was reached: "The direct influence of breastfeeding on survival remains of overwhelming importance."

Research in many countries, including those in Latin America [34], has detected improvement in child survival in the last half of the first year for breastfed infants. A number of authors have argued that breastfeeding should be most important in the countries (or the subgroups within a country) with the least favourable health conditions [31, 35]. Palloni and Millman's [36] evidence supports this hypothesis. Using World Fertility Study data from 12 Latin American countries, they found that consistent breastfeeding had a positive effect on child survival through the first year, which was stronger in countries with high levels of infant mortality and for children of less educated mothers. But when older ages (up to five years) were considered, although trends were in the direction of improved survival the longer an infant was breastfed, the differences were not statistically significant [34].

Breastfeeding also has an indirect effect on infant survival by lengthening birth intervals. Hobcraft et al. [37] found that children born after a short interval (less than two years) had a probability of dying in the first five years of life that was 52% to 161% higher, depending on whether the older sibling survived or died. Hobcraft's analysis did not control for breastfeeding of either the older or the index child. According to Vanlandingham et al. [31], others

> have argued that the effect of a short previous interval on child survival is not the result of a short duration of breastfeeding *per se* but is caused by other factors (probably maternal depletion, heightened competition for resources among siblings and greater risk of infection among children who are of similar age), because controlling for the duration of breastfeeding of the index child somewhat attenuates but does not eliminate the effect of the previous interval.

The role of maternal depletion has been suggested in research from Bangladesh and the Philippines. Shorter subsequent birth intervals also are associated with higher mortality of the index child, although the causal mechanisms have not been conclusively delineated.

Effects of reducing breastfeeding

We have seen that breastfeeding affects both the number of children borne by a woman who reaches age 50 and the number of her daughters who survive to join the next generation of parents. Reducing breastfeeding may, therefore, affect NRR in different directions, by increasing fertility and thus causing a rise in the number of daughters, and by increasing mortality and thus cansing a decline in the survival of those daughters. Do these effects totally counterbalance, cancelling one another? Or does one outweigh the other?

Palloni and Kephart [38] addressed this issue through analysis of data for Latin America from the World Fertility Surveys and through the development of an analytic and simulation model. Considering data for three countries, Colombia, Ecuador, and Peru, they found that if all women stopped breastfeeding without using contraception, infant mortality would increase by 3% to 10%. In two of the countries, the direct effect of stopping breastfeeding wonld account for about 95% of this effect and the indirect effect through birth intervals would account for the remainder. In the third country, the direct effect would still be about 70% of the total.

They also considered two groups of women, one using ineffective contraception and the other using effective contraception, both of whom stopped breastfeeding. In both situations, the effect on infant mortality was minimal, becanse these women were already spacing their children. Hence, the direct effect of giving infants foods other than breastmilk increased mortality only slightly. They found, under these and a wide range of other circumstances, with and without family planning, that a reduction in breastfeeding caused fertility to rise more than it caused child survival to fall. The net result of reduced breastfeeding is increased overall fertility and population growth. They also concluded that increased family planning can compensate for this fertility-increasing effect.

Conclusions

The evidence presented here overwhelmingly supports the desirability of promoting breastfeeding. Life chances for children are improved if women have the opportunity to breastfeed them for at least the first year of life, especially in harsh disease environments, where safe water for formula is not available and diseases that can be prevented by breastfeeding are more prevalent. Even in the best circumstances, the benefits of breastfeeding are demonstrable. Therefore, *policies that promote breastfeeding, at least for the first year, are strongly recommended.*

However, we must be judicious in our claims for the benefits of breastfeeding. We suggest two important cautions:

» Long-term breastfeeding cannot reduce fertility to less than half its biological maximum. Breastfeeding should be promoted for its major benefits for very young children and for its impact on overall fertility, but it alone will not reduce population growth rates to the low levels that ultimately must characterize the earth.

» Breastfeeding beyond the first year or 18 months of life appears to have little benefit either for the child or for reducing fertility and population growth. If long-term breastfeeding impedes other kinds of development, it can, overall, even be deleterious.

There is great concern that breastfeeding duration tends to decrease as a country's economy develops. This seems logical, as growing economies usually have greater female workforce participation and thus may offer women less opportunity to breastfeed. A drop in breastfeeding under these circumstances may lead to conflicting effects of socio-economic development on mortality. Mortality falls as economic circumstances improve, because of better access to health care and nutrition and better standards of pnblic health and hygiene. These mechanisms work at both the individual and the societal levels. Meanwhile, at the individual level, if these same populations breastfeed their children less, they expose children to greater risks of childhood diseases, and unless they use contraception that compensates for shorter post-partum periods, their fertility goes up. In most countries the positive effects of development have clearly outweighed the negative effects through less frequent breastfeeding. Yet there is room for policies and programmes to alleviate these negative effects.

We recommend policies that ensure the compatibility of a woman's participation in the labour force and breastfeeding for at least the first year, so that she is not forced to choose between two activities that both provide benefits to her children. The scientific evidence of the benefits to children overwhelmingly supports efforts to promote breastfeeding and to maintain and improve its compatibility with all aspects of mothers' lives.

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Discussion of paper by Menken and Kuhn

Unidentified speaker

If women in Bangladesh were to use contraception while they were breastfeeding, what would be the result?

Dr. Menken

I think the answer is that there is no reason to overlap other means of fertility control with breastfeeding in the first six months of life.

Unidentified speaker

But what if breastfeeding were to be replaced by a contraceptive device?

Dr. Menken

If you look at Hong Kong as a developing country, you find limited breastfeeding and massive use of contraception, leading to very low fertility (see table 5). If you look at the developed countries in the same table, it was assumed women breastfed for three months, but for most of those countries, breastfeeding was actually very limited. The damping of fertility came about through contraceptive use, so that if contraception is effective enough, it has a far more powerful effect overall than breastfeeding. Lactational amenorrhoea only prolongs birth intervals by a maximum of, say, 18 months. Long-term contraception can prolong them very much more, so that breastfeeding is not a competitor in the statistical race.

Unidentified speaker

No, no. You have not answered my question. You shifted to Hong Kong. I am asking you about Bangladesh. If you replaced breastfeeding by contraception in the Bangladesh conditions, what would happen?

Dr. Menken

In Bangladesh fertility has dropped radically as a result of family planning. There's been a long-term family planning programme that has offered contraception within people's homes in a society in which purdah is the common practice, so that women don't move freely out of their homes. The total fertility rate in Bangladesh is now under five, probably closer to four, and that decline has been achieved through the adoption of contraception. There has been some drop in breastfeeding, but it's mostly contraceptive use in combination with breastfeeding. Now, if you were to substitute poor contraception for the very good lactation practices (in terms of fertility-reducing effects), you might have a different effect. Suppose, for instance, you took women just post-partum and urged them to use Depo-Provera and gave them the injection. If they stopped lactating and after three months decided they didn't like Depo-Provera, what would happen? Fertility would go up. But that has not happened in most societies.

What one wants is to promote a system in which women can lactate, but not necessarily forever, if that means they can't work. One wants to promote a society in which women can combine these various roles. We need to try to make it feasible to breastfeed enough to benefit the child and to have fertility-controlling effects.

Dr. Colombo

Two small questions. One is very technical about Dr. Bongaarts' list. He speaks of the biological probability that conception will follow a single act of intercourse. What can he mean by that? A single act of intercourse has a probability that changes along the menstrual cycle. It is zero for most times of the cycle. Even in the fertility window, it is not a rectangular distribution. The second question is this. In aggregating studies of historical demography, it has

been found that there was a seasonal pattern in the birth rate. If we now compare the seasonal pattern north of the equator, it is opposite to that south of the equator. Is that biological or is it social?

Dr. Menken

Those are very good questions. I have been intrigued by the profound seasonality in fertility in Bangladesh for the last 20 years. Close to 50% of births occur in four months of the year, and you see this year after year. Some people said it was nutrition, and we did everything up, down, and sideways that we could do as demographers and yet found very little effect of nutrition. It turns out there is profound seasonality in the introduction of supplementation, that is, the move from full to partial breastfeeding. That appears to be related to the needs of the agricultural calendar and the jobs that women do. This move to supplementation appears to determine a great deal of the seasonality. We are about to do a study in Bangladesh, trying to measure ovulation to see whether there are differences in different seasons of the year, or whether differences in the intensity of breastfeeding explain part of the seasonality.

Dr. Colombo

So it's not a difference in the frequency of intercourse?

Dr. Menken

My hypothesis at the moment is that there are real differences in frequency of intercourse in different parts of the year. It would seem to me that seasonality is almost entirely socially determined, so it is not surprising that seasonality is different in different parts of the world, especially north and south of the equator.

Dr. McLaren

Could you respond to Dr. Colombo's other question about what Bongaarts meant about the chance of pregnancy?

Dr. Menken

If one figure is given, it is usually an average taken over the course of the month, so that if you assume there was a random chance of intercourse on any day, that average probably would apply. Bongaarts does include in his discussions of fecundability models the variation over the menstrual cycle in the probability that conception follows a single act of intercourse.

Unidentified speaker

I have a comment on the statement that breastfeeding has no effect on mortality after 12 months of age. I am not sure the literature is very clear-cut on that. I know at least two or three good studies that have shown an effect. The literature on morbidity certainly shows that the incidence of the number of infectious diseases is higher among non-breastfed children, even after one year of age. The protective effect certainly goes down with age, but I think it's hard to draw a line, particularly in societies where the alternative to breastfeeding, even in the second year of life, will certainly expose the child to a high level of infection.

Dr. Menken

The data that I was referring to came from several countries in Latin America. These are reports rather than prospective studies. There is no question that the benefits of breastfeeding are greatest for the poorest. Those who have the least access to other alternatives protect their children the most through their breastfeeding practices. In fairly careful searches of the literature, the large population samples I found have not shown any significant effect after the first year. It is an important area of research, and I'd like to see the references you have. I should add, though, that even if mortality consequences exist, by that age overall mortality rates have gone down enough that even if the relative risk is high, it's not going to have a large effect on the overall mortality.

Unidentified speaker

In support of what you've just said, we followed a very large cohort of children prospectively in Pakistan, and it turned out that 90% of the infant mortality occurred before the age of six months; 34% occurred in the first week of life. Mortality is, indeed, very early.

Dr. McLaren

Thank you again. Our last paper today is by Dr. Kathleen Rasmussen. We've heard a lot so far about the benefits of breastfeeding for the baby, the effects of breastfeeding on fertility, but Dr. Rasmussen is going to tell us about the effects of breastfeeding on maternal health and well-being.

Effects of breastfeeding on maternal health and well-being

Kathleen M. Rasmussen and Michelle K. McGuire

Abstract

Lactation occurs as part of a reproductive cycle and may have different effects on maternal nutritional status, depending on its duration and intensity. Thus, its effect on maternal health will differ with cultural setting and level of development. Lactation helps women to maintain a healthy body weight. Among well-nourished women, it may help to prevent obesity. Among poorly nourished women, breastfeeding also leads to weight loss, but with adequate birth spacing brought about by lactational anovulation, maternal depletion can be avoided. Lactation is probably not responsible for osteoporosis. Current evidence suggests that breastfeeding helps to prevent pre-menopausal breast cancer and is not associated with post-menopausal disease. Furthermore, breastfeeding may also help reduce ovarian cancer. Positive effects of breastfeeding occur at all levels of development and are most likely when biological, political, and sociocultural conditions interact to support its initiation and continuation.

Introduction

The effects of lactation on maternal health and well-being are many and varied. For example, lactation helps women maintain a healthy body weight. This is perhaps the most obvious biological effect of breastfeeding on women's health and is one that will be considered in detail. In addition, the hormonal changes characteristic of lactation influence maternal behaviour in ways that are supportive of both breastfeeding itself and positive mothering behaviours in general [1–4]. There is even evidence from animal studies that there are factors in milk that influence the behaviour of the nursing young [5, 6].

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Lactation occurs within a reproductive cycle

Lactation occurs as part of the reproductive cycle, and it may have different effects on maternal nutritional status, depending on its duration and intensity. Each time a woman reproduces, she goes through the cycle diagrammed in figure 1.

Each cycle may have very different characteristics. For example, the child could die in the neonatal period, and the cycle would then be very short. Alternatively, the woman might become pregnant while still breastfeeding; in this case there would be no non-pregnant, non-lactating interval. The woman and her husband could adopt some effective means of birth spacing and thus prolong the non-pregnant, non-lactating interval substautially.

The biological effect of breastfeediug on the nutritional status of the mother needs to be evaluated in the context of the whole reproductive cycle [7]. This is because some portions of the reproductive cycle deplete the mother, and some periods allow the mother to gain. Breastfeeding is commonly thought of as a time of depletion, but this is probably true only of the period of exclusive breastfeeding. Even this is not so in severely undernourished experimental rats, which actually gain fat while their nursing pups are starving [8].

In contrast, the period of partial breastfeeding may be one of repletion, and the longer it is, the more repletion may be possible [9]. Inasmuch as breastfeeding itself delays ovulation and therefore conception, breastfeeding may be associated with first depletion and then repletion of the mother. It is expected that the non-pregnant, non-lactating interval will serve as an opportunity for repletion. This assumption requires that the woman's food intake remain the same after the caloric demand of lactation has been removed and also that her workload does not increase above that which she experienced while nursing her infant. These assumptions may or may not be true and must be evaluated in a particular cultural or individual context.

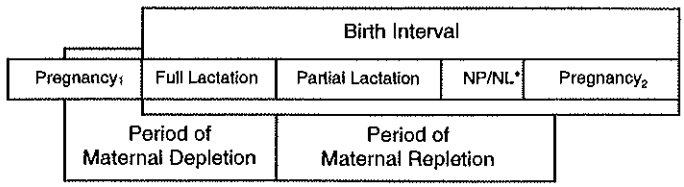

FIG. 1. Diagram of the reproductive cycle showing the birth interval and the periods of maternal depletion and repletion. *Non-pregnant, non-lactating

It should be clear, therefore, that the effects of breastfeeding on maternal health will be different in different cultural contexts or at different levels of development. The effects of breastfeeding on maternal health will also depend on the usual practices for exclusive or partial breastfeeding and on birth spacing. The effects of reproduction on a woman's health are cumulative over her lifetime, but because of the possibility that reproduction will result in net positive or net negative effects, the effects are not a simple multiple of the number of children borne. A more sophisticated analytical approach than this is needed if we are to understand the cumulative effects of reproduction, including lactation, on maternal health [7].

Lactation affects maternal health and well-being

Change in body weight

Women gain weight and body fat during pregnancy and tend to lose it during lactation [10]. The amount of weight gained during pregnancy is higher with better living circumstances [11]. The amount of weight retained after delivery shows this same discrepancy between poor and rich countries. In the United States, the rate of weight loss post-partum is often higher among lactating women than among non-lactating women (assuming that the women are not consciously dieting) [12]. The rate of weight loss is not constant [10]. It is greatest in the first few months post-partum and slows as solid foods are introduced into the infant's diet. Women may gain weight during partial breastfeeding and are especially likely to do so after weaning their infants.

Prevention of obesity

Among well-nourished women, lactation may help to prevent the weight and fat retention often associated with child-bearing. In fact, the effect of breastfeeding on helping a well-nourished woman return to a healthy body weight after delivery is fairly dependable [10]. Weight retention at the end of a reproductive cycle is influenced by the intensity and duration of breastfeeding. The data of Öhlin and Rössner [13] from Swedish women illustrate this point. They developed a "lactation score" that combined frequency and duration of breastfeeding. Among their subjects, weight loss from 2.5 to 6 months post-partum was greater as the intensity of breastfeeding increased. All women, however, lost weight in the subsequent 6 months, whether they breastfed or not, and the total weight loss after 12 months was the same among those who had been intensive breastfeeders as it was among those who had not. Unfortunately, in this study the investigators did not measure the weight change that occurred during the first 2.5 months post-partum, the time of greatest weight loss among breastfeeding women.

The data of Forsum and her co-workers [14] also provide information about the change in body fat that occurs during pregnancy and lactation among well-nourished women. They studied 22 Swedish women before and during pregnancy and during the first six months of lactation. Although by six months post-partum, women in this population of enthusiastic breastfeeders had lost nearly all of the weight and several kilograms of the fat that they had gained during pregnancy, they still retained almost 4 kg of the fat that they had gained. This fat was available to support continued breastfeeding in the second half of infancy and beyond. Unfortunately, no comparable data are available for non-lactating women.

Maternal depletion

In contrast, women living under poor circumstances are concerned about becoming too thin as a result of child-bearing.* Data from more than 1,000 women in the Cebu Longitudinal Health Study in the Philippines [15] show that the direction of weight change in the post-partum period is associated with mater-

* Marquis GS, Díaz J, Bartolini J, Creed Kanashiro H, Rasmussen KM. Peruvian mothers' decision-making processes concerning breastfeeding and weaning toddlers. Paper presented at the annual meeting of the American Public Health Association, San Diego, Calif, USA, November 1995.

nal weight immediately after delivery. Those who were the heaviest at this time gained weight during lactation, but women in other groups lost weight. Longer birth spacing might allow women in the other groups to return to their pre-pregnant weight before conceiving again.

A particularly relevant recent study [16] from Bangladesh goes even further. It accounts for initial maternal weight, duration of breastfeeding, and season in examining the effect of breastfeeding on maternal weight change. Weight loss was higher in lactating than in non-lactating women, and lower in women with low initial weight than in those with high initial weight. In this study, the rate of weight loss was highest 5 to 9 months post-partum and was near zero at 16 months post-partum. After this time, women gained weight. Nevertheless, season and time post-partum interacted so that women who reached the time of most intensive breastfeeding at a time of low food supply lost the most weight. Each additional birth was associated with a 280-g decrease in the mother's weight at conception. Furthermore, interpregnancy intervals of less than 18 months were far more important: each of these was associated with an 800-g decrease in the mother's weight at conception. The authors concluded that "women in Bangladesh have the potential to regain the weight they lose during the first 15 months or so of lactation despite a high and varying level of nutritional stress," but that this depends on adequate spacing between pregnancies to permit a woman to replace her reserves.

In summary, like their better-nourished counterparts, women living under poor circumstances lose weight during lactation. Furthermore, their weight loss is magnified by seasonal changes in their environment. Nonetheless, with adequate birth spacing brought about by lactational anovulation, women living under poor circumstances should be able to maintain a healthy body weight from one reproductive cycle to the next.

Changes in incidence of chronic diseases

Osteoporosis

As women live longer, osteoporosis is becoming a much more serious problem [17, 18]. It has been postulated that lactation might contribute to the development of osteoporosis because so much calcium is transferred from the mother to the infant in the milk during breastfeeding. Although the rate of calcium transfer from mother to infant is actually higher during the third trimester of pregnancy than it is during lactation [19, 20], the total amount of calcium transferred may be greater during lactation than during pregnancy if lactation is long enough [21]. However, many features of calcium metabolism change during lactation to compensate for the high rate of transfer of calcium from the mother to the infant [22]. For example, the rate of bone resorption increases [21], and renal calcium conservation also increases [20, 23].

Research presented or published recently shows clearly that bone mineralization returns to normal after lactation among well-nourished women with ample calcium intakes [21, 24]. The shorter the period of lactation, the sooner bone mineralization returns to normal. Nevertheless, if birth spacing is adequate, bone mineral densities will have returned to pre-pregnant values before the next conception. In a recently completed year-long trial, the milk-calcium output of calcium-supplemented Gambian women with habitually low calcium intakes did not increase, and neither did bone mineral content [25]. Bone mineral content, however, did not decline during the first year of lactation, as has been previously observed among women with higher calcium intakes.

The effect of breastfeeding on hip fracture, one of the most debilitating consequences of osteoporosis, has not been studied often, but the three studies that have investigated this association among women living under good circumstances have come to the same conclusion [26]. In all of them, there was a reduction in the incidence of hip fracture with increased duration of lactation.

Thus, it appears that lactation *per se* is probably not responsible for osteoporosis or its consequences. A woman's body can adapt to varying calcium intakes and lengths of lactation. Thus, this concern, although intriguing at one time, can now be eliminated.

Breast cancer

It has long been known that the incidence of breast cancer is associated with a woman's reproductive history. In particular, breast cancer is higher among women with late onset of menstrual periods, late age at first birth, and few total births [27]. Evidence of an association between lactation and breast cancer has been inconsistent [27, 28].

The most recent work [29], using a large sample of women from a multicentre case-control study, showed that breastfeeding reduces the risk of pre-menopausal breast cancer in a dose-dependent fashion (the longer the total period of breastfeeding, the lower the risk of breast cancer). In the same study, there was no association of lactation with post-menopausal breast cancer. Many researchers think that breast cancer in these two periods has different origins, so this lack of consistency is perhaps not surprising. In summary, the current evidence points to a beneficial effect of breastfeeding in preventing pre-menopausal breast cancer, and no association of breastfeeding with the post-menopausal disease.

Ovarian cancer

There are also conflicting findings about a possible association of breastfeeding with ovarian cancer. In a recent multicentre collaborative study, there was a 20% redncticn in the incidence of ovarian cancer with lactation [30], but this was not statistically significant. Nevertheless, the reduction in cancer incidence with increasing time spent pregnant was even greater. The authors speculate that this is because pregnancy is even more effective than lactation in suppressing ovulation.

Overall, we can say that lactation is not responsible for increasing the incidence of some chronic diseases in women and, in the case of pre-menopausal breast cancer, probably has a role in preventing this condition.

The effects of lactation vary with the circumstances of the woman's life

For women living in traditional societies (fig. 2), investigators have historically been concerned about undernutrition. In this situation, breastfeeding has both direct effects on maternal health and well-being and indirect effects that are mediated through fewer reproductive cycles. Some of the effects on the mother benefit the infant, in addition to the nutritional value inherent in the direct transfer of human milk. The infant also benefits from breastfeeding indirectly from the lengthening of the birth interval.

In transitional societies there is now concern about overnutrition in addition to concern about the undernutrition that still remains. This creates a more complex picture than the last, because chronic diseases, particularly those associated with obesity, are becoming a problem (fig. 3).

In industrialized societies the concern is primarily about overnutrition and the "diseases of affluence." In this situation few women use breastfeeding for birth spacing, so the indirect effects of breastfeeding on maternal and child health via prolonged birth spacing are eliminated, but the direct effeets remain and are important (fig. 4).

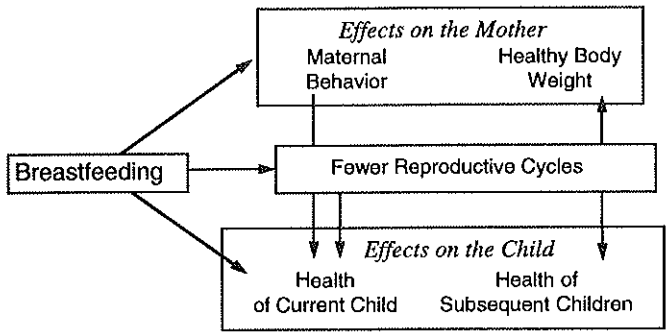

FIG. 2. Diagram showing how breastfeeding affects maternal and child health in a traditional society. Note that the effects of breastfeeding are both direct and indirect, via its effect on reducing the number of reproductive cycles

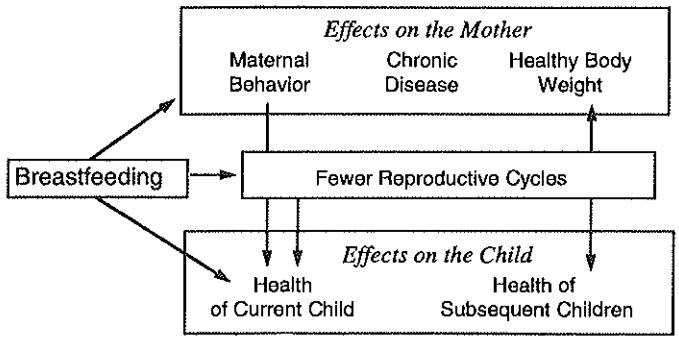

FIG. 3. Diagram showing how breastfeeding affects maternal and child health in a society in transition. Note that the effects of breastfeeding are both direct and indirect, via its effect on reducing the number of reproductive cycles

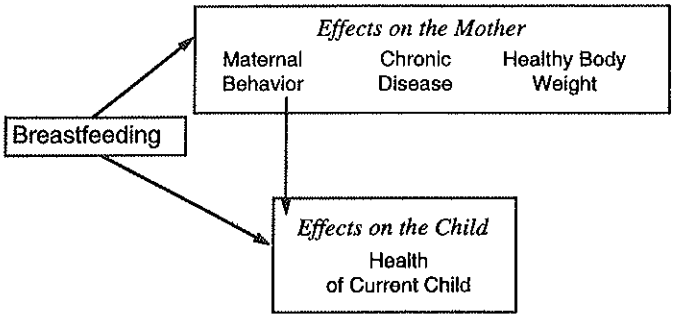

FIG. 4. Diagram showing how breastfeeding affects maternal and child health in an industrialized society

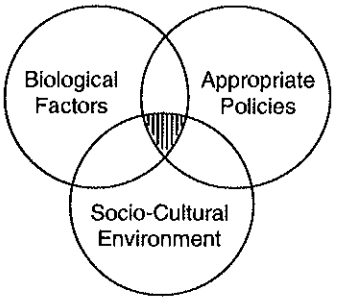

FIG. 5. Factors required to realize the benefits of breastfeeding for maternal and child health. Note that the appropriate biological, sociocultural, and political factors must all be present for the maximal positive effect

Conclusions and implications

This article has focused on the biological ways in which breastfeeding affects maternal health and well-being. To achieve these benefits, women must initiate and continue breastfeeding. As described earlier, for this to occur, the biological, political, and sociocultural environments must interact in a way that is supportive of breastfeeding (the shaded area of fig. 5).

As the figures illustrate, this interaction occurs in different ways under different living conditions. Appropriate interventions to promote and sustain breastfeeding will, therefore, differ with the circumstances. For example, in societies in which breastfeeding is the usual practice and mother and infant can be together all day, the usual activities to promote initiation of breastfeeding can work well. This may involve, for instance, supporting the Baby-Friendly Hospital Initiative. Supporting an adequate duration of breastfeeding and the timely introduction of complementary foods is more difficult but is, nonetheless, important. This may involve developing policies that are not now in place, especially for women who work in the informal employment sector. The principal future threat is urbanization and disruption of the culture in which breastfeeding is the norm.

In societies in which breastfeeding is not the usual practice, there are other concerns. In these societies, just getting women to consider breastfeeding is a problem, because there are strong societal pressures against starting to breastfeed. Therefore, supporting women to initiate breastfeeding in a relatively hostile environment is necessary, and this means more than just following the principles that are part of the Baby-Friendly Hospital Initiative. There are also pressures against women continuing to breastfeed. This is because women have taken on new roles in society that separate them from their infants and are living in situations in which their infants cannot be cared for by relatives. Thus, better maternity leave policies need to be developed, and child care near the mother's place of employment also needs to be provided.

In summary, lactation influences maternal and infant health in a number of positive ways. These vary with the circumstances in which women live, but positive effects are present at all levels of development. These positive effects of breastfeeding are most likely to occur when the biological, political, and sociocultural environments interact in ways that support both the initiation and the continuation of breastfeeding.

Acknowledgements

The thoughtful comments of Drs. Jean-Pierre Habicht, Cutberto Garza, and Grace Marquis are greatly appreciated.

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Discussion of paper by Rasmussen and McGuire

Dr. McLaren

Could you comment on what may be one of the larger effects of breastfeeding on maternal health and well-being, that is, avoiding two pregnancies back-to-back and two children under one year of age?

Dr. Rasmussen

That is covered in my considerations of the health of the subsequent child.

Professor Hanson

I understand that there is a protein in human milk that induces programmed cell death in many malignant cell lines. Could it be that in a mother who has been lactating several times, there would be such milk proteins remaining in the gland, which could induce apoptosis of cells that in time might turn into cancers?

Dr. Rasmussen

An attractive hypothesis, but I don't know enough about it to answer your question. Does anyone else want to take it on?

Professor Howie

No, I wouldn't like to take it on. I was going to ask a different question. One of the features of prolonged lactation is the reduction of the number of reproductive cycles that a woman has in her life. As I understand it, most circumstances that produce such a reduction also produce a reduction in ovarian carcinoma. Do you know of any direct evidence of that in women who have breastfed for a long time?

Dr. Rasmussen

I am not aware of people having looked at that, but again, it is an attractive hypothesis.

Dr. Pollitt

You indicated that breastfeeding had an effect on maternal behaviour. Could you say something more about that? And a second question. The United States is going through major social changes. Many children of teenage mothers of lower socio-economic class are born out of wedlock, often without a father present, and the use of drugs (in particular, crack) has reached epidemic proportions. What is the benefit of breastfeeding for this group of mothers?

Dr. Rasmussen

Dr. Garza has strong opinions on maternal behaviour, so I will ask him to respond to your first question. The issue here is that there are changes in the maternal brain as a result of breastfeeding that change the mother's responses to painful stimuli. Mothers become more placid.

Dr. Garza

The only thing I would add is that there are some very intriguing animal data suggesting that oxytocin, for example, may change maternal behaviour. It is very difficult to think that a hormone that has played such a basic role in animal physiology would not also have a similar impact on people. But of all the benefits—nutritional, immunologic, and bonding—the last is the least well documented and the least studied both in animals and in humans. A number of investigators around the world are taking a closer look at this. One symposium held in Europe about three years ago looked at the behavioural effects of hormones that we normally associate with lactation.

Dr. Pollitt

As a behavioural scientist myself, I think it is very attractive to think in terms of what breastfeeding does and how it could affect maternal behaviour, for

example, through oxytocin acting on the brain. But I don't think there are any hard data that would actually support the notion that breastfeeding changes maternal behaviour. Just to carry out such a study would be very difficult. The data on bonding have been primarily related to the issue of immediate contact between the infant and the mother and have not really been related to breastfeeding, as such.

Dr. Rasmussen

The point that you are making is correct. The hard data available are essentially nil. We are making an inference. I was very careful not to use the word bonding because of exactly the problems that you outlined. Bottle-feeding mothers do feel close to their infants, and what do we have as a measure of closeness? It's not easy.

On your second question, you posed the all-too-real situation of the teenage mother in the Uuited States. What do we recommend? Such young women are biologically capable of breastfeeding. The issue is whether we recommend it to them. Breastfeeding is done most effectively by women who are committed to it. Teenage pregnancy programmes around the country are giving these girls a lot of support, and some of the investigators are finding that these young women can successfully breastfeed with this kind of support. When you see that, you are seeing a whole lifestyle change, and they may be giving up some of the practices that got them pregnant in the first place. We would like to have a situation in which we could feel good about recommending breastfeeding.

Dr. Lawrence

Carol Bryant and colleagues did as controlled a study as you can on a teenage population under those circumstances. They randomly assigned young women to two groups. They educated the women in one group to breastfeed. In the other group, they supported the mothers in every other way but never mentioned breastfeeding. They measured the effects on the mother, and after one year, there was a clear difference. Those women who had breastfed had changed. They had established some self-esteem and had gotten hold of their lives, whereas the mothers who had not breastfed had not changed. They had not deteriorated, but they had not improved in their own self-image and some other behaviours.

Dr. Rasmussen

So, I do not know whether we can make this a general recommendation. It requires a whole lot of support to happen well, and that is the kind of thing that Carol Bryant is doing.

Dr. Lawrence

I have been involved in some support for grass-roots projects on mother-friendly workplaces. When we are thinking of policy, we should include schools as the teenage mothers' workplace. It is really amazing how much can be accomplished if teenage mothers can be encouraged to stay in school. Were you including sociocultural environment?

Dr. Rasmussen

I was considering the support for breastfeeding in the mother's particular home environment. Did her husband or partner support it? Did her mother-in-law, her mother, her family? I was thinking about various cultural environments. For example, upstate New York is pro-breastfeeding. Davis, California, is perhaps the classic pro-breastfeeding environment. In inner-city Baltimore, the breastfeeding rate is only 4%.

Dr. Prentice

What are your feelings about osteoporosis in women who do not have such high levels of calcium intake as those in Janet King's studies? What do we advise women who are breastfeeding in the United States and in the United Kingdom who wish to give up dairy products because they are worried about colic in the baby? We have seen quite a few breastfeeding women give up drinking milk completely because of concern about fat in the diet. Do you feel that the 300 to 400 mg daily calcium intake in these women would be sufficient to sustain repletion?

Dr. Rasmussen

The simple answer is that I don't know. There are a number of papers on women whose daily calcium intakes are 1,000 mg or more. They certainly have adeqnate calcium to make that repletion. I don't know of any study in which women with lower calcium intakes have been followed over a longer period. I am not sure how ethical it would be to randomly assign them to a calcium pill or no pill plus their usual intake. Certainly nobody has done a joint analysis of lactation history, usual calcium intake, and incidence of osteoporosis. You have hit a raw nerve, because I took calcium pills myself when breastfeeding, since I am a non-milk-drinker myself.

Dr. Prentice

In the Gambia we found a small loss of bone calcium in the forearm. In women who were fully breastfeeding with no snpplementation at all, there was a repletion before 12 months. There is an urgent need to follow at least some groups of women who are consuming low amounts of calcium. It doesn't have to be a trial, just an observational study.

Dr. McLaren

Before closing this session on the impact of breastfeeding on fertility, I would like to ask Bishop McHugh to comment on a point that some of us were discussing earlier today: whether it is acceptable to the Catholic Church and to the Holy Father if a woman decides to breastfeed with the express intention of not getting pregnant, of delaying her next pregnancy, of spacing her family.

Bishop McHugh

It is an easy answer. Yes, it is all right. There is no prohibition or inhibition on the part of the Church for a woman to use breastfeeding or the LAM (lactation amenorrhoea method) as a method of spacing or delaying future births. In fact, it is our intent to encourage that. As Dr. Pérez said, it very often correlates with the use of the natural methods of family planning, and indeed, many people in natural family planning today make a direct effort to combine breastfeeding with natural methods of family planning, as the early phase of deferring the next birth. There would be no prohibition by the Church to the use of breastfeeding to defer subsequent birth.

Dr. McLaren

Thank you, Bishop McHngh. I think that is a very important point.

Dr. Menken

Could I follow up on that? I assume there would be no objection to the use of methods of detecting ovulation, if the people could develop better means. Natural family planning is based on one method, a rather crude method. Would there be any problems if there were better methods of detecting when ovulation occurs?

Bishop McHugh

I would say no. As a matter of fact, at the earlier meeting on natural family planning, a lot of data on more technical methods were presented, but the more technical you get, the less useful it is to a population, especially to a third world popnlation. There is a direct effort being made to find more accurate methods of predicting ovulation.

Protective effect of breastmilk against infection

Peter W. Howie

Abstract

There is strong evidence that breastfeeding protects infants against infection in environments where clean water cannot be guaranteed, leading to substantial reductions in morbidity and mortality. This is particularly evident in the protection against gastrointestinal disease, although there is also evidence for protection against respiratory infection and otitis media. The evidence for a protective effect of breastfeeding against infection in developed countries has been more controversial, with criticisms being levelled at the methodology of many studies. Evidence is presented from a study in a developed country that met key methodological criteria to show that breastfeeding for 13 weeks offers substantial and continuing protection against gastrointestinal illness. Smaller, but still potentially important, protective effects against respiratory illness also occur. The results add strong support to policies that promote breastfeeding in both developed and developing countries.

Introduction

"Breast is best" is one of the most widely used and best-known slogans in the promotion of breastfeeding. There are several reasons to promote the support of breastfeeding for all mothers and babies, but one of the most important is the protection that breastmilk offers babies against infectious disease. There is very strong evidence from many studies that breastfeeding confers substantial protection against serious morbidity and mortality in those developing countries where access to clean water is not readily available [1–3]. This subject is discussed in more detail by Victora [4] in this issue.

Evidence both from epidemiologic studies in developing countries and from the physiological components of breastmilk strongly suggests that breastmilk has an importaut role in protecting babies against infection. In particular, lactoferrin, which binds iron necessary for coliform growth, and lysozymes, which have bactericidal activity against gram-positive and gram-negative organisms, are supportive of the antimicrobial effect of breastmilk. The influence of the immune system and the secretion of IgA in breastmilk is discussed in this issue by Hanson et al. [5]. Taken together, this evidence indicates a clear and important role for breastfeeding as a means of protecting infants from infection.

Breastfeeding and infant infection in developed countries

The central question in this article is the role that breastfeeding may have in protecting infants against infection in developed countries where clean water supplies are guaranteed. A number of authors have expressed skepticism that breastfeeding has such a role in developed countries [6].

In 1986 Bauchner et al. [7] reviewed all the articles that had appeared in the English-language literature since 1970 investigating the relation between infant feeding and health. They scrutinized all studies that contained at least 40 subjects in their sample and applied four key methodological criteria to evaluate the scientific quality and reliability of the studies. The criteria were the avoidance of detection bias, adjustment for confounding variables, a definition of outcome events, and the definition of infant feeding. They examined 14 cohort studies and 6 case-control studies. Eight of the cohort studies reported a pro-

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The results have previously been published in Howie PW, Forsyth JS, Ogston SA, Clark A, Florey CD. Protective effect of breastfeeding against infection. BMJ 1990; 300:11–6 (listed as reference 8).

tective effect of breastfeeding against infant infection, and six found no evidence of protection. Four of the case-control studies found evidence of a protective effect, and two did not. None of the studies found any evidence that breastfeeding might increase the vulnerability of infants to infectious disease.

The significant finding of the review by Bauchner et al. was that they identified significant methodological flaws in all bnt two of the studies, and even these two could be criticized for having inadequate sample sizes.

To avoid detection bias, it is necessary to ensure that comparative groups of bottle- and breastfeeding mother–infant groups are studied with equal vigour. For example, breastfeeding mothers may be more anxious and therefore more willing to report episodes of infection to their physicians. In addition, it is important to ensure that the interval between any possible infectious episode and the recording by the investigator is sufficiently short, because there is a high incidence of failure to recall significant episodes when the reporting interval is long.

In most developed countries, there is a strong social class bias between bottle- and breastfeeding mothers, with breastfeeding mothers coming from the higher socio-economic groups. This and other differences between bottle- and breastfeediug mothers can introduce important confounding variables that may explain differences in rates of infectious disease in children of the two groups that are not attributable to the method of feeding. Unless great care is taken to allow for confounding variables, it is not possible to attribute reliably any difference in infectious disease frequency to the effect of breastfeeding itself. Studies that do not take due account of confounding variables, therefore, must be regarded as scientifically flawed.

A third important factor is to make clear definitions of the outcome events and to apply them with equal rigour to both bottle- and breastfeeding groups of mothers. In particular, when studying the effect of infant feeding on diarrhoeal disease, it has to be borne in mind that the stool consistency differs between bottle- and formula-fed infants. Unless rigorously applied criteria are applied to the definition of infant disease, it is possible that spurious differences between bottle- and breastfed infants will be observed.

Finally, many mothers do not fall neatly into bottle- or breastfeeding categories, as early introduction of formula and solids, mixed feeding, and use of expressed breastmilk may complicate the definition of infant-feeding categories. It is important, therefore, that infant-feeding groups be defined precisely on the basis of carefully collected contemporaneous information about the feeding pattern of the infant.

Applying these criteria, Bauchner et al. found methodological weaknesses in the great majority of the studies that had examined the potential protective effect of breastmilk against infection in young infants. They concluded that "breastfeeding has at most a minimal protective effect in industrialized conntries." In my view it would have been more appropriate to conclude that a rigorous study of the potential protective effect of breastfeeding against infection should be carried out using a sample of sufficient size. Because of the methodological weaknesses in the previously published studies, it was equally as possible that an important protective effect of breastfeeding against infection had been concealed or minimized in some of the studies as that a protective effect had been reported that did not exist.

Dundee Infant Feeding and Health Project

Because of the unsatisfactory nature of the published reports, a study was performed in Dundee, Scotland [8], to investigate the relation of infant feeding and infectious disease using a methodology that took into account the requirements set out by Bauchner et al.

The specific aims of the study were (1) to compare the frequency of childhood illness in breast- and bottle-feeders after correcting for coufounding variables and (2) to determine if the frequency of childhood illness is influenced by the duration of breastfeeding.

Study sample

Details of the study sample and the methods of recruitment have already been published [8]. A total of 750 mothers were recruited to the study, of whom 6 withdrew after delivering their babies. Because the objective of the study was to include only healthy babies of normal birthweight, a total of 70 babies were excluded because they either were delivered before 38 weeks with a birthweight of less than 2,500 g or spent more than 48 hours in the Special Care Baby Unit. This left 674 mother–infant pairs, who were followed up for two years with a 91.5% completed follow-up rate.

Avoidance of detection bias

To overcome the problem of detection bias, follow-up was carried out by both "hot" and "cold" pursuit. Medical, social, and obstetric data were col-

lected at birth and used in allowing for confounding variables. Each mother–child pair was visited at home at 0.5, 1, 2, 3, 4, 6, 9, 12, 15, 18, 21, and 24 months after birth, and detailed information was collected about the child's feeding and health. Standardized questionnaires were used, and the visitors were given instruction sessions to standardize the method of data collection. In addition to this hot pursuit of information, further data were acquired by scrutiny of the general practice records to identify episodes of illness that were reported to the general practitioner bnt not to the health visitor. This method of data collection was applied with equal vigour to all groups of mothers in the study.

Definition of outcome event

The intention of the study was to define the effect that infant feeding would have on episodes of serious illness. The definitions of illness were adapted from those used by Chandra et al. [9] in a previous study. The episodes of infectious disease had to last at least 48 hours before they were considered significant. Gastrointestinal infection was defined as vomiting and diarrhoea, respiratory infection as coryza and cough or wheeze, and ear infection as painful discharging ear, all lasting for at least 48 hours. Infections of mouth and skin were determined by the presence of inflammation, and eczema was diagnosed by a physician on the basis of typical signs. The episodes of illness were reported to the study coordinator, and if there was any doubt whether an episode qualified for inclusion under the study criteria, a decision was taken by a paediatrician who reviewed the information without knowing the feeding category of the subject.

Definition of infant feeding

During each visit detailed information was collected about the infant's feeding in the previous 24 hours. This was done to ensure that accuracy of recall would be maximized. Information was collected about the number of breastfeeds, the number of formula feeds, the number of solid feeds, and the number of juice and water feeds. This information was used to calculate the dates of the first introduction of formula, cow's milk, and solid feed as well as the last date of breastfeeding.

On the basis of this detailed contemporaneous information about breastfeeding, babies were allocated to one of four groups. (1) *Bottle-feeders* were exclusively bottle-fed from birth. (2) *Early weaners* were breastfed for less than 13 weeks. (3) *Partial breastfeeders* were breastfed for 13 weeks or more, but formula or solid-food supplements were introduced before the age of 13 weeks. (4) *Full breastfeeders* were breastfed for 13 weeks or more, and no formula or solid-food supplements were introduced before the age of 13 weeks. The comparative analyses were carried out using these four infant-feeding groups.

Adjustment for confounding variables

A total of 40 potential confounding variables were identified in the groups of maternal factors, infant factors, and paternal factors. Although a number of factors differed between bottle- and breastfeeding mothers, the three most significant confounding variables among the main groups were social class, parental age, and maternal smoking. A regression analysis technique was used, and after allowing for these three factors, all other differences were nonsignificant. Reanalysis of data introducing a greater number of confounding variables made no difference to the final conclusions.

Calculation of sample size

The principal outcome variable was determined as the incidence of gastrointestinal disease in the first 13 weeks of life. This was expressed as the proportion of babies having one or more episodes of gastrointestinal disease during that time. On the basis of the data of Fergusson et al. [10], it was hypothesized that breastfeeding would lead to a reduction in the incidence of gastrointestinal illness from 16% to 8% in the first 13 weeks of life. It was calculated that a sample size of 560 mother–baby pairs would be needed to achieve a 90% certainty of a significant result at the .05 level (two-tailed test). Thus, the actual sample size of 674 resulting from the original recruitment of 750 mothers was more than sufficient.

Results

Incidence of gastrointestinal disease during the first 13 weeks

Figure 1 shows the percentage of babies with one or more episodes of gastrointestinal disease in the first 13 weeks of life, according to their infant-feeding category as defined above. The unshaded columns show the observed incidence of gastrointestinal illness, and the shaded columns show the adjusted incidence after allowing for the three confounding variables described above. The observed incidence of gastrointestinal illness in bottle-fed babies was

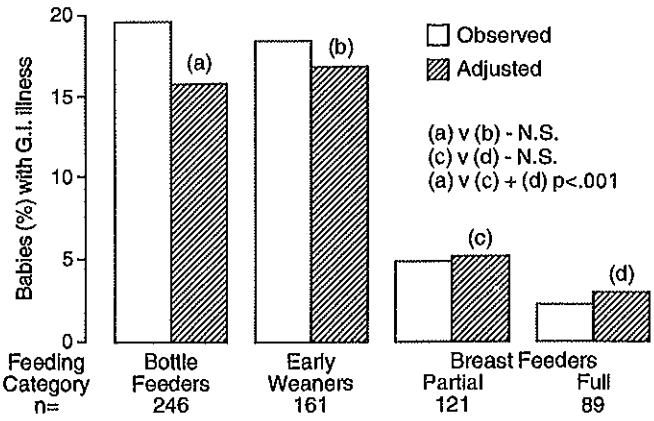

FIG. 1. Percentage of babies with one or more episodes of gastrointestinal illness during the first 13 weeks of life according to early infant-feeding group. Unshaded columns show observed percentages, and shaded columns show percentages adjusted for social class, parental age, and maternal smoking

19.3%. This did not differ significantly from the observed incidence (18.3%) in babies who were weaned before 13 weeks, usually within a few days of birth. These incidences contrasted sharply with those in the partially and fully breastfed groups (4.8% and 2.2%, respectively). The latter two groups did not differ significantly in the frequency of gastrointestinal illness. When the incidence of gastrointestinal illness in the breastfed babies, whether partially or fully breastfed, was compared with that in the bottle-fed babies, there was a highly significant difference that persisted after adjustment for confounding variables ($p < .001$).

Similar comparisons were made among these four feeding groups for the periods 14 to 26 weeks, 27 to 39 weeks, and 40 to 52 weeks. The results are shown in table 1. Although the relation between breastfeeding and protection against infection became less clear-cut as time progressed, there was a persistent reduction in the incidence of gastrointestinal illness in those babies who had been fully breastfed for 13 weeks compared with those who were bottle-fed from birth. This difference persisted despite the fact that many of the mothers who fully breastfed their babies during the first 13 weeks had completely weaned them by the age of one year.

The relation between infant feeding and respiratory infection was also analysed (table 1). In general, the incidence of respiratory infection during the first year of life was less among partially and fully breastfed babies, but the differences were much smaller than those for gastrointestinal illness, and they were only observed during the periods from 0 to 13 weeks and from 40 to 52 weeks.

Effect of breastfeeding on hospital admissions for infectious disease

The effect of breastfeeding upon the incidence of hospital admissions of babies for infectious disease was studied, using babies who were bottle-fed from birth as the comparative group (fig. 2). When the results were expressed as an odds ratio, the incidence of admission was similar for babies who were breastfed for less than 13 weeks and for those who were bottle-fed from birth. By contrast, the incidence of admission was significantly lower for all the groups of babies who were breastfed for more than 13 weeks than for those who were bottle-fed from birth. No significant protective effect of breastfeeding was observed against ear, mouth, eye, or skin infection, colic, eczema, or nappy rash.

Conclusions

Breastfeeding for 13 weeks reduces the rate of gastrointestinal illness in infants during the first year of life after correcting for confounding variables. The protective effect of breastfeeding is not dependent upon the avoidance of early supplements and persists beyond the period of breastfeeding itself. There is a similar but smaller reduction in the rate of respiratory illness in babies who are breastfed for 13 weeks. Breastfeeding for 13 weeks also reduces the incidence of hospital admission owing to serious episodes of infectious disease.

TABLE 1. Numbers (percentages and percentages adjusted for social class, parental age, and maternal smoking) of babies with infections up to one year of age according to method of feeding in the first 13 weeks

Type of infection	Weeks	Bottle-fed ($n = 246$)		Early weaners ($n = 161$)		Breastfed: Partially ($n = 121$)		Breastfed: Fully ($n = 89$)		% for adjusted rates: Bottle-fed vs early weaners	% for adjusted rates: Partially vs fully breastfed	% for adjusted rates: Bottle- vs breastfed	95% CI for difference between bottle- and breastfed
Gastrointestinal	14–26	47	(19.1, 17.9)	33	(20.5, 20.2)	8	(6.6, 6.9)	7	(7.9, 8.7)	0.33	0.21	8.06[a]	4.0 to 16.2
	27–39	55	(22.3, 21.8)	35	(21.7, 21.1)	20	(16.5, 16.5)	7	(7.9, 8.5)	0.03	2.79	4.03[b]	2.5 to 16.1
	40–52	55	(22.4, 22.7)	21	(13.0, 12.8)	19	(15.7, 15.2)	6	(6.7, 6.6)	6.23[b]	3.85[b]	6.70[a]	5.1 to 18.5
Respiratory	0–13	100	(38.9, 37.0)	54	(32.0, 31.7)	29	(23.0, 24.2)	22	(23.2, 25.6)	1.22	0.05	6.35[b]	3.9 to 20.3
	14–26	116	(47.1, 46.0)	76	(47.2, 47.2)	42	(34.7, 35.5)	34	(38.2, 39.9)	0.06	0.40	2.80	−0.8 to 17.4
	27–39	112	(45.5, 42.9)	85	(52.8, 52.6)	57	(47.1, 49.5)	32	(35.9, 39.6)	3.48	1.89	0.31	−10.8 to 7.5
	40–52	133	(54.1, 53.3)	72	(44.7, 44.6)	46	(38.0, 38.6)	38	(42.7, 44.2)	2.79	0.63	5.57[b]	2.7 to 21.1

Source: ref. 8.

a. $p < .01$.
b. $p < .05$.

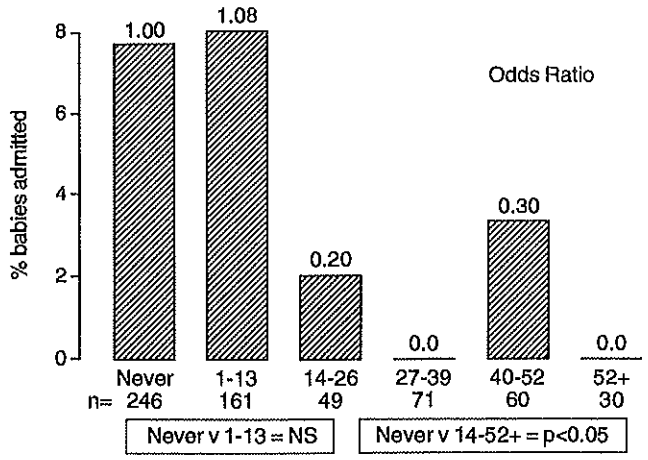

FIG. 2. Babies admitted to hospitals in their first year: odds ratio adjusted for social class, parental age, and maternal smoking according to duration of breastfeeding. Never breastfed is given an odds ratio of 1.0

Discussion

The conclusions of this article are entirely dependent upon the rigour of the methodology. Every precaution was taken to meet the methodological criteria set out by Bauchner et al. [7]. Assuming that the study is regarded as methodologically sound, it provides very strong evidence that breastfeeding offers substantial protection against gastrointestinal illness in developed countries. The 19% incidence of vomiting and diarrhoea during the first 13 weeks of life was very similar to the 16% incidence reported by Fergusson et al. [10] during the first four months of life in their study in Christchurch, New Zealand. Bearing in mind that the episodes of illness that were reported had to last for at least 48 hours, it is clear that babies who are bottle-fed from birth are exposed to a substantial risk of significant episodes of gastrointestinal illness not only during the first 13 weeks but throughout the first year of life, as shown by the much lower incidence of hospital admission among babies breastfed for 13 weeks or more.

A further analysis was carried out to examine the possibility that breastfeeding for less than 13 weeks would offer significant protection. The results showed that breastfeeding for 6 weeks did not confer the same level of protection as breastfeeding for 13 weeks, and confirmed the view that a minimum period of 13 weeks should be recommended to ensure a substantial degree of protection. Another important finding was that exposing infants to breastmilk for only the first few days of life is insufficient to offer any significant protection against infection, suggesting that exposure to colostrum alone is not enough.

This study provides strong evidence to support the promotion of breastfeeding for all mothers in developed countries [3, 11, 12]. It reinforces the need to provide mothers who wish to breastfeed adequate support and facilities in the form of health-service support, creche facilities, and adequate maternity leave. It is also possible that the benefits gained from breastfeeding in the early weeks of life may continue into later stages of infancy and childhood, and this possibility is being examined through further follow-up studies of this cohort of mother–baby pairs.

Acknowledgements

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Discussion of paper by Howie

Dr. Colombo

I recognize that the protocol for your study was rigorous, but I was a little confused and concerned because of so many interacting variables. You studied 40 variables, but I want to know how some were excluded and others were retained as important variables to make this statistical analysis conclusive. Thank you for your lecture and expert use of statistics.

Professor Howie

I am not a statistician, but I think our study demonstrates the power of regression analysis techniques. They have made valid and robust statistical analyses of this kind possible, which has been a very important step forward in statistical methodology.

Dr. Woolridge

I would like to ask one question about what is generally regarded as a very elegant study. When you discussed the instance of gastrointestinal illness from 0 to 13 weeks, you said that receiving colostrum had no impact (or appeared to have no impact) on reducing the incidence of infection. Nevertheless, when you came to 40 to 52 weeks, the early weaners had comparable rates to the partial breastfeeders and seemed to be distinct as a group from both the bottle-feeders and the full breastfeeders. Have you any way of accounting for this disparity at 40 to 52 weeks? Might that be due to a failure to control for another confounding factor at that age?

Professor Howie

It is possible that what you say is correct. Some differences appeared to emerge later in the first year, and it is possible that colostrum is having some effect. It does seem, however, to be a marginal effect rather than a dominant one. All the data were subjected to the correction of confounding variables throughout the study, so the differences that you see were the true, observed, and corrected differeuces.

Dr. Woolridge

I was just thinking about the additional confounders that might apply at a later stage, such as contact with other infants or toddlers from toddler groups.

Professor Howie

Contact with other children was one of the points that we specifically included as a variable. If older children are coughing over the infant, this is obviously a very important variable and was a point on which we collected specific information that was included in the analysis.

Dr. Pollitt

Dr. Colombo said it is a very elegant study and very nicely done, but I am not sure if I know what the mother craft variable is, and that may answer my question. I would like to point out, however, that the nature of your confounders is not the same as the nature of the behaviour in your study. In other words, the confounders that you have chosen are primarily structural variables, whereas breastfeeding is really a process variable. It could very well be that there are confounders at the process level that could perhaps account for a little bit more of the variance of the differences between groups.

Professor Howie

As to the first point: mother craft is parent craft. This was measured as attendance at classes during the antenatal period giving advice about preparation for motherhood and labour and so on. This variable was very strongly related to social class. If you cor-

rect for social class, you would at the same time correct for the mother craft variable. You are absolutely right that you can only do the best with what is quantifiable information when allowing for confounding variables. Studies of this kind will always be open to the possibility that we have not identified some confounding variable that may be important but not measurable. Short of being able to do a truly randomized controlled trial (which is not possible for breastfeeding), the best you can do is to collect and measure as many of the direct and indirect confounders as possible. You are right that despite all our efforts, we still may have failed to capture one or more of the crucially important confounding factors.

Dr. Pollitt

I am not trying to sound overly critical. The point I am trying to make and with which you agree is that in these kinds of studies you can never control for all the potential confounders. The best model would be a clinical trial. What I do want to emphasize is that unless we get information at the process level, particularly in interpersonal communication or relationships, we will be missing a very significant portion of the pie. I can give an example of the process variable. In the case of breastfeeding, this is the dynamic interaction between the mother and the child that involves certain kinds of behaviours that result in feeding. In the same way, there may be other interpersonal aspects of the relationship between the mother and the infant that do not have to do with feeding but could be correlates of it and account for the outcome variable. You are absolutely right that the ideal is a clinical trial, but we cannot always do that.

Professor Howie

I think cigarette smoking is a process variable in the sense that you are talking about, and that was an important confounder. Many of the important variables are associated with social class and disappear when it is controlled for.

Dr. Colombo

These are the normal difficulties of experimental surveys. You cannot always do experiments because of ethical problems.

Dr. Menken

With your early weaners, what did you do to correct for the possibility that illness might cause the end of breastfeeding? You had data on those early weeks.

Professor Howie

Yes, we did look at illness causing early weaning. If we thought that was the case, then the illness was attributed to the feeding category they were in before they had the illness. We looked at that specifically, but in fact it was relatively uncommon. In the analysis we adjusted both ways, for if we assigned mothers who weaned during an illness to the breastfeeding or the weaned groups, this made no difference to the overall conclusions. That was a point raised in the Bauchner study [7] and we did try to take account of it.

Dr. Garza

I, too, want to congratulate Professor Howie for a very elegantly carried out study. The exchange with Dr. Pollitt reminded me of a plea that an American politician once made of a scientist. He said he was looking for a one-armed scientist to testify before Congress, because scientists always said, "On the one hand you have this, and on the other hand you have that." The politician wanted to know if we couldn't find the one-armed variety, so that we could be as unambiguous as possible.

The key word that Professor Howie used was breastfeeding, which does refer to a process, as opposed to a single biological variable such as human milk. My second point is that there are some historical studies that came to some very comparable conclusions, without the degree of rigour that your study had, particularly looking at the persistence effect. This suggests that maybe we are looking at something beyond breastfeeding to mother craft and other similar variables. On the other hand, there are some biologically plausible explanations that I think Professor Hanson will get to.

Another point I want to make concerns HIV. I think HIV is a terribly important issue, and I want to ask if there is anyone here who has more recent information. The most recent information I have is that the P24 antigen, which is a good indicator of replicating virus, has been found only in colostrum. Thus, if vertical transmission occurs, it may occur only in the colostral phase. This may be because there are so many cells in colostrum, and HIV is an intracellular virus. Although antigens have been identified in the cell-free medium, I don't know whether these have any significance for the nature of transmission.

Professor Howie

If that's true, that is a very important point. I wasn't aware of it, and I am sorry I can't comment.

Professor Hanson

I don't have as many answers as I would like to have, but there are a number of risk factors that we know about. The main risk is that of infection of the infant via the mother's blood at delivery. There is clear evidence that this does occur. The second risk situation is when an infected lactating mother transmits the virus to the baby in the milk, despite the protective factors in human milk. The statement of WHO is partially based on the fact that if breastfeeding were not practised in areas of Africa, there would be an estimated 2,000 deaths from diarrhoea for each death from AIDS. This is a difficult matter, and there are two sides to it. I wasn't aware of Dr. Garza's point, and it is very important. However, African studies show that acute infection during lactation may be transmitted later than the colostral phase. This remains an open question.

Dr. Valdés

Coming back to your study, I am really impressed with the sustained effect of breastfeeding against infection. I am also curious about how you reached the conclusion that there weren't any further advantages to breastfeeding for more than 13 weeks. Surely if babies continue to breastfeed, they will be better protected.

Professor Howie

From the hospital admission data it looked as though there was a step down in the advantages after 13 weeks. We reanalysed for breastfeeding lasting only six weeks, but this seemed to be too short a time to establish maximal benefit. On the other hand, it looked as though the benefits of feeding beyond 13 weeks fell for both disease incidence and hospital admission. The data do show that the feeding method in the early weeks has long-term effects. I don't know if Professor Hanson is in a position to comment on this, but I believe there is some evidence that the first 13 weeks is a period of immunologic vulnerability. I have heard of the concept of the gastrointestinal tract maturing at about 13 weeks, so that before this time the baby is particularly vulnerable to disease. It may be that protection during this time is particularly important, but I am not as expert in this as some other people here. We can only report the results as we found them.

Dr. Valdés

We are doing a similar study. Infants were breastfed until an illness developed. Up to the age of six months, there was a real difference in the rate of infections between exclusively and non-exclusively breastfed infants.

Dr. Victora

I have a comment on the HIV problem. I was part of the WHO Working Group that drafted that resolution. As Professor Hanson mentioned, we had to calculate the number of deaths that would be prevented by avoiding breastfeeding and thereby reducing HIV transmission, versus the number of deaths that would be prevented by continuing breastfeeding. The initial problem is that in Africa you don't know which mothers are HIV-positive, because there is no widespread screening. This means that any kind of recommendation against breastfeeding would affect both HIV-positive and HIV-negative mothers. It is a major reason for concern, but with the current state of knowledge, the risks of HIV transmission through breastfeeding are much smaller than the risks of not breastfeeding, so that's why we arrived at the conclusion in favour of continuing breastfeeding.

Professor Howie

I certainly support the conclusion that the WHO came to, but as I am sure you are also aware, the concerns about HIV are being used by the milk manufacturers, particularly in Africa, to introduce a significant fear factor to the mothers, advising them to abandon breastfeeding. As you also say, this may lead to greater detriment than any benefits they may achieve. We have to be fully aware of this fear factor and make our views clear to the mothers.

Dr. Lawrence

Were there enough breastfeeders among the low-income mothers to enable you to analyse separately the impact of breastfeeding on the occurrence of disease in this group? This is important, because they are so often our targets.

Professor Howie

There was a deficiency in the number of breastfeeders in the lowest economic groups, but the benefits were striking in both the upper and lower socioeconomic groups. The main point of our study is that there has been a perception that advice in favour of breastfeeding is all right for the poor people of developing countries but is really irrelevant to the United States and Europe. What we found shows that this is not true at all. It puzzles me why we have an 18% vomiting and diarrhoea rate within the first three months in a place like Dundee, where we have clean water supplies. If we say that unclean water is the key issue, then Dundee should have far lower infection rates than Manila and other similar places. The fact that rates of gastrointestinal disturbance among bottle-feeders are so similar across

cultures makes me wonder whether we are really observing infection. Alternatively, it may be some disorder of the gastrointestinal tract other than infection that is actually making the babies vomit and have diarrhoea. Maybe we haven't yet identified the true nature of the problem of early vomiting and diarrhoea.

Dr. Victora

You might find a lot of rotavirus infection, which is widespread in both developed and developing countries and has nothing to do with water supplies.

Dr. Garza

We did a study that looked particularly at low-income populations in Houston about 15 years ago. We never published it, because we weren't confident that we could deal with some of the issues that were raised, but we found very substantial differences in diarrhoeal and respiratory infections in babies of low-income women who were breast- or bottle-feeding. We controlled for socio-economic status in that we recruited only women who were delivering at our public assistance hospital. But when we looked at our two groups, we found that despite our efforts to control for socio-economic status, the women who elected to breastfeed were taller and had infants with higher birthweights than the women who elected to bottle-feed. This suggests there is some inherent difference, even in a group of homogeneous socio-economic status, between women who choose to bottle-feed and those who choose to breastfeed.

Effects of breastfeeding on the baby and on its immune system

Lars Å. Hanson, Ursula Wiedermann, Rifat Ashraf, Shakila Zaman, Ingegärd Adlerberth, Ulf Dahlgren, Agnes Wold, and Fehmida Jalil

Abstract

Human milk is a very complex fluid with a number of components and multiple functions. New functions are continually being identified. It is clear that human milk can affect the immune system of the breastfed infant. This results both in enhanced vaccine responses and, at times, down-regulation of other immune reactivities, such as transplant rejection and the risk of developing certain immunologic diseases, such as type I diabetes. Breastfeeding presumably gives the infant the possibility for an optimal immune response by providing good nutrition, including a decreased risk of vitamin A deficiency. The control of the intestinal flora and the anti-inflammatory effects of maternal milk also increase the possibilities for an adequate immune response in the infant. Further study is needed of the roles of idiotypic and anti-idiotypic antibodies, growth factors, cytokines, and various anti-inflammatory factors in the maternal milk in the infant's host defence.

Introduction

Human milk is a very complex fluid with a multitude of proteins, cells, and other components. Knowledge is continually increasing about the effects of breastfeeding on the infant, including a number of direct and indirect effects on the immune system. Such influences are related to the fact that human milk is rich in various immunologically active factors, in particular the stable antibodies. Secretory IgA (SIgA) protects the mucous membranes of the infant's gastrointestinal and respiratory tracts, where most infections occur [1]. Mother's milk also contains IgG and IgM antibodies, hormones, antioxidants, vitamins, cytokiues, growth factors, complement factors, prostaglandins, granulocytes, macrophages, B and T lymphocytes, and so forth. Many of these milk components not only participate in the support of the infant's host defence but also affect the normal microbiological flora in the gastrointestinal tract. In addition, other tissues and organs, including the immune system, are influenced.

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Breastfeeding enhances vaccine responses in the infant and may affect transplantation outcome

A significantly higher salivary SIgA antibody response was obtained in breastfed than in non-breastfed Italian infants after parenteral vaccination with diphtheria and tetanus toxoids and after oral poliovirus vaccination [2]. Stool SIgA antibodies could not be used to measure the antibody response because of the presence of milk SIgA antibodies in the stool of breastfed infants. Instead, we analysed stool IgM, an isotype that is present at very low levels in maternal milk. The stool IgM response to parenteral tetanus toxoid and oral poliovirus vaccine was significantly higher in the breastfed group. These observations of the secretory antibody increases were obtained in infants 3 and 4 months of age. The infants had been vaccinated according to the ordinary vaccination schedule at 2, 3, and 12 months of age. Between the ages of 21 and 40 months, serum IgG antibodies to diphtheria toxoid and neutralizing serum antibodies to poliovirus were also significantly increased among the breastfed group compared with the formula-fed controls. These observations are in agreement with another study that determined the serum antibody response to the *Haemophilus influenzae* type b (Hib) polysaccharide capsule in breastfed and non-breastfed children who were vaccinated parenterally with an Hib–protein conjugate vaccine [3].

The explanation for this effect of breastfeeding on the vaccine response is not entirely clear. We favour

the hypothesis that at least some of the enhancing effect could be due to the anti-idiotypic antibodies (anti-antibodies) in human milk. We have shown the presence of such anti-antibodies against poliovirus in human milk [4]. In the proper concentration, anti-idiotypes can enhance immune responses [5]. Nevertheless, it is not clear how milk immunoglobulins could be taken up by the child, and other explanations are possible. Thus, maternal milk contains nucleotides that might affect the infant's immune response by stimulating lymphocytes [6].

If breastfeeding is enhancing vaccine responses, one might expect long-term positive effects of breastfeeding on the host resistance of the breastfed infant. In fact, Silfverdahl et al. [7] found a long-term protective effect of breastfeeding against invasive *H. influenzae* infections such as meningitis and epiglottitis.

Several early studies suggested that tuberculin sensitivity was transferred via mother's milk [8, 9]. Even if the resulting tuberculin sensitivity in the infant was temporary, the observation suggested that T lymphocytes present in milk could be transferred to the offspring. This may be the reason why vaccination against bacillus Calmette-Guérin seems to induce a stronger T-cell response in breastfed infants than in non-breastfed infants [10].

Transfer of milk cells may also result in immunologic tolerance (selectively reduced immune response) in the baby. Thus, a low response to paternal cells can be induced in newborn mice by letting them suckle a foster mother with the same transplantation antigens as their father [11]. This phenomenon may explain why renal transplants from mothers survive longer in offspring they have breastfed than in those they have not breastfed [12]. In premature infant baboons given radioactively labelled human colostral leucocytes, radioactivity accumulated in the gut wall, liver, and spleen [13]. This suggests that the milk cells are really taken up and have the capacity to influence the immune system of the offspring. Such an influence might explain the finding that breastfeeding can decrease the risk of the offspring developing autoimmune type I diabetes later [14]. The risk of type I diabetes determined by genetic factors is 30% to 40%. Nevertheless, the risk of inheritance from the father is two to three times greater than that from the mother. This difference may be at least partially explained by the effect of breastfeeding, which seems to halve the risk. In this connection, it may be added that breastfeeding seems to diminish the risk of developing lymphomas [15] and Crohn's disease [16]. This effect remains long after the breastfeeding has been terminated.

Breastfed infants respond to infections with respiratory syncytial virus with more interferon-γ (IFN-γ) than do non-breastfed infants [17]. The breastfed infants also produce higher total levels of SIgA in the urine than their formula-fed counterparts [18].

Breastfeeding, nutrition, and immunity

A major cause of undernutrition in poor countries is the frequent infections resulting from inadequate hygiene, with contaminated water, lack of latrines, ineffective vaccination programmes, inefficient primary health care, lack of education, and the like. As shown by Howie [19] in this Workshop, breastfeeding can effectively prevent many of those infections.

Breastfed infants are usually given extra water during the hot season. Several studies have shown that this is totally unnecessary [20, 21]. Extra water makes babies less thirsty, which causes them to suck less, so that less milk is produced. Therefore, during the hot season, when the risk of infection is highest, the babies will get less milk. We have shown in a study from Pakistan that infants given water have more frequent diarrhoeal attacks and a significant reduction of weight and of head circumference compared with those who are exclusively breastfed [21]. Whereas breastfeeding provides optimal nutrition to the infant, deficient or absent breastfeeding is clearly a risk factor for inadequate nutrition. The subsequent frequent infections add to the undernutrition, which can impair host defence in a number of ways. It is not always clear, however, that these disturbances of the immune system are of clinical relevance.

We have shown that vitamin A deficiency in rats causes a severe immunodeficiency, followed by a greatly reduced capacity to respond to vaccines and to resist infections, such as diarrhoea and septic arthritis [22, 23]. These animals also have severe protein–calorie undernutrition owing to the loss of appetite caused by the lack of vitamin A. When the vitamin deficiency is corrected by giving retinyl palmitate (vitamin A), their immune response normalizes, although their body weight remains some 30% less than normal.

Immunodeficiency in vitamin A–deficient rats is characterized by a 90% reduction of the intestinal SIgA antibody response to an oral cholera vaccine and a similar reduction of IgE antibody responses to soluble proteins. There is also a reduced IgM and IgG antibody production in response to T cell–dependent antigens. In addition, there is an up-regulation of certain T_H1 activities.

When these animals are colonized orally with a strain of *Escherichia coli*, the whole gut contains large numbers of bacteria, which translocate and are thus found in the local lymph glands. The rats get diarrhoea and at the same time show increased

levels of IgE antibodies to the colonizing bacteria and a normalization of the SIgA response, possibly owing to an adjuvant effect of the bacteria in the lymph nodes. These observations may be relevant to several unexplained problems with infection among non-breastfed infants in poor countries [24].

The most common cause of death between 3 and 28 days of age in poor populations in Pakistan is neonatal septicaemia [25]. The causative bacteria most likely originate in the intestinal flora. The subclinical vitamin A deficiency may increase the risk of translocation of intestinal bacteria so that these bacteria reach the bloodstream. The major cause of death after 28 days of age is diarrhoea, and 84% of the deaths occur after prolonged diarrhoea. Again, early subclinical vitamin A deficiency may pave the way for prolonged diarrhoea.

In Pakistan 34% of the mortality in the first two years of life occurs in the first week and 90% in the first six months [25]. Measures to protect infants during this sensitive period of life are therefore crucial. Vitamin A deficiency is common in mothers and infants in our study area in Pakistan (unpublished data), as in many other parts of the developing world. A significant reduction of this early mortality might be attained by giving the mothers vitamin A directly after delivery and ensuring that they start breastfeeding immediately, thus transferring most efficiently both vitamin A and SIgA antibodies.

In a pilot study in a Pakistani village, we have seen the effects of introducing a health programme that involves breastfeeding promotion, improved primary health care, and education of mothers. Infant mortality, stunting, and the prevalence of diarrhoea were all decreased by 50% within two years (F. Jalil, personal communication, 1995). It will be of interest to see what supplementation of breastfeeding mothers with vitamin A might do in this setting.

Breastfeeding and the intestinal flora

Other kinds of indirect effects on the infant's host defence presumably follow from the effects of breastfeeding on the intestinal flora. Non-breastfed infants in poor areas are quickly colonized by several potentially pathogenic aerobic bacterial strains, which show a continuous flux in the gut. In contrast, exclusively breastfed Swedish infants show a stable, more slowly developing intestinal flora, dominated among the aerobes mostly by a single strain of *E. coli* or sometimes *Klebsiella* [26]. This difference in the diversity of the enterobacterial flora in breastfed and non-breastfed infants has also been seen in other countries in Europe [27]. Certain *E. coli* may be favoured by breastfeeding, and so is their expression of the adhesin called type 1 fimbriae [28],* which, in contrast to other *E. coli* adhesins, is not associated with virulence. This may be due to the fact that type 1 fimbriae bind directly to mannose residues on phagocytes, which promote phagocytosis [29]. Other adhesins that may function as virulence factors seem to be suppressed by breastfeeding.*

It is obvious that various milk factors can prevent adhesion of certain *E. coli* to host tissues, presumably influencing the immune response. One example is shown in figure 1. Among such anti-adherence substances in milk are SIgA antibodies and various analogues to epithelial receptors that bind *Vibrio cholerae*, *E. coli* [30], *V. cholerae* enterotoxin [31], pneumococci, and *H. influenzae* [32]. Recently, a milk component, presumably a glucosaminoglycan, has been shown to inhibit the binding of human immunodeficiency virus (HIV) to its CD4 receptor on lymphocytes [33]. The continuons exposure of *E. coli* to milk components in the gut of the breastfed infant induces continuous changes of surface structures presumably tied to decreasing virulence [34].

Breastfed infants have higher counts of *Staphylococcus aureus*, *S. epidermidis*, and enterococci in the gut than non-breastfed infants [35–37]. In contrast, breastfed infants do not have higher counts of bifidobacteria, as is often presumed [38].

It seems likely that the immune response may differ in breastfed infants, who have a stable intestinal flora in which the aerobes are dominated by *E. coli* of little or no virulence, and non-breastfed infants, who have a variable flora containing various pathogens and who therefore are at high risk of diarrhoea and other infections. It could also be that various milk components modify the exposure to certain antigens or their presentation to the infant's immune system.

Human milk is anti-inflammatory

Mother's milk contains a number of anti-inflammatory factors with anti-oxidant activity that are able to block chemotaxis of granulocytes and inhibit production of free radicals, peroxidase, and so forth [39]. It is possible that these functions may enhance the well-being of the neonate by preventing inflammation. The neonate is colonized with gram-negative bacteria producing endotoxins in the gut that may induce the production of inflammatogenic, catabolic, and appetite-reducing cytokines such as interleukin-1 (IL-1), IL-6, and tumour necrosis factor-α (TNF-α). This cytokine production may be prevented by capacities of the breastmilk, which may be one explana-

* Slavikova M, Lodinava-Zadnikova R, Alderberth I, Hanson LÅ, Wold AE. Breast-feeding enhances the expression of type 1 fimbriae by *E. coli* in the gut of the newborn infant (submitted for publication).

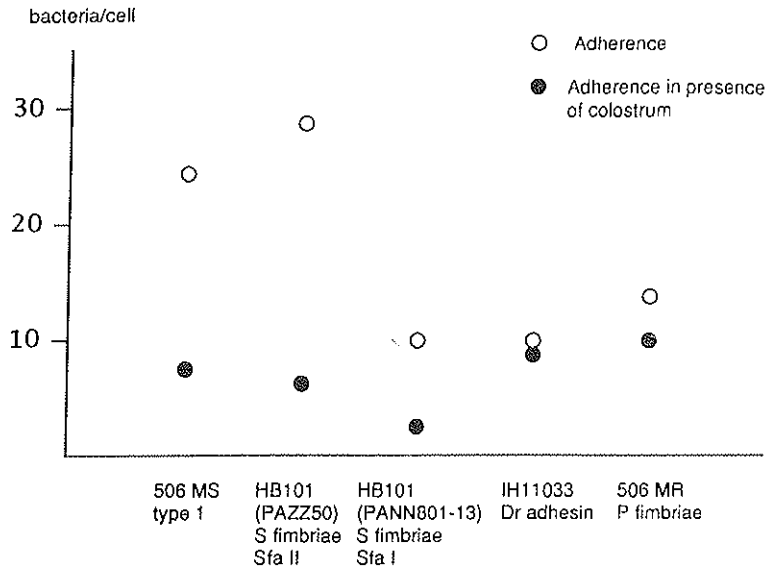

FIG. 1. Diagram showing that defatted colostrum can prevent adherence of *Escherichia coli* strains with certain adhesins to a colonic epithelial cell line

tion why non-breastfed infants lose significantly more weight during the first week of life than those exclusively breastfed [40]. In this connection, it is interesting that human milk lactoferrin, a major milk protein, can block endotoxin-induced IL-6 release from human cells [41]. On the other hand, a similar effect is obtained with undenatured bovine milk lactoferrin and its bactericidal peptide lactoferricin.

Human milk contains cytokines such as IL-1, TNF-α, IFN-γ, IL-6, transforming growth factor-β (TGF-β), and IL-10 [42–44]. Cytokine production can be induced from milk cells as well. Thus, the milk T cells can produce IL-2, IL-3, IL-4, IL-10, IFN-γ, and TNF-α [45], and the macrophages can produce IL-1_α, IL-1_β, IL-1ra (IL-1 receptor analogue), IL-6, IL-8, and IL-10. It is presently unknown whether all these cytokines, with capacities to strikingly influence immune responses, can also have such effects on the breastfed infant's immune reactivity. It is likely that their presence and potential activities are under strict control. The cytokine-modulating effect of lactoferrin mentioned above may be an example of such a control function.

Acknowledgements

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A combined discussion of this paper and the paper by Victora can be found after Victora's paper on page 397.

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Infection and disease: The impact of early weaning

Cesar G. Victora

Abstract

Although the protective effect of breastfeeding against infectious diseases has been long suspected, it has only recently been adequately quantified. This article reviews the available epidemiologic evidence. Breastfeeding provides marked protection against diarrhoeal morbidity and severity (as measured by its duration, level of dehydration, or case-fatality rate), and mortality. This is true for acute watery diarrhoea as well as for dysentery and persistent diarrhoea. A dose–response pattern is observed: the risk level for children receiving both breastmilk and artificial milk is between that of exclusively breastfed children and that of completely weaned children. Even the introduction of water or herbal teas to a previously exclusively breastfed infant increases the risk of morbidity and mortality. The protection is greatest for young infants, and the period immediately after weaning seems to carry the highest risk. Although breastfeeding does not seem to have an appreciable effect on the incidence of acute respiratory infections as a whole, there is evidence of an effect on the incidence of pneumonia, on the incidence of hospitalization for pneumonia, and on mortality from respiratory infections. The level of protection against pneumonia, however, is lower than that against diarrhoea. Breastfeeding also protects against otitis media and other infections, including neonatal sepsis, meningitis, and bacteraemia, although the number of relevant studies is small. A simulation exercise shows that a 40% reduction in the prevalence of non-breastfeeding would prevent up to 15% of diarrhoea deaths and 7% of pneumonia deaths occurring in regions with a short breastfeeding duration, such as urban Latin America. In regions where breastfeeding durations are longer, the emphasis should be on maintaining these high rates and increasing the proportion of young infants who are exclusively breastfed. The present review confirms that breastfeeding promotion is an essential child survival strategy.

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Introduction

The protective effect of breastfeeding against infectious diseases has long been known. Several studies from Europe in the eighteenth and nineteenth centuries indicated that non-breastfed infants were two to three times more likely to die than those who were breastfed [1, 2]. In the last 10 to 20 years, however, there has been a resurgence of interest in breastfeeding, and a large number of new studies have been produced.

Recent studies have shown improvements in sampling and in the operational diagnoses of different infectious diseases, as well as in data processing and analysis. In addition, a number of recent publications have addressed key methodological issues that may distort the findings of studies of breastfeeding and disease [3–6]. These issues include self-selection, reverse causality, and confounding.

Self-selection may occur when infants are weaned because they were not thriving on breastmilk. Those who continue to be breastfed, therefore, may represent a subgroup of particularly healthy infants. Reverse causality takes place when an infection leads to weaning, rather than the opposite. Confounding results when early weaning is associated with demographic, socio-economic, or environmental characteristics that may also affect morbidity. Such confounding factors may lead to a spurious association between breastfeeding and protection from infection. Some recent studies have attempted to avoid these pitfalls through specific improvements in their design and analysis [5]. Unless otherwise noted, the studies reviewed here were adjusted for confounding variables. Several investigators have also attempted to account for reverse causality and self-selection.

Virtually all studies of breastfeeding and infection have observational designs, such as case-control, cohort, or cross-sectional studies. Intervention trials would solve many of the methodological problems inherent to these designs, but the random allocation of mothers and infants to a breastfeeding or a control group is not ethically justified. In addition, ensuring compliance with a recommended feeding practice is extremely difficult, and the sample sizes required for studies with morbidity outcomes, in the presence of low compliance, would be enormous.

Another problem is that studies have addressed different types of disease outcomes. Some investigators have studied overall morbidity from, for example, diarrhoea or respiratory infections. Others have concentrated on more severe diseases, such as persistent or dehydrating diarrhoea or pneumonia. Finally, some studies have assessed mortality. The risk factors for acquiring an infectious disease may be quite different from the prognostic factors leading to a severe episode and finally to death. Therefore, an apparent lack of consistency between different studies may be due to the fact that different disease outcomes were being investigated.

Other participants in this Workshop have addressed the mechanisms through which breastfeeding protects against infections, as well as the epidemiologie literature from developed countries. I will concentrate on the epidemiologic evidence supporting this protective role, based on studies from less-developed countries. It is important to separate studies from developed and less-developed areas, beeause the effeets of breastfeeding are modified by a number of socio-economic, environmental, and dietary factors. For example, greater protection is likely to occur where there is poverty, crowding, or unsafe drinking water or where weaning foods are contaminated or of low energy density. Studies from developed countries, therefore, cannot be extrapolated to the rest of the world.

This review makes no claim to be exhaustive, as a number of comprehensive summaries of the literature on this topic are available [7–12]. Rather, I will use examples from a few investigations—with a strong bias towards studies in which I was involved —to highlight the key epidemiologic and public health issues.

Impact on diarrhoea

Feachem and Koblinsky [8] reviewed 35 studies on diarrhoeal incidence from 14 countries. There was a clear protection associated with breastfeeding, but this varied according to the child's age. The relative risks for non-breastfed infants compared with all those who were breastfed, either exclusively or partially, were 3.0 up to two months of age, 2.4 at three to five months, and about 1.4 thereafter. According to this review, protection after infancy was not evident.

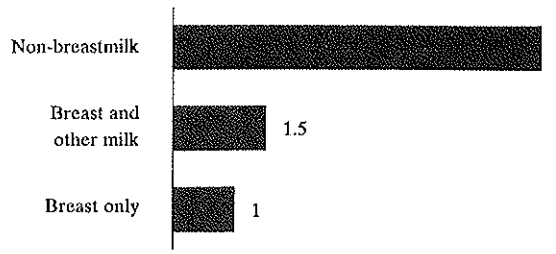

FIG. 1. Risk of dehydration (odds ratio) from diarrhoea in infants in Brazil in 1992 according to type of milk

Epidemiologic studies show that breastfeeding protects against shigellosis and cholera. Breastmilk also contains antibodies against a large number of other gastrointestinal pathogens [13]. It also protects against neonatal necrotizing enterocolitis [14].

Breastfeeding appears to provide even higher protection against more severe forms of diarrhoea. In a study we carried out in Brazil, dehydrating diarrhoea (defined by the presence of a persistent skinfold plus at least two other signs of dehydration) was 6.0 times more frequent among non-breastfed infants than among exclusively breastfed infants (fig. 1) [15]. If a child already had diarrhoea, the risk of developing dehydration was 3.3 times greater for the non-breastfed infant [16].

Another indication of severity is the duration of the diarrhoeal episode. When 400 Brazilian infants were followed from birth to the age of six months, those weaned during the first week of life had a risk of diarrhoea three times greater than those who were exclusively breastfed (including those also receiving water or herbal teas). When the analysis was restricted to episodes of persistent diarrhoea lasting 14 days or more, the relative risk was 5.1.

Yet another indicator of severity is ease fatality. In Rwandan children hospitalized with diarrhoea, the case-fatality rate was three to four times lower for those who were breastfed [17]. Breastfeeding, therefore, seems to provide even greater protection against severe diarrhoea than against mild diarrhoea.

The evidence from mortality is also eompelling. Several studies from the first half of this century showed a protective effect of breastfeeding. For example, Newsholme [18] compared infants who died of "epidemic diarrhoea" in Brighton between 1903 and 1905 with a population-based control group. Reanalysis of his data with logistic regression (fig. 2) shows that after adjustment for age, infants receiving condensed milk were 91 times more likely to die than those on breastmilk. The odds ratio for infants

FIG. 2. Risk of death (odds ratio) from diarrhoea in infants in England in 1903–05 according to feeding pattern

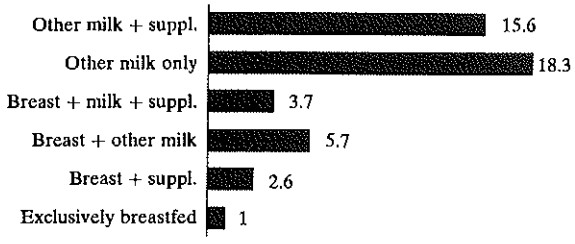

FIG. 3. Risk of death (odds ratio) from diarrhoea in infants in Brazil in 1984–85 according to feeding pattern

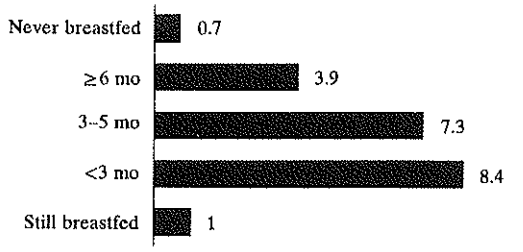

FIG. 4. Risk of dehydration (odds ratio for incidence) from diarrhoea in infants in Brazil in 1992 according to time since weaning

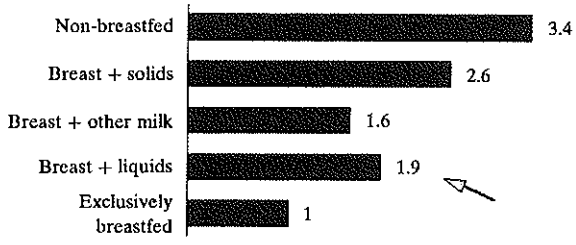

FIG. 5. Prevalence of diarrhoea (relative risk for percentage of days ill) in infants under two months of age in Peru in 1988 according to feeding pattern. Arrow shows doubling of prevalence when infant receives liquids in addition to breastmilk

on cow's milk was 40. These relative risks are probably inflated by reverse causality and other biases.

Our study from Brazil showed odds ratios for diarrhoeal mortality of 14.2 for totally weaned infants and 4.2 for those on both breastmilk and artificial milk, compared with those on breastmilk alone [19].

Figure 3 shows the results of this study for several feeding patterns. Children receiving only artificial milk were at a particularly high risk. The addition of any supplements, either artificial milk or food, resulted in at least a two- to threefold increase in the risk for breastfed infants.

In this study, deaths were broken down according to the clinical characteristics of the diarrhoeal episode. Non-breastfed infants were 21 times more likely than exclusively breastfed infants to die of acute watery diarrhoea, 10 times more likely to die of persistent diarrhoea, and 3 times more likely to die of dysentery [20].

The greater vulnerability of young infants was confirmed by this study, because the protection was even higher before two months of age (odds ratio of 23 for the non-breastfed infant under two months). A related issue is the especially high vulnerability of infants who were recently weaned. Figure 4 shows additional results from the above-mentioned study of dehydrating diarrhoea [15, 16]. The risk was highest for infants who had recently been weaned and decreased thereafter.

A major issue raised in the last 10 years is the importance of exclusive breastfeeding for the prevention of diarrhoea. Figure 5 shows the results of a Peruvian longitudinal study in which the percentage of days on which a child had diarrhoea was related to feeding patterns [21]. There was a doubling in the prevalence when the child received liquids such as water or herbal teas in addition to breastmilk. The diarrhoea mortality study from Brazil also showed that each additional fluid feeding resulted in a 40% increase in the risk of death from diarrhoea among breastfed infants [19, 22]. More recently, a study from the Philippines showed that giving fluids to breastfed infants two months of age resulted in a two- to threefold increase in the incidence of diarrhoea [23]. Both the Peruvian and the Filipino studies showed that the benefits of breastfeeding were considerably less after the first six months.

Impact on respiratory infections

Fewer studies have addressed the effect of breastfeeding on respiratory infections. This may be partly because of the difficulties in operationalizing and standardizing the diagnoses of these infections under field conditions.

A recent review of studies from less-developed countries showed that although breastfeeding did not seem to provide important protection against acute respiratory infections as a whole, there was evidence of an effect on the incidence of pneumonia

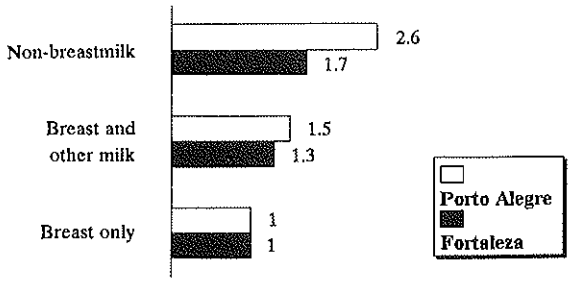

FIG. 6. Risk of pneumonia (odds ratio for incidence) in children under two years of age in two Brazilian sites, Porto Alegre and Fortaleza, in 1993–95 according to type of milk

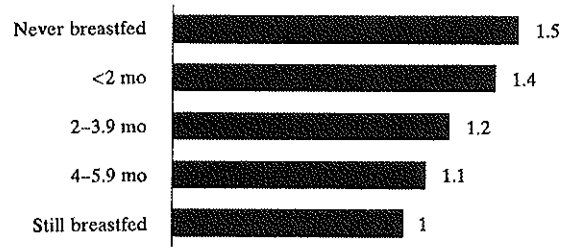

FIG. 7. Risk of otitis media (odds ratio for incidence in last month) in infants six months of age in Brazil in 1993-94 according to duration of breastfeeding

and of hospitalizations for pneumonia, as well as on mortality from respiratory infections [24]. For example, figure 6 shows the results of two recent case-control studies from two Brazilian cities in which the outcome was radiologically confirmed pneumonia [25, 26]. The risks for partially breastfed and non-breastfed children were clearly greater than those for exclusively breastfed children.

Breastfeeding also affects the case-fatality rate of respiratory infections. In Rwanda non-breastfed children were twice as likely as breastfed children to die of pneumonia [17]. Non-breastfed Brazilian infants were 3.6 times more likely to die of acute lower respiratory tract infections than those who received breastmilk and no artificial milk. Infants receiving both human and artificial milk had an intermediate odds ratio of 1.6 [19, 27].

An interesting but somewhat unexpected finding from two of the Brazilian studies deserves further investigation. Regardless of the type of milk consumed, infants who received non-milk food complements were 2.3 times less likely to develop pneumonia [25] and 3.2 times less likely to die [27].

The protection provided by breastfeeding against otitis media is well established, mostly through studies from developed countries [6, 9]. Figure 7 shows the results of a recent study of six-month-old Brazilian infants [28]. There is a clear gradient in

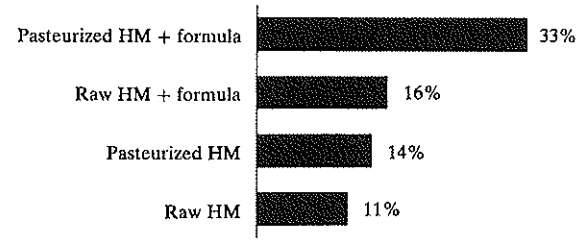

FIG. 8. Incidence of neonatal infections in a randomized trial of human milk (HM) versus formula in India in 1984 [30]

the risk of medically confirmed otitis media in the preceding month, according to the duration of breastfeeding. It is interesting to compare these findings with those shown in figure 4, where the most recently weaned babies showed the highest risk of dehydrating diarrhoea. This contrast, along with the finding that the protection against otitis media is also well documented in developed countries, suggests that the mechanism may involve the anatomical development of the upper respiratory system rather than any environmental risk factors.

Impact on other infections

Breastfeeding is known to protect against other infections, including neonatal sepsis, meningitis, and bacteraemia [11, 13]. Despite one study that failed to find protection against mortality from measles [29], the Rwandan study showed that case fatality from measles was reduced by one-third for breastfed infants [17].

The only randomized intervention trial examining the relation between breastmilk and infection that I am aware of was carried out in India. This study compared the effects of different milk combinations given by bottle to high-risk newborns [30]. Septicaemia, conjunctivitis, diarrhoea, and umbilical sepsis were the most common infections observed. Figure 8 shows that there were separate effects of pasteurization and of formula introduction on neonatal infection rates.

The Brazilian case-control study of mortality [19] included deaths from meningitis, skin infections, measles, whooping cough, neonatal sepsis, and tuberculosis. Because of the small number of cases in each category, these were grouped together. Compared with infants receiving breastmilk without any artificial milk, non-breastfed children were 2.5 times more likely to die of these infections. Infants receiving both breastmilk and artificial milk were at lower risk (odds ratio, 0.4), but this difference was not statistically significant.

Summary of the evidence

This review began with a discussion of methodological problems affecting observational studies and argued that experimental, community-based studies would in general not be feasible or ethical. The Indian trial described above was an exception, since it was a hospital-based study for high-risk neonates who were all bottle-fed [30]. In some circumstances, however, one may carry out quasi-experimental studies in the community by taking advantage of existing interventions. In the Brazilian city of Guarujá, a lactation centre has been well established for several years [31]. Mothers giving birth in the city hospitals are invited to join the centre, and about half of them eventually attend at least once. This is obviously not a random process, because mothers who attend may differ from those who do not, but in this study it was possible to interview the mothers in the hospital before they were invited to join the centre and to collect a large amount of baseline data. There were some differences between attenders and non-attenders in social and demographic variables. There were no differences in reported maternal attitudes towards breastfeeding, but attenders were more likely to have received breastfeeding advice during pregnancy. These confounding factors were handled later in the data analysis.

All mothers were followed up until the child was six months old. At four months, 42% of attenders were exclusively breastfeeding, against 12% of non-attenders. At six months of age, after adjusting for the above-mentioned confounding variables, the incidence of diarrhoea in the previous two weeks among non-attenders was 1.7 times that among attenders, a significant difference (fig. 9). Non-attenders also had almost twice as many hospital admissions as attenders for diarrhoea since birth, but this difference was not significant ($p = .09$). This

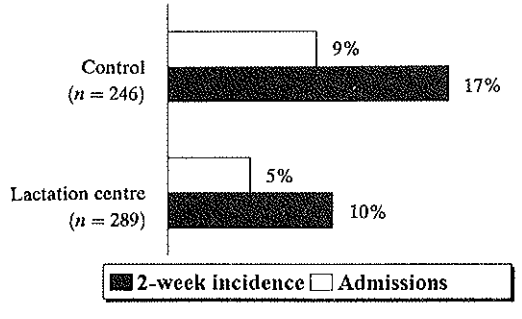

FIG. 9. Risk of diarrhoea (odds ratio for diarrhoea in the last two weeks) and hospital admission in infants six months of age in Brazil in 1993 in the control and intervention (lactation centre) groups [31]

study brings us closer to an experimental design. Because the comparison is based on attendance and not on successful breastfeeding, reverse causality bias is avoided, as well as some of the self-selection bias (in fact, mothers facing difficulties may be more, rather than less, likely to attend). Self-selection and confounding are further reduced by obtaining prior information about attitudes and practices regarding breastfeeding at the time of delivery, and by adjusting in the analyses for any differences. It is reassuring that the protection provided by breastfeeding against diarrhoea is confirmed in a stricter study design.

The main findings of this review may be summarized as follows. Breastfeeding reduces the incidence of diarrhoea. In addition, for children who have already developed diarrhoea, breastfeeding reduces the severity of the episode, whether measured by duration of the episode, risk of dehydration, or case-fatality rate. As a consequence, breastfeeding strongly protects against diarrhoeal mortality. There is a clear effect of age, with the greatest protection among young infants. There is also evidence that recently weaned infants may be more vulnerable. Although partial breastfeeding results in a reasonable degree of protection against diarrhoea, exclusive breastfeeding for young infants is essential to achieve the highest protection. This is because the mere addition of water or herbal teas to the diet sharply increases the incidence of diarrhoea and mortality due to diarrhoea.

The protection afforded by breastfeeding against respiratory infections is not well established. However, studies from less-developed countries clearly show a protective effect on severe respiratory infections, as measured by the incidence of pneumonia and by hospitalizations and mortality due to respiratory infections. There is also consistent evidence of protection against otitis media. A dose–response trend is clear in several studies, with partially breastfed children having intermediate levels of risk. Nevertheless, the protection is several times smaller than that provided by breastmilk against diarrhoea. This finding is consistent with biological knowledge, because in addition to its systemic effects, breastmilk has a direct effect on the gastrointestinal immune system and flora, as well as leading to the avoidance of possibly contaminated weaning foods.

Evidence of the impact on infections other than diarrhoea and respiratory infections is not as clear-cut, but several studies suggest some level of protection.

On the basis of simulations we recently performed for the World Health Organization [24], our group has calculated the likely impact of breastfeeding promotion on mortality from diarrhoea and respiratory

TABLE 1. Percentage of children not breastfed according to age in populations with different durations of breastfeeding

Age (mo)	Duration of breastfeeding		
	Long	Intermediate	Short
0–5	0%	7%	19%
6–11	2%	16%	40%
12–17	12%	31%	62%

Source: ref. 32.

TABLE 2. Expected percentage reduction in mortality among children under five years of age resulting from a 40% decrease in the prevalence of non-breastfeeding in populations with different durations of breastfeeding

Cause of death	Duration of breastfeeding		
	Long	Intermediate	Short
Diarrhoea	1.0%	11.6%	14.8%
Pneumonia	0.5%	3.3%	7.0%

infections, the two major killers of children in the world. Data on three typical populations that differed in the dnration of breastfeeding were taken from the WHO Collaborative Study on Breastfeeding (table 1) [32]. Based on the literature, it was estimated that full or partial breastfeeding would lead to a 50% reduction in deaths from respiratory tract infections and a 66% reduction in deaths from diarrhoea among children aged under 18 months. It was further assumed that it would be possible to reduce the prevalence of non-breastfeeding by 40%, a reasonable figure based on results from intervention studies. Table 2 shows the proportions of deaths among infants under five years of age that would be prevented through this intervention.

Breastfeeding promotion would obviously have very limited impact in areas where most children are already breastfed, such as rural Africa, South Asia, and Central America. It would have a substantial impact, however, in areas where early weaning is common. These include many urban and rural areas in South America and South-East Asia as well as some of the largest African cities. These calculations are conservative, because the benefits of partial breastfeeding are not considered, but they serve to illustrate the potential life-saving effect of breastfeeding promotion.

The Bible says, "Blessed is the womb that bore you and the breast that you sucked" (Luke 11:27). Recent research is confirming how correct this statement is.

Acknowledgements

I would like to thank my colleagues Sandra Fuchs and Fernando Barros for their contribution to the Brazilian studies reviewed here.

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Discussion of papers by Hanson et al. and by Victora

Dr. McLaren

I have two questions. The first is for Professor Hanson. I was very interested in your data on type I diabetes. You showed that the genetic componeut was inherited from the father two or three times more often than from the mother, and that the risk was twofold more in bottle-fed than in breastfed babies. It would be very interesting to know whether the risk was equally from the father and the mother in the bottle-fed babies. In other words, it would be helpful if you could separate out the bottle-fed and the breastfed and look at the inheritance from the father and the mother. My guess is that this hasn't been done, or you would have told us. If it turned out to be equally inherited from the father and the mother, then it would support your interpretation. I also wonder whether other autoimmune factors have been looked at, because more and more diseases today seem to be autoinmune in character.

Professor Hanson

You are right. That analysis has not been done. The origin of the interest in this study was that the inheritance from the father and the mother differed, and that the difference may be at least partially attributed to the mother's breastfeeding. There is a large Finnish-Canadian study examining the possibility that bovine milk proteins may be part of the initiation of the autoimmune process, but this is still an open question. As for other autoimmune diseases, some have been discussed, but there are no data yet. The results of experimental studies in newborn mice administered, via the milk, cells from the mother with the same transplantation antigen as the father showed a modifying effect on the reactivity of the offspring against the paternal transplantation antigen. Obviously, maternal cells in the milk can influence normal as well as abnormal immune responses in the offspring. I very briefly mentioned Crohn's disease, whose origin is unknown, but we know that cytokines are involved in the inflammation in the gut. Obviously, the mother–infant relationship through breastfeeding is not just passive, as we used to think; it is also active. The fact that vaccine responses are enhanced and transplant rejection is diminished is quite significant.

Dr. McLaren

My second question is more general and is relevant also to Dr. Victora. It arises from something that Professor Hanson said about the greater risk of gastrointestinal infection among the babies in Pakistan who had extra water. I had always thought that during very hot weather, both in Pakistan and in England, babies actually needed water as well as breastmilk. Perhaps that is wrong, but if it isn't wrong, then did babies in Pakistan who did not get extra water have some other deleterious consequence? In other words, is extra water needed when it is very hot?

Professor Hanson

There have been a number of studies showing that the extra water is not necessary. We have investigated this in Pakistan dnring the hot and dry season, and considering the concentration capacity of the kidney, extra water is totally unnecessary. It just brings the risk I suggested; if you give the baby water during the hot season, it will suck less, and less milk is produced. I would strongly discourage this, as it brings increased risk of infection. Last summer was very warm in Sweden, up to 30° to 35°C, and the newspapers erroneously stated that one must give extra water to breastfed infants. This is a very common belief, and in many traditional societies the mothers say, "Oh, yes, yon have to give extra water." This has very unfortunate consequences in poor countries with a high risk of infection, especially during the hot season, as we have shown an

increased number of episodes of diarrhoea and impairment of short-term linear growth, even of head circumference.

Dr. Victora

I have nothing to add to Professor Hanson's comment.

Dr. Garza

I would like to add a slight modification to what Professor Hanson has said, which I think you would agree with. Although what Professor Hanson has said is certainly true of breastfed infants, because the renal challenge of human milk is so low, that is not true of children who are fed substitutes, because the renal challenge is high enough that those children do need extra water. It is very important that we do not leave here thinking that all infants regardless of how they are fed don't need extra water. I realize that does not contradict what you said earlier.

Dr. Prentice

I just wanted to add to that the case in support of prolonged breastfeeding, because that also seems to provide water for children for long periods. Studies in Bangladesh and elsewhere have shown that the severity of dehydrating diarrhoea is reduced in children who are still receiving breastmilk in the second year of life, showing that it is a very important source of clean water.

Dr. Rasmussen

I wish to put a question to Dr. Victora. In your presentation you seemed to indicate that there was a period after the end of breastfeeding when the infant was particularly vulnerable. Yet we have heard elsewhere, particularly from Professor Howie, that the positive benefits of breastfeeding seem to go on for some period of time, and there are others who have reported the same fiuding. Those reports don't seem to be in accord.

Dr. Victora

They don't seem to me to be in accord, either. I think we always run the risk of lumping together all infections and different parts of the world in our breastfeeding studies. There are so many variables that may affect how breastfeeding may or may not protect uuder certain circumstances. Therefore I don't think it is a surprise that we find apparently contradictory results. We found particularly strong evidence of a vulnerable period for dehydrating diarrhoea for three mouths after weaning. If, however, we look at diarrhoea mortality as a whole, there is no evidence of a vulnerable period by the other case-control study I presented. Overall, 62% of those deaths were due to persistent diarrhoea, so that we are talking about different syndromes with different pathophysiologies. It may well be that this vulnerable period is present for some infections but not for others. I would like to see more studies separating the different clinical types of diarrhoea to see whether this is confirmed. You may remember that my findings regarding otitis media were quite different, showing a long carry-over effect of breastfeeding, so that we are talking about entirely different things.

Dr. Colombo

Dr. Victora, if I did not understand well, it is because my English is limited. You spoke of a survey in which you started from the death of the infant in the hospital, and then you went back to get information and calculated rates of mortality. What are the numerator and the denominator of these rates?

Dr. Victora

The study was not only hospital-based. Eighty-five per cent of the deaths occurred in the hospital, but the data on the other 15% came from cemetery registries or from other registration offices. I have calculated the odds ratios from the case-control study: for example, the cross-product ratio in a two-by-two table of exposure against disease. These odds ratios correspond mathematically to the incidence-density ratios. We could actually have shown the population rates, because the entire population was under surveillance, but in that particular presentation only the relative risks or odds ratios are changed.

Dr. Garza

You concentrated most of your comments on the impact of early weaniug. Would you care to comment on the effects of delayed weaning? I know you have studied this in the past, but do you have any recent data that would help us evaluate how long breastfeeding is protective?

Dr. Victora

No, I don't. My studies go up to two years of age, and I can find a protective influence on infection up to that age.

Dr. Garza

What about the uutritional status?

Dr. Victora

The nutritional status studies we have carried out tend to show that at some stage around one year of

age, children who are no longer breastfed tend to grow faster than those who are breastfed, showing, therefore, an inverse association between growth and breastfeeding. Again, there are many caveats because this varies from society to society. Dr. Prentice recently reviewed work from China showing the opposite trend. I guess my reading of the literature on breastfeeding during the second year is that most studies show this inverse association, that is, breastfed babies grow less rapidly than babies who are not breastfed. Nevertheless, there may be a number of confounding variables, self-selection and other factors that may affect the association. On the other hand, all the studies on mortality or infection in relation to breastfeeding in the second year of life tend to show a positive effect, although not all of them are significant, as Dr. Menken mentioned yesterday. So, we have this dilemma in the second year, whether this poorer growth is enough to justify any policy change. My feeling is that the positive effects of breastfeeding are greater than the negative ones.

Dr. Garza

When you say growth, do you mean weight-for-age, length-for-age, or both?

Dr. Victora

Different studies have looked at different things. My own studies have shown a greater effect on weight-for-length, but there are studies from other countries showing effects on length-for-age as well.

Professor Hanson

You say they grow more, but do you know what is optimal growth? Another question concerns your mentioning the lasting effects of breastfeeding. I do not think I have made myself clear on that point. The newborn would have relatively few lymphocytes with which to respond against different micro-organisms. Breastfeeding obviously enhances the response, and the result is that there will be many more lymphocytes in the baby to respond to each micro-organism, which means that there will be a lasting effect, because next time the immune response will have many more cells to respond with and will be more efficient. This would be a lasting effect of the immune enhancement from breastfeeding.

Dr. Prentice

I want to get some clarification from Dr. Victora about the effects he sees up to two years. Do you mean you see effects in children who are still receiving milk for two years or in those who were exclusively breastfed for three months and showed effects for two years afterwards?

Dr. Victora

No, I was referring to children who were still receiving breastmilk in the second year of life.

Professor Howie

May I ask Professor Hanson a question? I was very impressed by your data that showed lower responses to immunization in formula-fed than in bottle-fed babies. My question is whether this leads to any suggestion that bottle-fed babies with lower antibody responses are more prone to the relevant diseases, or are the levels of response still sufficient to mount protection? This could obviously be important for diseases such as tuberculosis in Africa, where the HIV epidemic is expressing itself very strongly as an increased incidence of tuberculosis.

Professor Hanson

That is a very good question. Let me first say that the control groups were really two groups on different formulas, feeding at different protein levels. There was no difference between those two, but the breastfed group did better. Now, your question, of course, requires that we know the protective level of the antibodies we measure. That is known for just a few infections, like rabies and *Haemophilus influenzae*-type infections. Actually, we also know the protective level for diphtheria toxin antibodies, so there we could find an answer for you, but, otherwise, I think we have to rely on the general principle that more antibodies give a better chance of protection. On the other hand, I should add another observation we made with Dr. Cruz of INCAP (Institute of Nutrition of Central America and Panama) in Guatemala. If the mother is infected with diarrhoeal agents during pregnancy, the antibodies she has in her milk against certain pathogens come down during the period of infection. Then they return again. This may mean that it is important to prevent maternal infection during lactation, so that the protection of the breastfed infant does not decrease. We know the protection of the breastmilk relates to the amount of secretory IgA antibody to cholera bacteria and toxin and to *Shigella*, *Campylobacter*, and so forth.

Dr. Garza

Professor Howie's question related to the quantity. I know that you have also looked at the quality of the antibody in mother's milk in relation to the mother's

nutritional status. Are there any differences in the quality of the antibodies that are made by breastfed and bottle-fed infants, in terms of avidity and other properties?

Professor Hanson

What a nice question. I don't know the answer, but avidity is the capacity of the antibody to bind. The more effectively it binds, the better it neutralizes toxins, and the better it may protect. I don't know the answer, because nobody has done the study, which needs to be done. Nevertheless, we have shown that moderate undernutrition of the mother does not impair the avidity of the milk antibodies.

Dr. Rasmussen

I have a question for Professor Hanson that is off the subject of lactation. What you said this morning would cause me to revise my teaching in maternal health, so I wish to be clear about what you said. You contended that the immune system controls pregnancy, if I am paraphrasing you correctly. I would like you to confirm exactly what you said, and ask you what mechanisms may be involved.

Professor Hanson

Two years ago I would not have believed this new concept. There are a number of animal studies, and now more and more human studies, to support the conclusion that the cytokines from the maternal–antipaternal immune response are a driving force during pregnancy. Thus, the trophoblasts are stimulated to grow primarily by interleukin-3 (IL-3) and granulocyte-colony stimulating factor (G-CSF). They stimulate placental formation. The decidua is prepared by cytokines to receive the blastocyst. Cytokines induce the production of human chorionic gonadotrophin (hCG) and progesterone, as well as placental prolactin. Cytokines finally induce the production of the prostaglandins that result in delivery. IL-8 comes in both at menstruation and at delivery, so that a lot of neutrophils come in, surely to defend the bleeding surfaces open to infections, but also to provide the collagenase that opens up the cervix. IL-6 induces the baby to produce surfactant protein A. It all comes together in a most remarkable way. This is the positive side, with an overweight of T_H2 cells driving and protecting pregnancy by production of IL-3, IL-4, IL-5, IL-6, and IL-10. If there is a predominance of the T_H1 cells stimulated by IL-12, then there may be too much interferon-γ on tumour necrosis factor-α (TNF-α), resulting in intrauterine growth retardation or even abortion. IL-10 can down-regulate the T_H1 cells to produce less interferon-γ. So the question is obvious: can we demonstrate intrauterine growth retardation that can be prevented by IL-10? Of the 20% of children with low birthweight in Pakistan, 75% have intrauterine growth retardation, and in India the figures are even higher.

Breastfeeding and child development

Ernesto Pollitt and Patricia Kariger

Abstract

The literature reviewed in this article suggests that breastfeeding positively influences cognitive development. Studies comparing the effects of early feeding methods on cognition consistently show mental test score advantages for breastfed infants over bottle-fed subjects. Also, breastfeeding may function as a buffer against adverse developmental outcomes from early traumatic events such as low birthweight or neurologic insults. It is recognized that breastmilk contains long-chain polyunsaturated fatty acids that are necessary for the normal development of the retina and cerebrum. Yet, breastfeeding may not always promote optimal development in children. Infants breastfed by mothers using alcohol or marijuana have lower scores on developmental tests. Thus, while breastfeeding has the potential for contributing to the healthy development of infants, it may also be capable of transferring toxic substances known to interfere with normal development.

Introduction

Human biology and psychology provide support for the hypothesis that breastfeeding benefits mental development. On the one hand, biochemical components of breastmilk affect particular elements of the neural circuitry that contribute to information processing [1–3]. On the other hand, in addition to the emotional ties that arise between mother and infant from suckling, it is plausible that breastfeeding helps the development of interpersonal communication between infant and caretaker [4].

Several lines of research bear on the issue of the effects of breastfeeding on mental development. The most obvious is the search for a direct relationship between the presence or absence of breastfeeding, at one end, and measures of cognition, at the other end. A second line, which has received little attention in the literature, refers to breastfeeding as a primary or secondary preventive agent. Finally, there is research that raises a caveat to the idea that breastfeeding can do no wrong. At issue is whether breastfeeding could operate as a developmental risk factor by the transfer of toxic elements such as alcohol that could limit mental development.

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Direct effects of breastfeeding

Several studies have attempted to test the hypothesis that breastfeeding gives infants developmental advantages over those who are bottle-fed. Limitations in research design prevented most of these studies from carrying out a fair test of the hypothesis. By definition, correlational studies do not address issues of causality because of the uncertainty that all potential confounders have been controlled for.

Because developmental scales that are used to test infants and toddlers do not assess the same psychological constructs as those assessed by intelligence tests administered to older children, we have separated studies of infants and toddlers from the remaining studies. Longitudinal studies that include assessments at both ages were placed in both age groups.

Infants and toddlers (table 1)

Five studies [5–9] are included in this group. All used the Bayley Scale of Mental Development for the developmental assessment. Because the study by Rogan and Gladen [7] also included evaluations with the McCarthy Scales at three, four, and five years of age, we included their later results in the following section.

The definition of the independent variable (feeding method) varies among the studies and prevents

TABLE 1. Studies of the effect of breastfeeding on development in infants and toddlers

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Temboury et al., 1994 [6]	Prospective, longitudinal, correlational study Cognitive development measured once between 18 and 29 mo Data on background variables collected when subject was tested Subjects classified by method of feeding: *bottle*, breastfed ≤1 mo ($n = 99$); *breast*, breastfed ≥3 mo ($n = 130$)	229 newborns from Madrid hospitals; about half middle and half lower SES	Gestational age <36 wk Birthweight <2,400 g Perinatal complications Major birth anomalies Poor 5-min Apgar score Breastfed for 2 mo Follow-up testing not completed	Bayley MDI and PDI scores at 18–29 mo **Covariates:** Maternal education, age, working status SES No. of siblings Psychosocial risk Testers also coded for shyness, temper tantrums, hyperactivity	Low MDI scores at 18-29 mo were predicted by: bottle-fed: $R = 1.86$, $p = .044$ low maternal education: $R = 2.90$, $p = .012$ no. of siblings: $R = 2.63$, $p = .002$ tantrums: $R = 2.38$, $p = .016$
Rogan & Gladen, 1993 [7]	Prospective, longitudinal, correlational study Mothers interviewed about feeding methods from birth to 5 yr Cognitive development measured at 6, 12, 18, and 24 mo Subjects classified by duration of breastfeeding and weaning age: short: $n = 97$, 0–4 wk breastfed, weaning age ≤9 wk medium: $n = 184$, 0–4 or 5–19 wk breastfed, weaning age >9 or <19 wk long: $n = 294$, 5–19 or >20 wk breastfed, weaning age >19 or ≤49 wk very long: $n = 177$, >20 wk breastfed, weaning age >50 wk bottle-fed: 0 wk breastfed, weaning age 0	600+ full-term infants from mostly white, middle SES, well-educated families in North Carolina, USA	Mothers did not intend to breastfeed or lacked interest in being in long-term study	Bayley MDI and PDI scores at 6, 12, 18, and 24 mo **Confounders:** Maternal age, race, occupation, education, smoking and drinking during pregnancy Child's sex, birthweight, birth order	Mean differences at 24 mo: *Very long* vs *short*: +6.7 points, MDI *Very long* vs *bottle-fed*: +5.6 points, MDI; +5.9 points, PDI Positive effects for maternal age and birth order were also found

Morrow-Tlucak et al., 1988 [5]	Prospective, longitudinal, correlational study Cognitive development measured at 6, 12, and 24 mo Household characteristics measured at 12 and 24 mo Subjects classified by duration of breastfeeding: *bottle only* ($n = 157$); *breast* ≤4 mo ($n = 39$); *breast* >4 mo ($n = 23$)	229 mostly low SES infants whose mothers were recruited during prenatal care visits at a Cleveland hospital	Gestational age <37 wk Perinatal complications Admission to neonatal care unit Known maternal drug use or psychosis Primary language not English Child placed for adoption Delivery and discharge on weekend Family intends to move from area	Bayley MDI and PDI scores at 6, 12, and 24 mo HOME scores at 12 and 24 mo **Confounders:** Race, parental education, maternal intelligence, cigarette use, maternal disciplinary attitude	Mean MDI score advantages for *breastfed* vs *bottle only*: Breastfed group / Age tested (mo) / Point advantage ≤4 mo / 12 / +4.80* >4 mo / 12 / +10.1 ≤4 mo / 24 / +7.40** >4 mo / 24 / +13.9 *$F = 3.24$; $p = .041$ **$F = 3.76$; $p = .025$ Regression analyses indicated breastfeeding duration still significantly related to MDI score at 12 and 24 mo, even with confounding variables and HOME scores entered in the analyses
Young et al., 1982 [8]	Retrospective, cross-sectional, correlational study Cognitive and motor development measured once at 6, 8, 10, 12, 14, or 16 mo Mothers reported feeding method used Subjects classified by feeding method: *artificial*, breastfed ≤2 mo; *mixed*, breastfed, then given cow's milk after 2 mo of age; *breastfed*, breastfed >7 mo	1,000 infants selected from data bank set up from Tunis birth records. Equal numbers of infants from 5 social classes represented for each age group	Social class not verifiable	Bayley MDI and PDI scores, body length and weight, disease prevalence, allergies **Confounders:** No. of siblings; maternal education, smoking, alcohol use	MDI mean advantages for *breastfed* over *mixed* and *artificial* combined, according to sex, SES, and age: +3.86 ($t = 3.02$; $p < .01$) for males, high SES, 10 mo +5.85 ($t = 2.04$; $p < .05$) for females, high SES, 10 mo +4.97 ($t = 2.82$; $p < .01$) for females, low SES, 12 mo +5.93 ($t = 2.77$; $p < .05$) for males, high SES, 12 mo +3.50 ($t = 1.92$; $p < .10$) for males, high SES, 14 mo None of the confounding variables were found to influence MDI scores

TABLE 1—*Continued*

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Florey et al., 1995 [9]	Follow-up correlational study examining the influence of feeding method on motor and mental development at 18 mo Feeding data obtained from hospital forms and records of nurses' home visits in the first 2 mo Bayley MDI and PDI administered to 582 children at 18 mo Subjects classified by feeding method: *breastfed* ($n = 228$); *bottle-fed* $n = 354$)	Population-based sample of 846 firstborn singletons delivered in a hospital in Dundee, Scotland		Bayley MDI and PDI scores at 18 mo	Mean MDI scores: *breastfed*, 110.2; *bottle-fed*, 102.5 No group mean differences were found for PDI scores

Abbreviations: HOME, Home Observation for Measurement of the Environment; MDI, Mental Development Index; PDI, Psychomotor Development Index; SES, socio-economic status.

TABLE 2. Studies of the effect of breastfeeding on development in children

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Hoefer and Hardy 1929 [12]	Prospective, longitudinal, correlational study of growth Subjects classified by duration of exclusive breastfeeding: *artificially fed* ($n = 38$); *≤3 mo* ($n = 78$); *4–9 mo* ($n = 77$); *10–20 mo* ($n = 190$)	383 children 7–13 yr of age	No data on feeding method	IQ, EQ, PQ scores (tests not specified); age talking	Mean scores for tests according to duration of exclusive breastfeeding: Duration (mo) / *n* / IQ / EQ / PQ / Age talking (mo) artificially fed / 38 / 102.3 / 106.5 / 122.0 / 15.2 ≤3 / 78 / 101.9 / 109.6 / 125.3 / 13.7 4–9 / 77 / 107.6 / 112.1 / 128.3 / 13.3 10–20 / 190 / 100.6 / 105.5 / 121.5 / 14.5
Rogan & Gladen, 1993 [7]	Follow-up to study described in table 1 Cognitive development measured at 3, 4, and 5 yr		See table 1	McCarthy Scale scores at 3, 4, and 5 yr 3rd-grade report card grades in English and math	Results on all scales showed a trend for higher scores in the breastfeeding groups at all ages Mean score advantages ranged from +2.8 to +4.8 points for *very long* breastfed vs *short* breastfed or *bottle-fed* No significant differences between groups in 3rd-grade report cards

<table>
<tr>
<td>Fergusson et al., 1982 [13]</td>
<td>Prospective, longitudinal, correlational follow-up study
Cognitive development measured at 3, 5, and 7 yr
Subjects classified by months of breastfeeding: <i>bottle-fed</i> (0 mo breastfeeding); <i>breastfed</i> <4 mo; <i>breastfed</i> >4 mo</td>
<td>Birth cohort of children participating in a New Zealand developmental study</td>
<td>Missing data on feeding method</td>
<td>IQ test scores: age 3, Peabody Picture Vocabulary Test; age 5, Stanford-Binet; age 7, Wechsler IQ
LC test scores: ages 3 and 5, Reynell Developmental Language Scales; age 7, Illinois Test of Psycholingnistic Abilities
Confounders:
Maternal intelligence, education and child-rearing knowledge, SES; children's gestational age at birth and birthweight</td>
<td>Mean advantages for breastfed vs bottle-fed groups on IQ and LC tests, controlling for confounders:
<table>
<tr><th>Age (yr)</th><th>Breastfeeding duration (mo)</th><th colspan="2">Advantages</th></tr>
<tr><td></td><td></td><td>IQ</td><td>LC</td></tr>
<tr><td>3</td><td><4</td><td>+1.25</td><td>+3.15</td></tr>
<tr><td></td><td>>4</td><td>+2.42</td><td>+2.71</td></tr>
<tr><td></td><td colspan="3">$F = 3.87$; $p < .05$</td></tr>
<tr><td>5</td><td><4</td><td>+2.53</td><td>+2.18</td></tr>
<tr><td></td><td>>4</td><td>+2.39</td><td>+1.97</td></tr>
<tr><td></td><td colspan="3">$F = 7.49$; $p < .001$</td></tr>
<tr><td>7</td><td><4</td><td>+1.94</td><td>+2.02</td></tr>
<tr><td></td><td>>4</td><td>+2.31</td><td>+2.03</td></tr>
<tr><td></td><td colspan="3">$F = 4.65$; $p < .01$</td></tr>
</table></td>
</tr>
<tr>
<td>Rodgers, 1978 [11]</td>
<td>Longitudinal, correlational study
Data from achievement tests obtained at 8 and 15 yr
Mothers interviewed every 2 yr from child's birth to age 18
Subjects classified by feeding method: breastfed only ($n = 1,291$); bottle-fed only ($n = 1,133$). Other subjects classified by age (months) at which they were changed from breast- to bottle-feeding</td>
<td>5,362 infants born in 1 week of March 1946, selected to represent all singletons born that week</td>
<td>Missing data on feeding method</td>
<td>Age 8: performance on school-administered picture intelligence tests and reading tests
Age 15: performance on sentence completion, nonverbal ability, and math tests
All scores were standardized on the survey population to give a mean of 50 and an SD of 10
Confounders:
Parental interest in school, SES, maternal and paternal education, family size, birth order</td>
<td>Mean score advantage for breastfed only group vs bottle-fed only group on sentence completion test at age 15 was +3.5 ($F = 4.89$; $p < .001$)
Regression analyses showed all listed confounders significantly predicted performance on sentence completion test
Predicted mean score advantage for breastfed only group vs bottle-fed only group, confounders held constant:
<table>
<tr><th>Age</th><th>Test</th><th>Advantage</th><th>F</th><th>p</th></tr>
<tr><td>8</td><td>picture intelligence</td><td>+1.76</td><td>12.78</td><td><.001</td></tr>
<tr><td>15</td><td>non-verbal ability</td><td>+1.76</td><td>12.51</td><td><.001</td></tr>
<tr><td>15</td><td>math</td><td>+1.55</td><td>11.50</td><td><.001</td></tr>
<tr><td>15</td><td>sentence completion</td><td>+1.73</td><td>13.82</td><td><.001</td></tr>
</table></td>
</tr>
</table>

Abbreviations: EQ, Educational Quotient; IQ, Intelligence Quotient; LC, Language Comprehension; PQ, Performance Quotient; SES, socio-economic status.

pooling the data to draw any generalizations. For example, the number of types of feeding methods ranges from two [6] to five [7]. Likewise, the nutrient composition of the formulas given to the bottle-fed babies was generally not reported, and the nature and number of potential confounders accounted for and the socio-economic status (SES) of the subjects varied among studies.

None of the studies reported significant differences among any of their feeding groups during the first 11 months of life. The earliest differences were observed at 12 months. For example, Morrow-Tlucak et al. [5] reported that at 12 months the mean Mental Development Index (MDI) of exclusively bottle-fed infants was 10 points lower than that of the babies who were breastfed for at least four months ($p < .05$) (table 1).

After the first year of life, bottle-fed babies consistently obtained lower MDI scores than the respective comparison groups with the longest periods of breastfeeding. The intergroup differences ranged from 3.5 [8] to 13.9 [5] MDI points. However, there are inconsistencies in the data. For example, on the one hand, Temboury et al. [6] reported that infants breastfed for more than three months had higher MDI scores than bottle-fed babies (table 1). On the other hand, breastfeeding from 5 to 19 weeks did not give an advantage over bottle-feeding in the Rogan and Gladen [7] study (table 1).

Developmental scales generally lack the sensitivity to detect subtle delays in mental development during the first year of life (see, for example, ref. 10). It is therefore not surprising that the MDI scores of the bottle-fed and breastfed babies in the studies cited above first appeared after 12 months of age. Of importance here is that the MDI obtained during the second year of life is generally a modest predictor of later intelligence [11]. Pearson correlations between MDI scores and later intelligence quotient (IQ) scores are generally less than 0.50. Consequently, the developmental significance of the observed MDI differences is questionable. A conservative conclusion is that, during the second year, the behavioural repertoire of the breastfed baby is broader than that of the bottle-fed baby.

Children (table 2)

In addition to a study published in 1929 [12], we found three studies [7, 13, 14] that reported the comparisons of scores from intelligence and school achievement tests in childhood of breast- and bottle-fed subjects. As with the studies of infants and toddlers, these studies do not constitute a homogeneous set. There are differences in the ages at the time of testing, in the tests administered, and in the number and nature of the confounders accounted for. In one study [7] the last assessment occurred at 5 years of age, and in another [14] the subjects were tested up to 15 years of age. The tests also differed. For example, Rogan and Gladen [7] used the McCarthy Scales for the assessment of pre-schoolers, whereas Fergusson et al. [13] used the Peabody Picture Vocabulary Test for pre-schoolers, the Stanford-Binet Scale for five-year-olds, and the Wechsler Scale for seven-year-olds. Rodgers [14] used a picture intelligence test and tests of specific cognitive abilities (e.g., mathematics).

The studies of children generally included large samples, ranging from 383 [12] to more than 5,000 [14], and found relatively narrow numerical differences between groups to be statistically significant. An evaluation of the importance of this issue, however, must consider the consistency of the findings across studies. The results form a distinct pattern. Independently of age and the tests used, subjects who were breastfed generally had higher IQs and achievement scores than those who were bottle-fed. For example, a study in Great Britain compared the performance of 1,291 exclusively breastfed (duration not specified) and 1,133 exclusively bottle-fed subjects in tests of sentence completion at 15 years of age [14] (table 2). The breastfed subjects obtained consistently higher scores than the bottle-fed subjects.

Problems of studies of direct effects

There are two salient features in the studies of both infants and toddlers and of children. One is the weakness of the correlational design, which precludes conclusive inferences. The other is the consistency across studies in different populations and social contexts of the cognitive advantage of breastfed over bottle-fed subjects. Although the second feature cannot compensate for the weakness of the first, it strengthens the scientific merit of the original hypothesis.

The search for direct effects of breastfeeding on mental development has closely followed the prescription of the main-effect model in the biomedical literature. This model posits that exposure to a particular influential factor or event during critical early periods of brain growth results in structural changes that, in turn, determine the presence of a particular developmental outcome. At issue here is that this model is rarely indicated today in research on developmental psychobiology, because more often than not it has not worked (see, for example, Sameroff and Chandler [15]). Theoreticians argue that the influences on development are multiple and interactive, and that one single determinant seldom causes the type of effects attributed to breastfeeding [16]. In the particular area of developmental risk, it has

been shown that it is generally the number of risk factors to which an organism is exposed, rather than the nature of the factors, that influences cognition [17, 18].

In conclusion, shortcomings of design have prevented a fair test of the hypothesis that breastfeeding confers developmental advantages to infants. However, the consistency in the results strengthens the scientific merit of the hypothesis and indicates future experimental research, with the admonition that the magnitude of the effects is not likely to be large. Future research should be rooted in basic contemporary premises of human development, which underscore the influence of interactions between developmental determinants.

Bonding

In addition to providing nourishment for the infant, the act of breastfeeding has been associated with the establishment and promotion of the mother–child relationship. It has been proposed that the physiological changes that occur during breastfeeding may be related to the occurrence of emotional changes in the mother [19]. That is, it is suggested that breastfeeding may enhance a mother's feelings of connectedness with her baby, which, in turn, positively influences the developing mother–child bond. However, the data to support this notion are weak, at best. In fact, the concept of bonding has been described as "scientific fiction" [20].

Preventive effects

The potential preventive effects of breastfeeding may be divided into *primary effects*, by which breastfeeding would prevent a nutritional deficiency known to have adverse effects on mental development, and *secondary effects*, by which breastfeeding would protect the development of cognitive function from the adverse effects of an early neurologic disorder.

Primary prevention (table 3)

Although there are no published studies addressing this issue head-on, sufficient relevant information exists to document the role of breastfeeding as a primary preventive factor. Iron deficiency is associated with developmental delays among infants and toddlers [21]. In addition, although there are discrepancies in the data, well-controlled clinical trials have shown that the developmental delays of babies with iron-deficiency anaemia are reversed following iron repletion therapy [22].

The iron in breastmilk is of low concentration but is highly bioavailable, so that breastfed infants are significantly less likely to become iron-deficient during the first six months of life than bottle-fed infants, especially infants fed cow's milk [23]. Thus, if breastmilk prevents anaemia, it also prevents the developmental delays associated with anaemia.

Further support for this argument is found in a randomized, controlled trial recently conducted in Canada on the preventive effect of iron-fortified formula [24] (table 3). Two groups of infants up to two months of age were randomly assigned to receive Enfalac with 12.8 or 1.1 mg elemental iron per liter. Subsequently, the Bayley Scales of Infant Development tests were administered to the subjects at 6, 9, 12, and 15 months of age. The treatment-by-time interactive term of an analysis of variance accounted for a significant portion of the variance of the Psychomotor Development Index (PDI). In particular, there were significant differences in the expected direction between groups at 9 and 12 months. Fortified formula prevented the delays in psychomotor development observed in those who received low-iron formula. No differences were observed in the MDI. Since the MDI is a poor indicator of mental development during the first 12 months, the absence of differences in MDI is not surprising.

In conclusion, when infants are artificially fed without iron fortification, breastfeeding is likely to operate as a shield against developmental delays associated with iron-deficiency anaemia. This is particularly true in low-birthweight infants, who are at high risk for iron-deficiency anaemia [25]. However, exclusive breastfeeding after six months of age is not likely to have this effect against iron-deficiency anaemia [26].

Long-chain polyunsaturated fatty acids (LC-PUFA) are components of neural tissue, and recent research on their effects on selective neural function in laboratory animals and humans provides strongly suggestive evidence of the potential contributions of breastmilk to cerebral function [27, 28]. Briefly, LC-PUFA, particularly arachidonic and docosahexaenoic acids, play important roles in the development of the retina and cerebrum, and deficiencies of these in laboratory animals and low-birthweight infants may cause selective dysfunctions in visual function and learning [1, 27].

In utero, effective transfer from the mother across the placenta satisfies the need for LC-PUFA in the foetus. Later, maternal milk, a rich source of docosahexaenoic acid, meets the needs of the young infant [29]. Generally, however, the contents of docosahexaenoic acid in formula are insufficient for newborns or young infants, as demonstrated by the low plasma levels of docosahexaenoic acid in formula-fed infants and by visual function differences between breastfed and formula-fed infants [29–31]. In one study, pre-

TABLE 3. Studies of the primary preventive effects of breastfeeding

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Moffatt et al., 1994 [24]	Prospective, longitudinal, randomized clinical trial comparing the effects of iron-fortified and regular formula on the cognitive and motor development of infants 112 subjects received *iron-fortified* and 113 *regular formula* for 15 mo Cognitive and motor development measured at 6, 9, 12, and 15 mo	225 bottle-fed infants 0–2 mo old born in hospitals in the area of Winnipeg, Canada		Bayley MDI and PDI scores at 6, 9, 12, and 15 mo	No significant differences between groups in MDI scores Mean score advantage for *iron-fortified formula* vs *regular formula* group in PDI scores: Age (mo) — Advantage 6 — +0.6 9 — +4.0 12 — +6.3 15 — +2.8 $p = .02$ (group × time interaction)
Agostoni et al., 1995 [31]	Prospective, quasi-experimental study comparing the effect of breastmilk, LC-PUFA-enriched formula, and standard formula on neurodevelopmental scores at 4 mo Infants whose mothers chose to breastfeed were randomly assigned to receive LC-PUFA-enriched formula or standard formula Neurodevelopmental responses measured with the Brunet-Lezine psychomotor development test at 4 mo Blood fatty acid content measured at 4 mo	90 infants born in a clinic in Milan, Italy, during 1 yr Classification of subjects: *exclusively breastfed* ($n = 30$); *LC-PUFA formula* ($n = 29$); *standard formula* ($n = 31$)	Gestational age <37 wk Apgar score <7 Any perinatal disorder or disease	Scores on the Brunet-Lezine psychomotor test, which assesses gross and fine motor function, social reactions, and language	Brunet-Lezine scores significantly higher in the *exclusively breastfed* and *LC-PUFA formula* groups than in the *standard formula* group ($p < .05$) Group — Mean score exclusively breastfed — 102.2 LC-PUFA formula — 105.3 standard formula — 96.5 Blood fatty acid levels significantly higher in the *exclusively breastfed* and *LC-PUFA formula* groups than in the *standard formula* group

Abbreviations: LC-PUFA, long-chain polyunsaturated fatty acids; MDI, Mental Development Index; PDI, Psychomotor Development Index.

term (four months adjusted age) and full-term infants who were fed human milk performed significantly better than formula-fed infants in tests of visual evoked potentials and of preferential looking acuity. Further, at 36 months the breastfed term infants also performed better than the formula-fed term infants in dot stereo acuity and letter-matching ability tests [1].

A recent study [32] compared the developmental test performances of three groups of subjects receiving human milk, conventional formula (with LC-PUFA precursors), or an experimental formula supplemented with pre-formed LC-PUFA (table 3). All eligible subjects were between 37 and 42 weeks gestational age, were free of any type of diagnosable disorder, and had five-minute Apgar scores of 7 or better. Mothers of 30 of the subjects chose to breastfeed their babies. The remaining subjects were randomly assigned to receive either the conventional formula ($n = 31$) or the experimental formula ($n = 29$).

A psychomotor developmental test (Brunet-Lezine) was administered to 86 of the subjects at age four months (two subjects in the conventional formula group and two subjects in the experimental formula group could not be tested). The Brunet-Lezine Test assesses gross and fine motor function, social responses, and language. A developmental quotient score is obtained from scores on the subscales. The mean score on the Brunet-Lezine Test for all subjects was 101 (SD = 11) and the range was 80–136, similar to the standardized values reported by the authors of the test. Infants receiving the LC-PUFA-enriched formula or human milk scored significantly higher (105.3 and 102.2, respectively) on the Brunet-Lezine Test than the subjects receiving the conventional formula (96.5). There were no differences among the three groups in parental and socio-economic variables. Blood analyses for a subgroup of infants revealed that fatty acid levels were higher for the infants receiving the LC-PUFA-enriched formula or human milk than for the infants receiving conventional formula.

Although these and other similar studies [33] help our understanding of the relations among breastmilk, LC-PUFA, and cerebral function, they do not speak directly to the question of the contribution of breastmilk to the growth of intelligence. Neither theory nor empirical data suggest that visual acuity, visual evoked potential, or letter discrimination during the first months of life are precursors of the development of central information processing or of abilities that constitute the cornerstones of intelligence. Further, although the Brunet-Lezine Test, the Bayley Scale of Mental Development, and other developmental scales are useful tools to describe the behavioural repertoire of four-month-old infants, in most cases developmental scale scores obtained at that early age do not predict later developmental scale performance even at the end of the first year of life. Developmental scales administered in early life do not measure cognition.

Secondary prevention (table 4)

At issue here is the potential protective effect of breastfeeding against the sequelae of prematurity or an early neurologic disorder. Lucas and collaborators [34–36] have published a series of articles on the short- and long-term effects of breastfeeding and formula-feeding on the performance on developmental and IQ tests by children born prematurely with very low birthweights (1,850 g). The basic design is that of a prospective, randomized trial in five centres to assess the effects of diet on neurodevelopment (table 4). A limitation of these studies is that the definition of the samples is very limited, and the articles do not discriminate between the subjects who participated in the different studies. Further, the direction of the hypothesis tested in each study is not clearly indicated.

A study published in 1989 [34] compared the development of pre-term infants admitted to the neonatal units in Cambridge, Ipswich, or King's Lynn, England, from 1982 to 1984, who were randomly assigned at birth to either donated banked breast milk (BBM) or pre-term formula (PTF) (2 g protein, 0.335 MJ; 35 mg phosphorus; 70 mg calcium; 45 mg sodium, 100 ml) as the sole diet. The mothers in this trial (trial I) had chosen not to provide their own milk to their offspring. In trial II, comparisons were also made among the offspring of women who elected to express their own milk to feed their children. These children were also randomly assigned to either BBM or PTF to supplement their intake from maternal milk. The diets were discontinued when the children were discharged from the neonatal unit or when their body weight was at least 2,000 g. Comparisons were made at nine months of age on their performance in the screening inventory of Knobloch et al. [37], which includes five developmental areas (adaptive, gross motor, fine motor, language, and personal-social). This assessment tool is a screening inventory rather than a developmental scale, and is not generally recognized as a test of intellectual development, as suggested (p. 320) by the authors. A neurologic examination (Amiel-Tison and Grenier) was also administered to the children, who were classified as normal, equivocal, or impaired.

When the data from both trials were pooled at nine months of age, the subjects who had received PTF, either as the sole diet or as a supplement, had significantly higher scores in the adaptive, fine motor, language, and personal-social areas than those who

TABLE 4. Studies of the secondary preventive effects of breastfeeding

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Lucas et al., 1989 [34]	Prospective, longitudinal, randomized trial comparing the effects of donated BBM and PTF on the behavioural development of pre-term infants. Subjects received the treatment until discharge from the hospital or until attaining a weight of 2,000 g Data on behaviour obtained at 9 mo Subjects classified into 2 groups according to mother's decision to breastfeed or not to breastfeed Within each group, subjects randomly assigned to receive BBM or PTF via nasogastric tube while in hospital Treatment was given as a supplement to mother's milk to infants whose mothers chose to breastfeed, and as sole diet to infants whose mothers chose not to breastfeed	502 pre-term infants born in 3 hospitals in England and admitted to special care unit No. of subjects included in final analysis: *Breastfed* group: *mother's milk + BBM* ($n = 170$); *mother's milk + PTF* ($n = 173$) *Not breastfed* group: *BBM only* ($n = 83$); *PTF only* ($n = 76$)	Birthweight >1,850 g Major congenital anomalies	Scores on developmental screening inventory of Knobloch et al. at 9 mo. Five areas of behaviour assessed: adaptive behaviour, gross motor, fine motor, language, and personal-social Overall DQ obtained by averaging scores on all scales	Comparisons for all subjects receiving BBM vs subjects receiving PTF at 9 mo regardless of whether or not they received mother's milk: BBM / PTF overall DQ 97.9 / 100.4* adaptive 101.3 / 104.0* gross motor 99.9 / 102.3 fine motor 96.6 / 99.2** language 93.3 / 95.6** personal-social 98.0 / 100.6** *$p < .05$; **$p < .025$ Comparisons for subjects receiving treatment as supplement to mother's milk (*breastfed* group): BBM / PTF overall DQ 98.2 / 101.2* adaptive 102.1 / 105.0** gross motor 100.4 / 103.7 fine motor 97.2 / 100.0 language 93.1 / 95.8** personal-social 97.7 / 101.5* *$p < .05$; **$p < .025$ Comparisons for subjects receiving treatments as sole diets (*not breastfed* group) were not significant
Lucas et al., 1994 [35]	Prospective, longitudinal, randomized trial comparing the effects of donated BBM and PTF on the cognitive and motor development of pre-term infants	502 pre-term infants born in 3 hospitals in England and admitted to special care unit	Birthweight >1,850 g Major congenital anomalies	Bayley MDI and PDI scores at 18 mo	No significant effects of treatment type (BBM or PTF) or of presence or absence of breastfeeding on MDI or PDI scores

	Data on cognitive and motor performance gathered at 10 mo Subjects classified into 2 groups according to mother's decision to breastfeed or not to breastfeed Within each group, subjects randomly assigned to receive BBM or PTF via nasogastric tube while in hospital Treatment was given as a supplement to mother's milk to infants whose mothers chose to breastfeed, and as sole diet to infants whose mothers chose not to breastfeed	No. of subjects included in final analysis: *Breastfed* group: *mother's milk + BBM* ($n = 134$); *mother's milk + PTF* ($n = 139$) *Not breastfed* group: *BBM only* ($n = 62$); *PTF only* ($n = 52$)			
Lucas et al., 1992 [36]	8-yr follow-up of cognitive development of pre-term infants participating in 2 prospective, randomized clinical trials Trial 1 compared the effects of regular formula and PTF on cognitive and motor performance of pre-term infants at 10 mo Trial 2 compared the effects of BBM and PTF on cognitive and motor performance of pre-term infants at 9 and 18 mo	300 children 7.5–8 yr old born pre-term and admitted to special care unit at 5 hospitals in England	Birthweight >1,850 g Major congenital anomalies	Scores on abbreviated WISC-R Test at 7.5–8 yr	Mean score advantages for *breastfed* vs *not breastfed* children on various WISC-R scales: Scale — Advantage verbal +10.1 performance +10.1 overall IQ +10.2 $p < .001$ Analyses for randomization trial outcomes (e.g., regular formula vs PTF and BBM vs PTF) not reported

TABLE 4—*Continued*

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Lucas et al., 1992 [36]	Treatment was given as a supplement to mother's milk to infants whose mothers chose to breastfeed, and as sole diet to infants whose mothers chose not to breastfeed Subjects classified in 2 groups according to whether or not they were breastfed: *breastfed* + treatment ($n = 210$); *not breastfed* (treatment only) ($n = 90$) Data on cognitive performance obtained at 7.5–8 yr				
Lanting et al., 1994 [38]	Retrospective correlational study examining the relation between infant-feeding method and development of neurologic disorders in childhood Subjects classified soon after birth as having *normal*, *slightly abnormal*, or *frankly abnormal* neurologic status on the basis of a standardized neurologic examination Subjects selected for follow-up given a standardized neurologic examination at 9 yr	Selected from cohort of 3,162 infants born 1975–78 in a hospital in the Netherlands	Feeding data incomplete Mother could not recall feeding practices Pre-term infants Infant admitted to special care ward	Performance on neurologic examination at 9 yr Neurologic status classified as: *normal*, *minor dysfunction-grade 1* (fewer symptoms), *minor dysfunction-grade 2* (more symptoms), or *abnormal*	For analysis, subjects *breastfed with formula supplement* at least 3 wk were combined with subjects *exclusively breastfed* at least 3 wk For *all subjects breastfed* at least 3 wk, regardless of neurologic classification at birth, scores on the 9-yr neurologic examination and the likelihood of being classified as normal at 9 yr were higher

	Subjects classified according to infant-feeding practices on the basis of a questionnaire completed by parents: *formula-fed* ($n = 358$); *breastfed with formula supplement* at least 3 wk ($n = 33$); *exclusively breastfed* at least 3 wk ($n = 135$)				
Menkes, 1977 [39]	Retrospective, cross-sectional, correlational study examining the relation between infant-feeding method and development of learning disabilities in childhood Subjects were classified as those with *learning disorders* and a *control* group of children with other neurologic disorders *Breastfed* children defined as those receiving breastmilk for at least 4 wk	*Learning disorder* subjects were 29 white, middle-class children born 1959–70 and referred to author for neurologic assessment and treatment *Control* subjects were patients of the author who presented with a variety of other neurologic disorders Subjects matched by sex and age ($n = 53$)	Pre-term infants (no definition provided) Major congenital malformations Infants whose feeding methods were determined by circumstances	Subjects in the *learning disorder* and control groups were classified as *breastfed* or *bottle-fed*	13.8% of children with *learning disorders* and 47.2% of *control* children were breastfed ($p = .004$)

Abbreviations: BBM, banked breastmilk; DQ, Developmental Quotient; IQ, Intelligence Quotient; MDI, Mental Development Index; PDI, Psychomotor Development Index; PTF, pre-term formula WISC-R, Wechsler Intelligence Scale for Children, revised United Kingdom version.

had received BBM. Further, in trial II those subjects who had received PTF had a higher developmental quotient than those who had received BBM, as well as higher scores in the adaptive, language, and personal-social subscales. A finer analysis showed that among those who had received some milk from their own mothers, those who had received more than 50% of their total intake from BBM were at the highest disadvantage. Moreover, the covariation between diet and development was stronger among those classified as small for gestational age (below the 10th percentile).

A natural conclusion from this study is that at nine months of age, pre-term babies who were fed a PTF with the specifications listed had a developmental advantage over those fed BBM. The authors note that part of the developmental importance of this finding is that the screening inventory includes many of the items of the Gesell Schedule, which is a good predictor of later intelligence. However, in contrast to this claim, a vast body of literature on infant development shows that the predictive validity of developmental scales administered during the first 12 months of life is not different from zero [11]. In our view, the reported differences in the performance of pre-term infants fed PTF and BBM are anecdotally interesting but of limited developmental significance over the long term.

In a follow-up at 18 months of age, Lucas et al. [35] assessed 387 of the infants in the original sample with the Bayley MDI and PDI scales. In contrast to the nine-month follow-up, no advantage was found for subjects receiving PTF; infants fed with BBM performed about as well as subjects receiving PTF on both the MDI and PDI scales. Additionally, no significant differences were found for MDI or PDI scores when the subjects were grouped according to whether or not they received mother's milk as a supplement. The authors suggest that the failure to find results in the same direction as the nine-month follow-up may be due to the subjects' recovery from earlier nutritional deficiencies.

In a 1992 article, Lucas et al. [36] reported the effects of breastmilk fed to pre-term babies on intelligence quotients obtained seven to eight years later (table 4). In this second study, the subjects were admitted to the special-care baby units in Cambridge, Ipswich, Kings Lynn, Norwich, and Sheffield between January 1982 and March 1985. Two of these care units (Norwich and Sheffield) were not included in the study published in 1989. Also, in the first study the subjects were selected up to 1984, whereas in this second study the recruitment extended to March 1985. The authors do not specify the degree of overlap between the subjects in the 1994 study [35] and those in the present study. However, they do suggest that both fall out from the same clinical trial and follow the same design. One feature of the 1992 publication is that it does not include data on the subjects who received only BBM.

At $7\frac{1}{2}$ to 8 years of age, the subjects who had received milk expressed from their own mothers (group 2) had higher IQs than the children whose mothers chose not to provide breastmilk for them (group 1). In particular, the differences were observed in the Verbal Performance and Overall Scale (group 1, 92.8; group 2, 103) of the Wechsler Intelligence Scale for Children. According to an analysis within group 2 of the subjects who received breastmilk from their mothers in comparison with those who did not, the overall IQ of this last subgroup (94.8) was similar to that of group 1 (92.8), and both groups had significantly lower IQs than children whose mothers were successful in expressing milk (103.7). A final analysis restricted to the children of the successful mothers showed a dose–response relationship between mother's milk and subsequent IQ.

In conclusion, feeding maternal milk to pre-term babies with very low birthweights improved their middle-childhood IQs, as compared with IQs of pre-term babies who did not receive maternal milk (and who received PTF, mature, pasteurised donor drip breastmilk, or term formula). The authors concluded that the data supported the causal hypothesis that breastmilk promotes the neural development of pre-term babies. They found additional support for their hypothesis in the existing information that human milk contains various factors, such as long-chain lipids, that might affect nervous system development. This impressive set of findings requires confirmation by other laboratories and a control for the extent to which the mothers who succeeded in expressing milk did or did not differ in their child-rearing practices from the remaining mothers.

Lanting et al. [38] studied the relation between feeding method and neurologic functioning at nine years of age (table 4). Three groups of children were formed on the basis of a neonatal neurologic examination. One group ($n = 160$) was defined as neurologically abnormal (e.g., hemisyndrome, hypotonia, hypertonia) at birth; a second group consisted of a random sample of children ($n = 322$) with minor abnormalities (e.g., mild hypotonia); and a random sample of normal children formed a third group ($n = 322$). Nine years after birth, a standard neurologic examination was given to the children in the three groups and they were again reclassified as normal, having minor neurologic dysfunction (two categories), or abnormal. In addition, information was obtained at this new examination on early feeding practices, and three feeding groups were formed: exclusively formula-fed, breastfed plus formula-fed within the first three weeks of birth, or exclusively breastfed for at least three weeks.

Across groups, at nine years of age the children who had been exclusively breastfed were neurologically better off than the formula-fed children. Moreover, among the children classified with minor neurologic dysfunction during the neonatal period, those who had been breastfed were less likely to have minor neurologic dysfunction. In particular, the frequency of minor neurologic abnormalities was twice as high for formula-fed children as for those who were breastfed. The authors suggested that the type of feeding during the first weeks of life plays a role in later neurobehavionral development.

Of interest here is a retrospective stndy published in 1977 which showed that early feeding history predicted learning disorders [39] (table 4). The frequency of breastfeeding was compared in two groups of children: 29 children referred to a paediatric neurologist because of learning disorders and 53 children seen in the same office because of neurologic conditions other than learning disorders. In the latter group, 47.2% of the children had been breastfed, compared with only 13.8% in the former group. The intent of this comparative study was to test the hypothesis that the high protein content (1.5 to 3.3 g/100 ml) of the formula contributed to the evolution of learning disorders.

Breastmilk as risk factor (table 5)

Two studies are reviewed here that address the question of whether breastmilk operates as a risk factor by the transfer of toxic substances from the mother to the infant [40, 41]. Because of their correlational nature, these studies have limitations in design similar to those discussed above regarding the direct effects of breastmilk. There is no way of discriminating between group differences due to the independent variable and those due to confounders, nor can the effects associated with the prenatal and postnatal periods be separated. A particular concern is whether the use of a toxic substance is associated with caretaking behaviours that hinder rather than foster development.

The first study was a prospective, longitudinal study that tested the effects of alcohol consnmption during the lactation period on mental and motor development at 12 months of age [40]. The subjects were 400 middle-class infants. The independent variable was represented by a score that indicated the infant's exposure to alcohol through breastmilk. Maternal reports of daily alcohol consumption were obtained along with reports of the number of breastfeeding days per month. These scores were then related to the Bayley PDI and MDI scores at 12 months of age. A statistically significant linear trend was observed between alcohol consumption and PDI. A comparison of the end points of this continuum shows a difference of 19 PDI points (>1 standard deviation) between infants of mothers who consumed no alcohol and those with the highest consumption.

The second study, which was also longitudinal and correlational, examined the potential effects of the use of marijuana during lactation on the mental and motor development of the offspring [41]. Of importance here is that marijuana appears in the milk of lactating women who use the drug [42]. The criterion for inclusion in the study was breastfeeding for at least two weeks. As in other studies, the Bayley MDI and PDI scores were obtained from all infants at 12 months of age. Again, although there were no differences between children of users and non-users of marijuana in the MDI, there was a clear trend in the expected direction for the PDI. The mean PDI of the infants of mothers with 0 days of exposnre was 102, whereas that of the infants with 15 to 30 days of exposure was 90.

As noted, inherent limitations of correlational studies prevent conclusive inferences. Moreover, even under controlled conditions, data from two studies alone are generally insufficient to guide policy. Therefore, definitive recommendations regarding breastfeeding for mothers who consume alcohol and marijuana are unwarranted. However, the findings are suggestive and indicate a need for further information.

General discussion

Breastfed children have a modest advantage over artificially fed children in developmental scales, IQ tests, and tests of particular cognitive processes. Although no definitive conclusions on causality are warranted, the consistency of the findings across studies carried out in different populations and social contexts is quite remarkable. These suggestive findings point to the need for experimental studies leading to conclusive statements.

In addition to limitations of design, the studies have had a restricted focal concern, first, on main effects, and second, on *products* of development such as IQ or psychomotor indexes. Possible differential effects of breastfeeding as a function of contextual (e.g., social and economic) factors and organismic status have been disregarded. There is also suggestive evidence that the duration of breastfeeding may have an effect.

Rather than focusing on developmental outcomes, studies should also examine the contributions of breastfeeding to the *processes* of development. In this line of reasoning, wc believe that a particular area of enormous potential is the assessment of the role of breastfeeding in the formation of secure attachment in early childhood. Besides their univer-

TABLE 5. Studies of breastmilk as a risk factor

Study	Study design	Sample	Exclusion criteria	Outcome variables	Significant results
Little et al. 1989 [40]	Prospective, longitudinal, correlational study examining the effects of maternal alcohol use during lactation on infant mental and motor development Cognitive and motor development measured at 12 mo Maternal alcohol use measured by questionnaire during mo 1 and 3 *Breastfed* children defined as those receiving the majority of intake from breastmilk (<16 oz/day of non-human milk or supplement)	400 infants, mostly white and middle-class, born to mothers belonging to a health maintenance organization in Seattle, Washington, USA	No prenatal care before 6 mo gestation	Bayley MDI and PDI scores at 12 mo **Independent variable:** *Infant AA score*, used to indicate infant's exposure to alcohol via breastmilk, estimated from mother's reports of daily alcohol consumption and days of breastfeeding per month during mo 1 and 3	Infant AA score not related to MDI scores at 12 mo Significant linear trend found for effects of infant AA score on PDI score at 12 mo ($p < .006$) AA score / *n* / PDI 0 / 111 / 104 >0–0.4 / 188 / 103 0.5–0.9 / 71 / 99 1–1.4 / 25 / 98 ≥1.5 / 4 / 85
Astley and Little, 1990 [41]	Longitudinal, correlational study examining the relation between maternal marijuana use during lactation and cognitive and motor development of infants Cognitive and motor performance measured at 12 mo *Breastfed* children defined as those receiving the majority of intake from breastmilk (<16 oz/day of non-human milk or supplement) for at least 2 wk	323 infants, mostly white and middle-class, born to mothers belonging to a health maintenance organization in Seattle, Washington, USA	Infants not breastfed at least 2 wk Infants who did not have 12-mo assessments	Bayley MDI and PDI scores at 12 mo **Independent variable:** Infant's exposure to maternal marijuana use during lactation estimated from mother's reports of daily marijuana use and days of breastfeeding per month during mo 1 and 3	No significant effect of exposure to marijuana on MDI scores at 12 mo Mean PDI scores at 12 mo according to days of exposure to maternal marijuana use during 1st month postpartum: Days exposure / *n* / PDI 0 / 81 / 102 1–14 / 38 / 106 15–30 / 17 / 90 Mean difference between groups with 0 and 1–14 days exposure and group with 15–30 days exposure is significant ($p < .005$).

Abbreviations: MDI, Mental Development Index; PDI, Psychomotor Development Index.

sality, breastfeeding and attachment have had significant evolutionary value, and their interconnectedness could well have served human adaptation.

The suggestive evidence that breastmilk contributes to the healthy mental development of premature infants is impressive. Moreover, the use of breastmilk as an experimental variable provides guidelines for future research with at-risk and normal newborns. Even though the data refer to premature infants with very low birthweight, these findings contradict much of the contemporary theorizing and research data on the causes and risk factors of development. As noted above, we accept that the causes of development are multiple and interactive, and that individuals reach the same end point by different developmental trajectories [43, 44]. It is indeed curious that differences in feeding for 27 days could orient development along very different courses. There is a great need to replicate these findings, which are of major importance to clinical paediatrics.

The external validity of these data is limited, and their relevance for populations where malnutrition is endemic is questionable. The high prevalence of low birthweight in third world countries is attributed primarily to the number of small-for-date newborns [45, 46]. Pre-term birth is a condition that is more prevalent in industrialized societies. The pathophysiology of prematurity is different from that of intrauterine growth retardation.

A natural extension of the data on pre-term babies is the idea that breastmilk operates as a secondary preventive factor. Pre-term babies will benefit from breastmilk because it is rich in LC-PUFA, particularly docosahexaenoic acid, an essential component in the development of the visual system and cerebrum. The correlational work by Lanting et al. [38] and the controlled study by Agostoni et al. [32] support this uotion.

The nutritional and immunologic value of human milk is well established, and the suggestive evidence of beneficial behavioural consequences fits with our understanding of the physiological processes involved in lactation. Societal changes, economic pressures, and technological advancements, however, could impose limitations in some instances on the value of human milk. It is plausible that breastmilk transfers drugs and chemicals used by the mother to the nursing infant, which could have adverse developmental consequences. The data on alcohol and marijuana which we reviewed are insufficient to draw any conclusive inferences, but they certainly post a sign for caution.

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Discussion of paper by Pollitt and Kariger

Dr. Colombo

An expert from the Institute on Brain Research in Frankfurt, who specialized in the growth and development of the brain in children, was sitting here a few months ago, and I asked him, "How long do these developments last?" I was expecting him to say for two or three years, but he said until puberty. Certainly, if there are clear differences, he said that they may show up at 12 months; but if we have to wait a long time, so many confounding factors intervene that the analysis may fail to give clear answers. As a layman, I can see that this would be a problem for the analysis. Now, I wish to give the floor to more respected colleagues. Thank you.

Dr. Lawrence

I am intrigued by the comment you made at the end that an area of enormous potential was assessing the role of breastfeeding in the formation of secnre attachment in early childhood. Do you think of that as a maternal behaviour or an infant behaviour or both, and, if so, what is the mechanism that you postulate? This is particnlarly interesting in light of the question you asked me yesterday abont the weakness of the evidence of maternal behaviour.

Dr. Pollitt

Infant attachment to the caretaker (biological or surrogate mother) is first observed at six to eight months, and it generally stems from the continnous social and emotional interactions between both members of the dyad. It is theoretically plausible that interactions leading to attachment are induced and sustained by behaviours or behavioural cues of both the infant (for example, smiling) and the caretaker (for example, scent of the nipple). Breastfeeding would provide a medium for the presence of particular behavioural interactions (for example, sucking and milk release) that would help the development of secure attachment between the infant and the caretaker.

Dr. Lawrence

Do you see this attachment in the breastfed infant as being singularly different from that of the bottle-fed infant?

Dr. Pollitt

I do not know, but I suspect this is the case because bottle-feeding and breastfeeding represent different behavioural systems, including similar and distinct behaviours of both parties. For example, the organization of sucking behaviour occurs earlier in the breastfed infant than in the bottle-fed infant, and the scent of the mother's nipple is different from the scent of a nipple on a bottle. Further, whereas the composition of maternal milk changes during feeding, this does not happen in artificial feeding. These differences between bottle-feeding and breastfeeding might be independent of the social and emotional development of the child. Nevertheless, the nature of the behavionrs snpports the proposition that there is scientific and programmatic merit in testing the hypothesis in the field.

Dr. Garza

I'd like to explore your comment that even if we accept the validity of the present findings, with all of their limitations, the differences between breastfed and bottle-fed babies are rather modest. If we think of them as half a standard deviation, I agree with your assessment for those ranked around the mean. That is, I don't know whether half a standard deviation in either direction would have mnch functional significance. If, however, those differences are homogeneously distributed, they conld theoretically have an enormous adverse impact on the number of func-

tionally impaired people. Or the converse might be true: you would almost double the number of gifted people. Is there any reason to suspect that improvement would not be distributed homogeneously? Or is this such a theoretical construct that it has no merits?

Dr. Pollitt

The question refers to two separate but related issues. One is whether the alleged effects of breastfeeding are equally distributed along the entire distribution of scores, whatever cognitive measures are used. I do not have an answer, and I doubt whether at present there are relevant data to address this question. The second issue is the behavioural significance of the effects of breastfeeding on cognition. Even though the effects reported were relatively modest, they could still have significant developmental importance if they were found in different cognitive areas. Behaviourally, small benefits over a wide range of cognitive domains (for example, short- and long-term memory, attention, concept formation, and vocabulary) may be more advantageous than large benefits over a single domain (for example, short-term memory).

Dr. Garza

In relation to the comment made by Dr. Colombo, it may be useful for you to comment on the rather extraordinary finding from Guatemala that a limited intervention during gestation and the first 3 years of life was still of functional significance 15 years later, despite the fact that nothing had been done to sustain the intervention.

Dr. Pollitt

The study involved four rural communities. Pregnant and lactating women and children up to the age of seven years participated in this study from 1969 to 1976. Two of these communities received a high-energy (180 kcal × 180 ml) and high-protein (11.5 g × 180 ml) supplement called atole, and the remaining communities received a low-energy supplement (one-third of that in atole). A 1988 follow-up showed that those in the first group performed significantly better than those in the second group in a wide range of cognitive tests (for example, arithmetic, reading comprehension, and vocabulary). The data necessary to explain the mechanisms behind these effects are unavailable. It seems likely, however, that two different sets of mechanisms were involved. One is that atole made a difference in the development of particular areas in the brain or in the neurotransmitter systems that facilitated cognitive function. The other involves the benefits of atole on physical growth, neuromotor maturation, activity level, and interactions with the social and physical environment. These advantages pooled together could have increased the educational opportunities of the children and fostered cognitive development.

Dr. Woolridge

I have two questions. The first regards the two slides on alcohol and marijuana use. If I understand them correctly, they both refer to breastfeeding mothers. Are there data from those studies to show what sort of effect you would get for non-breastfeeding mothers? One may assume that use of alcohol and marijuana may affect other aspects of the mother–child relationship. The effect could lead to lower development in the children of users. For my second question, I wanted some clarification on the issue of pre-term births. I think I read in the reviews by Villar and Belizán that the proportion of low-birthweight babies who are pre-term is smaller in developing than in developed countries because there are so many intrauterine-growth-retarded babies. Because the figures for pre-term births are expressed proportionately does not necessarily mean that the incidence of pre-term births is lower in less developed countries.

Dr. Pollitt

I agree with what was said regarding the prevalence of low-birthweight babies in developed countries and have nothing to add. I also agree with the speaker that mothers who bottle-feed their infants and use alcohol and marijuana might hinder the development of their offspring through different channels.

Dr. Victora

When we are looking at contaminants in breastmilk, we must realize that the alternatives to breastmilk can have contaminants, too, although they may be of different types. In New Zealand recently, the soya bean milk formula was found to have oestrogens, and the babies' intake was equivalent to about 12 pills per day, which is quite significant. I was wondering what is the effect of low-lead exposure on IQ, because we are trying to get lead out of petrol and similar things because of its effects on children.

Dr. Pollitt

There is no consensus on the cut-off point that should be used to define elevated lead levels in the

blood. Recently, the cut-off point in the United States was lowered to 10 μg/dl (0.48 μmol/L). Nevertheless, the World Health Organization still uses the former cut-off point. Studies on the effects of elevated lead levels on cognition in children are limited by problems of research design. The use of experimental protocols is precluded because of obvious ethical concerns. Further, strong criticisms have been made of the validity and reliability of the data collected. In my view, there is still no evidence to support the contention that cerebral function is at risk with blood lead levels less than 25 parts per million.

Dr. Garza

What level of lead exposure would be needed to effect a change of one-half of a standard deviation in IQ?

Dr. Pollitt

I do not know.

Dr. Hartmann

How is it possible to differentiate between the effects of marijuana or alcohol on the infant through the maternal milk and the direct effects during gestation when the mother was also using alcohol or marijuana?

Dr. Pollitt

The published studies do not discriminate between the effects on the offspring of the mothers' consumption of drugs (alcohol or marijuana) before and during lactation. The authors, however, caution the reader against drawing unwarranted conclusions.

The cultural context of breastfeeding and breastfeeding policy

Penny Van Esterik

Abstract

Breastfeeding is not instinctive behaviour but is dependent on learning and is, therefore, influenced by social and cultural factors. Thus, the social sciences as well as the biological sciences should be engaged in explanatory research about breastfeeding. To rebuild breastfeeding cultures to protect, support, and promote breastfeeding, a biocultural model of breastfeeding and child care that takes a broader view of culture must be developed: a view that attends more to differences than similarities, that provides more detailed contingencies of context, that is more sensitive to the forces that constrain women's lives, and that can be more directly linked to policy-making. This article explores the interdisciplinary nature of breastfeeding research and suggests some areas where anthropological theory and method could be put to better use to ask new research and policy questions about breastfeeding.

Introduction

Breastfeeding is the epitome of a biocultural phenomenon in which the processes of biology and culture are inextricably linked [1]. It is not instinctive behaviour but is dependent on learning; it is, therefore, influenced by social and cultural factors. Because breastfeeding is at the intersection of biological and cultural processes, the social sciences as well as the biological sciences should be engaged in explanatory research about breastfeeding. This article explores the interdisciplinary nature of current breastfeeding research and examines cultural factors and cultural context as two different ways to approach the "cultural" in "biocultural." I suggest some areas where anthropological theory and method could be put to better use in breastfeeding promotion and conclude that breastfeeding policy can be influenced by social science research.

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Interdisciplinary nature of breastfeeding research

The participants in this Workshop come from many different disciplines but share a commitment to research and policy to strengthen breastfeeding. To work profitably together, we must acknowledge disciplinary differences. These differences emerge out of hundreds of years of Western philosophy and logic that have kept the sciences, social sciences, and humanities apart—or, in the case of breastfeeding, brought them together on biomedical terms. Anthropology straddles these divisions and permits an easier integration of the biological and the cultural.

Interdisciplinary work is not easy, as the different epistemological assumptions of each discipline need to be acknowledged. The term "biocultural" stresses the relation between biology and culture and, hence, is important for our discussions of breastfeeding and society. Most research on breastfeeding, however, examines either the cultural or the biological aspects. The few people who put the two together often write and speak as if the biology part provides unquestioned facts, and the culture part provides the less important, ephemeral context.

Medical anthropology has been found to be "a powerful tool for reassessing what is taken as natural and normal in connection with the human body" [2]. Science has determined generalities or laws about breastfeeding, many of which have been reviewed at this Workshop. But generations of mothers who breastfeed their children have also formed some generalities about the process. Our task should be to bring these two kinds of generalities or laws into a specifiable relation with each

other, not to dismiss one, or to reduce one to the other. Millard [3] notes that the "guidelines" that Mexican women have about infant feeding are principles; that is, they are statements of natural tendencies or laws, conceptualizations of ultimate causes, and guides to practice. These guidelines also have commonalities with scientific practice. Application of cultural principles involves logic and situational decision-making on the part of the mother. These principles are used in conjunction with other sets of principles, such as the humoral system, to decide how individual infants should be fed.

Some concepts hinder and others enhance communication across disciplinary boundaries. In the past, "culture" and "cultural factors" have been used in ways that have not always increased understanding of infant-feeding practices or encouraged interdisciplinary collaboration between anthropology and the health sciences. As a term such as culture crosses disciplinary boundaries, its meaning and significance often change.

Defining culture and stating that cultural factors are important for understanding infant-feeding decisions does not alter the fact that the concept is very difficult to use. Just as biologists have difficulty agreeing on a definition of life, theologians on a definition of God, and doctors on a definition of health, anthropologists seldom agree on a definition of culture. We are unlikely to be able to find narrowly defined or easily measured cultural variables or indices to capture the variations within or between different infant-feeding patterns. Continuing to search for these elusive cultural factors may result in culture being blamed for generating attitudes and beliefs that are seen by health planners as obstacles that must be overcome by education.

Cultural factors in biomedical models

What sociocultural factors have been singled out for integration into biomedical and epidemiologic models of infant feeding? Common factors include religion, marital relationship, family composition, residence pattern, and values. Qualitative data have been used successfully to support findings from epidemiologic and biomedical research, but qualitative data can also be used to raise new questions and examine relations that are not amenable to reductionist models. Questions about values, attachment, nurturance, and sexuality—all intimately connected with breastfeeding and society—require interpretation from social science paradigms.

There is in the literature on breastfeeding clear agreement that maternal attitudes towards breastfeeding and bottle-feeding are culturally conditioned and, indeed, influence infant-feeding decisions. The most widely accepted method in health and nutrition research is the construction of knowledge, attitude, and belief questions that can be administered by a single context questionnaire, where respondents are asked whether, or to what extent, they agree or disagree with a statement about infant feeding. Scores on these questions may then be related to a mother's actual infant-feeding decisions.

There are numerous problems with this approach. Infant feeding in general and breastfeeding in particular are very personal and emotionally charged subjects. For this reason, it is difficult to obtain reliable, valid information on mothers' attitudes, beliefs, and knowledge through survey methods. Because the interviewers often have had no previous contact with the respondents, it is difficult for them to evaluate how the interview setting affects mothers' responses.

Interviewers' biases may encourage mothers to predict what the interviewer wants to hear and answer accordingly. This problem is complicated by respondents' desire to be polite to strangers or their hesitancy to speak frankly to authority figures perceived to possess power. In addition, standardized knowledge and attitude statements about infant feeding often reflect verbal cliches or key images developed through health-education or breastfeeding-promotion campaigns. The problem of phrasing culturally appropriate questions or statements without biasing the response is particularly difficult.

Serious conceptual problems also arise in relating knowledge, attitude, and belief to actual practice. The links between knowledge and belief, belief and attitude, and attitude and practice are both poorly understood and ambiguous. Not only can we not demonstrate a causal relationship between attitude and behaviour, but we often cannot even predict the direction or order of the relationship. Behaviour may well change before attitude changes, not after. For example, breastfeeding-promotion campaigns, based on linear reasoning linking knowledge to belief, attitude, and practice, often aim to increase correct knowledge about the importance of breastfeeding. It is therefore not surprising that breastfeeding-promotion campaigns based on improving knowledge, attitudes, and beliefs about the benefits of breastfeeding have not, by themselves, proved to be an effective means for changing infant-feeding patterns. The success of these methods depends on whether women's knowledge of breastfeeding was acquired through formal classes, observation, books, or women's stories. Learning the practical management of breastfeeding is quite distinct from trying to teach someone else to do it right.

Underlying much of the literature on the determinants of infant-feeding practices is a nagging, unanswered question. Can we, given our current research methods, distinguish between mothers who want to

breastfeed yet cannot, and mothers who do not want to breastfeed and do not? Women belonging to both of these categories may fail to initiate breastfeeding or may breastfeed for only a short period of time. We assume that women in the the former group have the knowledge and attitudes to support breastfeeding but are unable to do so. They are constrained by something, such as inappropriate medical practices, excessive promotion of breastmilk substitutes, or lack of social support. We assume that women in the latter group do uot want to breastfeed or will breastfeed for only a short time.

The difference between these two categories of women lies not only in their demographic characteristics but also in their heads—in the ideas, beliefs, and assumptions about infant feeding that make up the cognitive and affective dimensions of human behaviour. Studies of the determinants of infant-feeding practices often include these factors uuder the variables of maternal knowledge and attitudes or cultural factors. Studies that do not emphasize these factors acknowledge their possible importance.

This approach to knowledge and attitudes, based on social-psychological methods and theories, does not reflect the way anthropologists approach human behaviour. Nor does it do justice to the complexity aud flexibility of human decision-making about infant feeding. For example, in the complex calculus of infant-feeding decisions, a woman may weigh such factors as preference for dresses zippered up the back, avoiding sexual intercourse, or thwarting her mother-in-law. Even an apparently straightforward interpretation of behaviour may generate erroneous assumptions about cultural attitudes. For example, the conclusion that the use of Western-style blouses indicates a desire for modesty and a negative attitude towards exposure of the breast may be unjustified. In areas of the world where it is believed that the evil eye can poison breastmilk, blouses may, in fact, be worn to protect the breasts and breastmilk from danger.

Moreover, people have the capacity to tolerate an amazing degree of inconsistency between what they say they "believe," what they do believe, and what they do. The capacity of mothers to tolerate inconsistency, to hold contradictory beliefs and attitudes about infant feeding, and to interpret options reinforces the need for means of data collection and analysis beyond traditional knowledge and attitude assessment. Whereas cultural factors are determinants in chains of cause and effect, cultural context is a much less circumscribed concept that permits other kinds of information, such as the political context or the gender context, to guide explanations. This broad background information is referred to here as the "cultural context" of infant-feeding decisions. This context may be thought of as an additional level of analysis that integrates social, cultural, and biological factors. Such an additional level of analysis is necessary for interpreting attitudinal data. Survey responses alone seldom provide the data necessary for such contextual interpretation. For example, the knowledge that women agree that breastfeeding makes breasts sag, without the accompanying knowledge of how sagging breasts relate to women's body image and self-iinage, may easily result in misinterpretation of this information or distortion of its meaning. Body image, beliefs about breast size, and ideas of beauty are embedded in culture-specific systems of gender ideology.

Breastfeeding context

Breastfeeding as a process is culturally constructed: that is, in spite of its physiological base, the process itself, its meaning, and the way it is integrated into cultural systems varies globally. Until recently, we have had minimal information on the sociocultural context of breastfeeding from detailed, long-term ethnographic analysis. This evidence is now available, and it demonstrates that women's lives and child-care practices are changing rapidly.

One conceptual model emerging from these ethnographic data approaches cultural context as the interaction between style and structure. Style refers to the manner of expression characteristic of an individual, a period of time, and a place. The concept of infaut-feeding style communicates fundamental cultural assumptions underlying infant-feeding decisions. It refers to the manner of feeding infants in particular communities and includes both the way to feed an infant and the values, attitudes, and beliefs associated with that behaviour. Infant-feeding style includes the style of interaction between mothers and infants, eating style (how does the infant-feeding pattern fit with the household meal pattern?), breastfeeding style (how is breastfeeding accomplished?), and feeding "in style," reflecting the fact that infant-feeding choices are part of dynamic, changing trends and fashions.

To understand differences in breastfeeding style, it may be useful to distinguish between breastfeeding as a process and breastmilk as a product. Process or product interpretations may be emphasized in different contexts [4].

Both personal and shared styles of infant feeding interact with organizational and institutional structures, such as health-care institutions and marketing systems. These structures are important in influencing mothers' infant-feeding choices. The interaction between style and structure should allow us to predict how infant-feeding choices might be affected by different policy options.

Rebuilding breastfeeding cultures

A meeting of WHO and UNICEF policy makers in 1990 resulted in the adoption by 30 governments of a global initiative, the Innocenti Declaration, on the Protection, Promotion, and Support of Breastfeeding [5]. This Declaration stated that for optimal breastfeeding,

> all women should be enabled to practice exclusive breastfeeding, and all infants should be fed exclusively on breastmilk from birth to four to six months of age. Thereafter, children should continue to be breastfed, while receiving appropriate and adequate complementary foods, for up to two years of age or beyond.

In order to bring this about,

> efforts should be made to increase women's confidence in their ability to breastfeed. Such empowerment involves the removal of constraints and influences that manipulate perceptions and behaviour towards breastfeeding, often by subtle and indirect means. This requires sensitivity, continued vigilance, and a responsive and comprehensive communications strategy involving all media and addressed to all levels of society. Furthermore, obstacles to breastfeeding within the health system, the workplace, and the community must be eliminated.

This carefully worded statement is a challenge to change many priorities of the modern world to rebuild breastfeeding cultures. The language stresses the empowerment of women to breastfeed, rather than their duty to breastfeed, a change that should bring more advocates for women's health to support breastfeeding policies.

To rebuild breastfeeding cultures that will protect, support, and promote breastfeeding, we must work from models of breastfeeding and child care that are more sensitive to gender and the forces that constrain women's lives. What is entailed in recreating breastfeeding cultures? In some parts of the world, changing assumptions about body image is a priority; ensuring women are adequately fed is of higher priority elsewhere. A great deal of political will to make changes benefiting women and children is crucial in all state and international institutions.

At some point, policy makers need numbers to evaluate and finance policies and programmes. But that does not mean that ethnographic observations and other cultural information are merely illustrative anecdotes. The linkage between cultural data and policy can be directly relevant to establishing priorities. Because ethnographic description is both holistic and richly contextualized, it is easy for policy makers to picture the real-life conditions of the families that their policies will affect. Some products of ethnographic fieldwork, such as community sketches and mothers' life histories, are available much faster than survey data, which require substantial processing.

Solutions to infant-feeding problems must come from the cultural context underlying infant-feeding decisions. The same "culture" that some policy makers view as an obstacle to development must ultimately provide solutions assembled from available options, ideas, and strategies already in the cultural repertoire. In this case, the task of the policy maker is to choose options and implementation strategies that are most compatible with the infant-feeding style in different countries.

Knowledge of style without consideration of structural constraints or supports would, however, be unproductive. Structural constraints, such as the powerful influence of the health-care system, the marketing practices of transnational manufacturers of infant foods, and structural supports, such as vendors selling porridges or traditional midwives, must also be included in policy decisions to suggest new directions to improve infant-feeding practices.

Breastfeeding-promotion activities, mother-support projects, and consumer-advocacy campaigns are often viewed in isolation from each other and from other programmes. Nevertheless, breastfeeding has been linked to related child-survival campaigns, such as immunization, family planning, growth monitoring, and oral rehydration therapy. To encourage the changes envisioned by the Innocenti Declaration, breastfeeding advocates must seek new allies and closely examine the concerns such potential allies have with regard to past promotion of breastfeeding. A number of potential allies could be called on to offer support for breastfeeding initiatives.

Links have already been made between breastfeeding and child-spacing programmes. The World Bank's "A case for promoting breastfeeding in projects to limit fertility" [6] identifies three arguments that have been used against the promotion of breastfeeding for its contraceptive effect:

- Breastfeeding does not need to be promoted in areas where it is still the norm.
- Declines in breastfeeding are inevitable and will have negligible demographic impact if compensated by increases in the use of modern contraception.
- Breastfeeding is not a reliable contraceptive for the individual woman.

The World Bank report challenges these arguments and demonstrates the advantages of breastfeeding for child spacing. It is, however, important to note that African women's groups in particular have warned against linking breastfeeding to family planning too closely and have argued for breastfeeding to be promoted for its own sake.

Fewer commonalities have been recognized with

environmental groups. Lactation and breastfeeding had no place in the report of the World Commission on the Environment and Development entitled *Our Common Future* (unpublished report, Geneva, 1987), although the report's treatment of issues such as sustainable development, the international economy, population, human resources, food security, energy, and industry all could be related to infant-feeding choices. The environmental movement and advocates for sustainable development are potential allies for breastfeeding. They could be shown how breastfeeding furthers their interests and encouraged to link breastfeeding into their planning. But breastfeeding promotion that treats women as producers of natural resources is bound to fail.

The strongest supporters of breastfeeding should be women's groups. Breastfeeding is seldom considered an important issue to be discussed in national or regional women's organizations in developed or developing countries. For example, national women's organizations were not immediately supportive of Brazil's breastfeeding initiatives because they saw it as a means of isolating women in their homes. Similarly, women's groups in India protested against legislation to control the marketing of infant formula, calling the bill draconian, fearing it would damage women's careers and force them back to the kitchen.

According to a review of American maternity policies by Kamerman [7]:

> Although the women's movement clearly has played an important role in improving the status of women, maternity and other family benefits have not been at the forefront of its agenda.... Heretofore, the women's movement has viewed family politics as either too traditional a focus for unenlightened women, or as too open to criticism as conservative.

In Scandinavian countries, efforts to support breastfeeding have been more strongly supported by the women's movement:

> The new feminist movement in Norway has encouraged women's self-confidence and pride—both prerequisites for breastfeeding. Unlike similar movements, the Norwegian feminist movement has never seen a contradiction between women's liberation and breastfeeding [8].

The antagonism to breastfeeding that exists in many parts of the European and North American women's movements results in difficulties in establishing breastfeeding as a priority in international women's meetings. This antagonism or apathy will be particularly destructive to efforts to implement the Innocenti Declaration unless it is countered by clear recognition of breastfeeding as a woman's right. Thus, there is a need to reconsider breastfeeding in relation to human rights. Programmes that promote the child's right to breastmilk rather than the mother's right to breastfeed without consideration of maternity entitlements are likely to be damaging in the long run.

The issue of breastfeeding has been invisible in the women's movement, either because it is taken for granted in some parts of the world or because it is totally out of women's consciousness in other parts of the world. It is the responsibility of breastfeeding advocates to integrate their issues with other concerns of women. This process was begun at the Beijing Conference on Women in September 1995, where a number of measures protecting breastfeeding were included in the final action plan. Women's organizations need to be informed about how breastfeeding entitlements can complement their other policy objectives and then be mobilized to support breastfeeding policies. If feminist theorists and activists supported breastfeeding, they might well be able to reformulate a more global, holistic approach to gender, care, mothering, and empowerment.

Conclusions

Indigenous cultural knowledge about child feeding is critically important for successful breastfeeding research and programmes, but there are ways this knowledge can be better used. I suggest that anthropologists can be most useful to breastfeeding research if they resist the pressure to reify culture, or to provide checklists of cultural factors affecting infant feeding. No list would be adequate to the task, and the temptation to reduce culture to one or two factors within a biomedical framework may draw attention away from more important questions about power, class, or gender. Whenever we use the concept of culture, we should ensure that it is firmly situated in understandings of material conditions of life and fields of power. Anthropologists should develop innovative ways to communicate about other patterns of infant feeding without resorting to homogenizing generalizations and dangerous reifications that can be used to create or perpetuate stereotypes: "All Bangladeshi women reject colostrum," "All Mexican women wean abruptly," and so forth. We should strive to make visible the cultural systems in which we operate, examining assumptions about our own health-care systems and the tenets of biomedicine and not treating them as natural or as givens. Finally, we should resist the commoditization of culture by insisting on the necessary theoretical framing of the concept and locating it more directly within various social science disciplines. In this way, we can make room for metaphor as well as measurement in breastfeeding research, programmes, and policy.

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Discussion of paper by Van Esterik

Bishop McHugh

I'd like to make two comments. The first draft of the document to be used in Beijing for the International Women's Conference did not contain the word breastfeeding. Now, how can you write a document about women and empowerment of women and not even mention it? I understand that it has now been included.

Van Esterik

No. I was at the preparatory conference, and I welcome a chance to bring you up to date. The fascinating thing is that breastfeeding was there in the regional conferences in South-East Asia and Latin America and the Vienna Conference on Human Rights. Breastfeeding was very clear because the World Assistance for Breastfeeding Action (WABA) lobbied to make sure, and it went in under "women's health," "human rights," and "employment," so that if it was removed in one section, it would be there in another. When those drafts came to New York, every reference to breastfeeding was removed. So we went to the preparatory conference for Beijing and we lobbied, and we know for sure that one reference is in under "structural adjustment," because one of our WABA members is the Swaziland representative, and she stayed up until midnight when they were finishing, and she got it in there. But all the most important places—"human rights," "women's health," and "infant health"—were bracketed, which means they will not be discussed until Beijing. That document was not out until the last day of the preparatory conference, and so we have a lot of work to do.

Bishop McHugh

I agree. But I also think it underscored part of my concern, and that is, it is part of a cultural context that eliminated it. When the documents came to New York, it was a different understanding of women that is perhaps local to ten square blocks of New York City that wrote the document and excluded that concept, because that's not part of their lexicon. The second comment I want to make is that you did not have to feel uncomfortable showing the *Playboy* pictures. In fact it's important to show them, because we in the United States face recurring court cases brought by women who have been excluded from restaurants or other places for breastfeeding. They have to go to the courts to vindicate what seems to me ought to be a natural right. But you can walk into any drugstore, and what you have is mild compared with what you can get from the so-called girlie magazines.

Dr. Sommerfeldt

Just a very brief comment on the Women's Conference in Beijing. I had a call from someone from New York asking if the Demographic and Health Survey could give an estimate of the burden that breastfeeding imposes on women. I think the reason for this question was to support an argument that it was difficult to breastfeed and perhaps that women shouldn't do it. I said that, first, I didn't think it was a burden. Second, I said there was no way we could provide that kind of quantification, although all they had to do was pick up our report and take whatever information they wanted from it. I also said that if a woman didn't breastfeed and didn't use contraception and conceived again very soon, that would be a much greater burden on her than breastfeeding. She never contacted me again. Maybe she got an answer from someone else. I don't know.

Dr. Van Esterik

We had a major problem. The Health Caucus was controlled by someone who was very close to multinational companies, and we had BINGOs (Business Interest Non-Governmental Organizations) in that

caucus, not women's interests NGOs. One thing that made it very difficult was that they went around to some people we were lobbying and talked about how people who were promoting breastfeeding were just trying to make women feel guilty if they couldn't breastfeed. They kept asking other people for statistics about how many women couldn't breastfeed. I will leave you with a popular article, as well as an academic one, arguing that breastfeeding is a feminist issue. The first is designed specifically for radical North American and European women's groups that do not usually think about breastfeeding, and the second is to tell them why they should consider breastfeeding as a feminist issue.

Dr. Menken

I think we would be unrealistic if we said that breastfeeding was not a burden. It is a burden if women are hassled in the ways that we have been talking about. It's made a burden, and I think that's exactly the kind of point we are addressing. These are burdens caused by culture, and many of the issues we need to address are making it comfortable, promoting an atmosphere, just as many people live in an atmosphere where their attempts to breastfeed are frowned upon and discouraged. My first kid was born in Bethesda Medical Center. Let me tell you, the fight to breastfeed 29 years ago was really something. Not many people have the energy. They are fighting too many other battles. What we need to say is that under the right circumstances, it is not a burden; it's much better, and it's much easier, but I think we have to recognize that.

Dr. Pérez

I was going to make this comment in a later session, but I believe that now is the moment. We are all interested in promoting breastfeeding, but we have to remember that the breast is one of the most important sexual symbols of a woman's body. More than that, it is not only a symbol, it is a very important organ that participates in the sexual union. The nipple is especially important in a woman's orgasm. Thus, if somebody proved that it is true that breastfeeding destroys this symbol, this organ, we would have a great enemy. If it is not true, we have to teach women that it's not true. I do not know if it is true or not, but we have to keep in mind that the breast is not only a place where women produce milk. It is a very important organ in the sexual relationship of couples.

Dr. Van Esterik

Most of the work that I have been doing this month at the Bellagio Study Center concentrates on the cultural construction of women's bodies. I'd like to argue that the breast is not universally a sexual symbol. It could be buttocks or legs or other body parts that are considered most attractive about a woman. But I agree with you in terms of having to consider breasts as sex objects. Hundreds of years of Cartesian dualisms, mind versus body, sexuality versus nurturance, maternity is over here and sexuality is over there. Breastfeeding advocates have a lot of work to do to show that this is not an either/or situation. It is both.

A woman was arrested in Ontario for obscene behaviour for taking her shirt off, and I was an expert witness. I spent two hours on the stand trying to argue that I could comment on ordinary breasts, not just lactating breasts. I argued that men's breasts and nipples are also sexually responsive and are also important in sexual foreplay, and women have to sit there and control themselves if a man takes his shirt off, and it's not considered obscene behaviour. Although there are differences, the differences must be culturally constructed, because you can go to beaches in parts of Europe and it's not shocking, as you mentioned the other day. But a woman breastfeeding on a nude beach—that's what's shocking. Basically, we have to change the whole way we've been thinking for the last 500 years, so we have a lot of work to do.

Dr. Pollitt

I will play the devil's advocate. In a way, I don't think what Professor Hanson has presented is social construction, because there is no cultural constructivism in immunology or in many other biological aspects of breastfeeding. I worry that if we emphasize the social behavioural component of breastfeeding too much, where is the seed for cultural constructivism? There may be a possibility of losing some strength in the argument of how important breastfeeding is from a biological perspective, and although I agree with you that one goes with the other, we must try to evaluate whether, by putting too much emphasis on cultural construct, we may lose some strength in the argument for the biological importance of breastfeeding.

Dr. Van Esterik

I think you have made the biological points pretty clearly over the last few days.

Dr. Garza

Well, it's brief, but it's important, I hope. Because we've constructed most of this discussion around changing behaviours, I'd like you to talk a little

about how we protect the social constructs that exist, because we saw data earlier showing that 50% to 90% of women are breastfeeding. Thus, we seem to have a significant advantage in protecting a practice that does exist. How do we use the cultural constructs that have maintained this for the last 20 to 25 years?

Dr. Van Esterik

I don't have a clear answer. It is very important that we work with very local and specific understandings of infant feeding. We shonld pay much more attention to language and linguistic issues within communication campaigns to ensure we are using the words of the women we want to influence. In other words, we should put much more emphasis on the experiences of women themselves. I would hope that these experiences, in fact, will be parallel discourses. In other words, the scientific and the biological discourse will be much better understood if they are related to women's experiences, so that women's breastfeeding experiences will be much more prominent. I think these narratives are absolutely critical. I don't know how they would fit in with your research designs, but I don't see that they would do any harm as illustrating another way of thinking alongside the scientific papers on this topic.

The role of education in breastfeeding success

Veronica Valdés and Janine Schooley

Abstract

Many of the factors that have contributed to the decline in breastfeeding around the world can be overcome by education and support. Examples of successful approaches to education at different levels (mother, health professional, institution) that impact breastfeeding are discussed. For example, because breastfeeding is a learned behaviour for both mother and baby, providing the mother with information, skills, and support for the breastfeeding process is integral to her ability to breastfeed successfully. In addition, because the health professional plays a pivotal role in the success or failure of breastfeeding, it is essential that education and training of health professionals be adequately addressed. By using an approach to health-professional education that builds on a highly trained core and spreads to all levels through a built-in multiplier effect, improvement of breastfeeding practices can be assured. In order to sustain these results, however, health-professional school curricula must include adequate information on the science of lactation and the clinical management of breastfeeding. The experience of Chile's National Breastfeeding Programme is used to illustrate the power of education at each of these levels in influencing the success of breastfeeding, and the feasibility of using education of both mothers and health professionals as a way of preserving this incredible natural resource.

Breastfeeding is a learned behaviour

Why does breastfeeding, something so biological, natural, and part of the essence of being a mammal, need to be taught and learned? Lactation occurs in every female after delivery as a biological response to hormones present in that period, and yet 38,000 infants die every day because they are not breastfed [1]. Clearly breastfeeding is a behaviour that needs to be learned for the survival of the species [2].

In nature, young females observe their elders caring for and breastfeeding their offspring. That experience will allow them to take care of their own when they reach reproductive age. A good example of the power of this experience is the case of a female gorilla named Dolly who had been raised at the San Diego Zoo. When she delivered her first offspring, she did not know what to do. She hugged the placenta and was afraid to touch the baby, whom she was not able to breastfeed. During her second pregnancy, the curators decided to teach her about mothering and breastfeeding. They showed her videos of mother gorillas in the wild nursing their infants and gave her a doll to teach her to be gentle in holding and nursing a baby. The teaching programme was a success, and she has been able to nurse and care for several other babies since then.

Something similar occurs with women in modern society [3]. With urbanization and the lack of extended families, most first-time mothers have not seen their mothers or relatives breastfeeding. Even worse, from everywhere around them they have been receiving the message that what is normal and modern is bottle-feeding. As young girls, they are given a doll and bottle to play with, and their mothers also probably bottle-fed. Formula companies advertise their products to the public, and for many women, this is their only source of information regarding infant feeding [4]. As more deliveries occur in hospitals, more women are influenced by hospital practices that often interfere with breastfeeding [1]. There, they do not receive the necessary support from the health-care team, because health professionals generally lack the knowledge and skills for good clinical management of breastfeeding [5]. In addition, an increasing number of women are working away from their homes and their infants.

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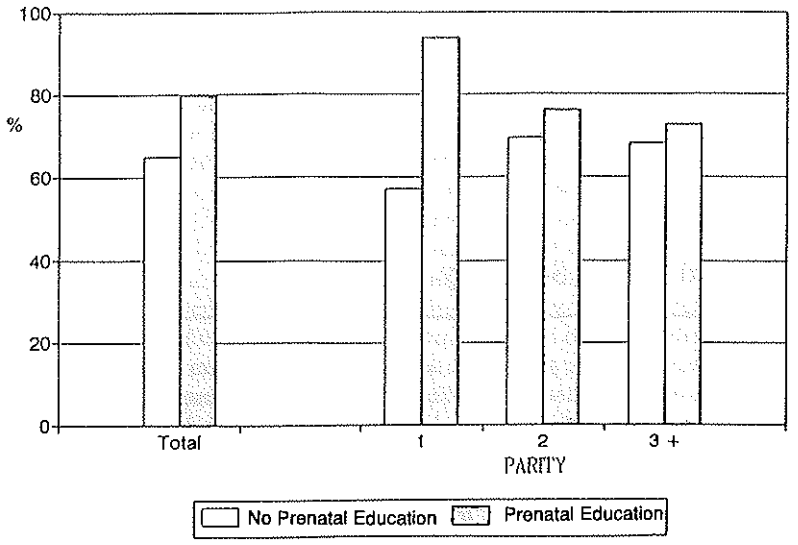

FIG. 1. Percentage of mothers exclusively breastfeeding at six months according to presence or absence of prenatal group education and parity

Therefore, the natural behaviour of breastfeeding is subverted by a variety of forces, as reflected in the often abysmal rates of prevalence and duration of exclusive breastfeeding.

Educating women about breastfeeding has a positive effect on breastfeeding performance

One way to minimize this interference with breastfeeding is through the education and support of mothers. Several studies show that providing breastfeeding education for women has a positive impact on the success of breastfeeding [6–11]. This impact has been underscored by results achieved at the Hospital of the Pontifical Catholic University of Chile, which showed a significant increase in exclusive breastfeeding at six months post-partum among women who received prenatal group education [12]. Eighty per cent of 59 women who received prenatal group education as part of a breastfeeding-promotion programme completed six months of exclusive breastfeeding, versus 65% of the 363 who were part of the same study but did not receive prenatal group education ($p < .003$). This effect was even larger among primiparas, where only 57% of those who did not receive prenatal group education, versus 94% of those who did, were breastfeeding exclusively by the end of the sixth month (fig. 1).

These results were obtained in the context of a prospective study on the impact of a breastfeeding-promotion programme on the duration of exclusive breastfeeding among lower-middle-class urban women. This study took place in the hospital and outpatient clinic of the Pontifical Catholic University in Santiago, Chile [13]. The study included a control group of 313 mother–infant pairs and an intervention group of 422 mother–infant pairs. Both groups were followed monthly for six months. Thirty-two per cent of the control group were able to complete six months of exclusive breastfeeding. This was, in fact, a relatively high prevalence, because only 2% of infants that age were exclusively breastfed according to a national survey carried out by the Ministry of Health in 1986. The higher prevalence in this population was due to the fact that the hospital of the Pontifical Catholic University has always promoted breastfeeding and had rooming-in, and medical and nursing students are taught that breastfeeding is important.

Before recruiting the study population, there was a need to develop a comprehensive programme designed to promote exclusive breastfeeding. The breastfeeding-promotion programme involved educating all health-care providers at the institution who take care of mothers and infants; changing policies that interfere with breastfeeding to make them more supportive of optimal breastfeeding practices, such as immediate contact between mothers and infants; delaying supplements or solid foods until the end of the sixth month if the infant is growing well; creating a Lactation Clinic to prevent and solve breastfeeding problems; providing breastfeeding education for women during the prenatal and postnatal periods, including how to breastfeed and how to prevent problems; and emphasizing the effect of exclusive breastfeeding on delaying the return of fertility and the use of the lactation amenorrhoea method for child spacing.

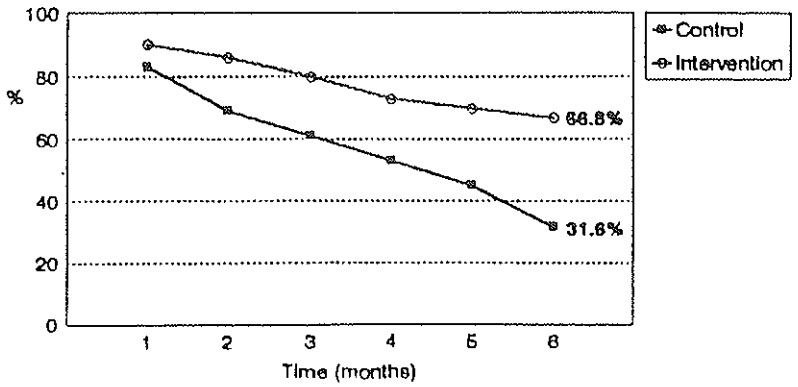

FIG. 2. Duration of exclusive breastfeeding before (control) and after (intervention) completion of a breastfeeding-promotion programme at the Pontifical Catholic University of Chile in 1993.

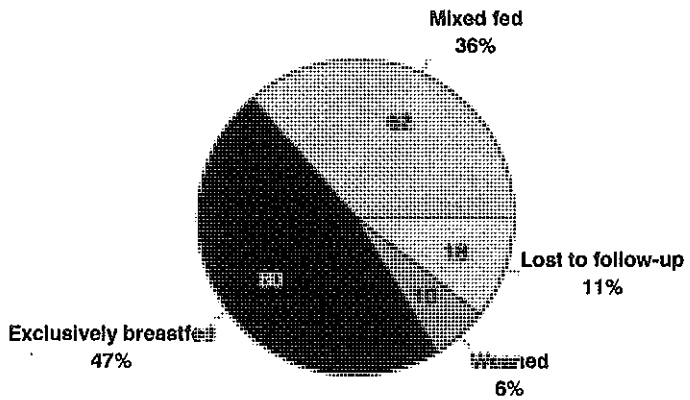

FIG. 3. Feeding status at six months among infants of working women

After the implementation of the breastfeeding-promotion programme, 67% of the study population completed six months of exclusive breastfeeding (fig. 2). The prevalence has even improved in the broader population cared for at the hospital of the Pontifical Catholic University after the institution of the Lactation Clinic and the use of the lactation amenorrhoea method by an increasing number of women. Education and support activities were developed for women who work outside the home. When mothers were taught how to hand-express and store their own milk and were offered monthly clinical follow-up, 47% of the working mothers were able to feed their infants exclusively with their milk for six months, and fewer than 6% of the 170 mother–infant pairs who were followed weaned before six months (fig. 3). None of the women in the control group (those not receiving education and support) who continued to work completed six months of exclusive breastfeeding. All of this happened in an institution where the personnel thought they were already promoting breastfeeding, but the results show that much more could be done. What made the difference?

Health-professional education is the cornerstone of improvement in breastfeeding practices

The difference was due to the intensive education of a core team of health professionals in the science of lactation and the clinical management of breastfeeding, and the resulting multiplier effect [14]. Before implementing the breastfeeding-promotion programme, a multidisciplinary team composed of a paediatrician and an obstetrician participated in Wellstart International's lactation management education programme. During their trip to San Diego for the course that would initiate their participation in the lactation management education programme, these professionals, like the hundreds of others throughout the world who have participated in the

programme, asked themselves, "What can we learn that is new about breastfeeding and lactation during a whole month?" At the end of the four-week course, like all the others who have participated in the programme, they had acquired new knowledge and skills, shared experiences, and realized that lactation was such a broad topic that they had only just begun to learn. Wellstart's lactation management education programme is designed to develop core resources of expertise that can form the basis of teaching and promotion programmes at the institutional, national, and regional levels, using the following approach:

» *Education of educators.* By recruiting teachers and decision makers who are in positions to influence institutional or national policy, the lactation management education programme has included a built-in multiplier or cascade effect that helps to ensure the continuation and expansion of the breastfeeding-related efforts to colleagues and families.

» *Provision of sound scientific foundation and clinical expertise.* Preparing health-care professionals to teach others and gain the necessary respect and recognition from their peers requires a significant quantity and quality of current, scientifically sound information and the acquisition of associated clinical skills.

» *Selection of multidisciplinary teams.* For breastfeeding promotion and support to be effective, families must receive coherent and consistent information from the entire health-care team. The lactation management education programme brings these disciplines together as working teams and models this approach within its own faculty.

» *In-country (or institutional) ownership of action plans.* The programme focuses on providing participants with knowledge, skills, and resources and on assisting them to plan and carry out programmes of their own design, in their own countries.

» *Provision of teaching materials.* Participant teams require tools to use and adapt for their own teaching and promotion efforts. Each team receives funds to pay for a selection of slides, videos, books, and a variety of teaching aids. These materials complement the syllabus, the textbooks, and a collection of over 1,000 relevant journal articles that become the basis of a lactation library for their institution.

» *Provision of follow-up.* Field-based follow-up with an emphasis on institutionalization and sustainability is an essential component of the lactation management education programme. Once the participants have finished the four-week course, they become "associates" (not trainees, graduates, or alumni). This terminology reflects the ongoing, collegial nature of the relationship.

» *Factor X—the broader human experience.* The term "factor X" is used to describe an intangible but essential ingredient of the lactation management education programme: the attention to detail and special treatment of participants, which helps lead to lifelong motivation, close relationships, and a sense of *esprit de corps*. There is an important intercultural exchange and sharing of experiences and memories that are necessary to balance the rigorous technical and programmatic curriculum.

The lactation management education programme has had an impact throughout the world, not so much because of what it has done, but because of the galvanizing effect its approach has had on others. By putting essential tools and resources into the hands of teachers and decision makers, the programme has served as a catalyst for a powerful multiplier effect in a number of countries. More than 550 associates from over 50 countries have participated in the lactation management education programme. In part because of their participation, National Breastfeeding Programmes are developing in more than 20 countries, National Training Centres in 13 countries, and Regional Training Centres in 5 countries. The impact is particularly great in countries where the UNICEF/WHO Baby-Friendly Hospital Initiative is under way, and many positive influences are at work.

Chile provides an excellent example of the effect of health-professional education on breastfeeding. In October 1990 the results of the research project "The effect of a breastfeeding promotion program on the fertility of urban women in Santiago, Chile" [15] were presented in a three-day breastfeeding course for health professionals. The course was designed to offer participants basic knowledge on the anatomy and physiology of the mammary gland, clinical management of breastfeeding, updated benefits of breastmilk and breastfeeding, and the relation between fertility and breastfeeding, along with the results of the above-mentioned project and several others. Two years later, a questionnaire was sent to the participants to see if the course had had an impact on their actual practices and recommendations regarding breastfeeding. The results showed there were significant increases in clinical practices supporting breastfeeding, which included teaching the mothers and supervising breastfeeding techniques. The weaning recommendations given to mothers, including when to begin weaning foods and milk supplements and when to complete weaning, reflected a postponement of over two months compared with earlier practices (fig. 4) [16].

This course was also the beginning of a process of creating a critical mass of people with knowledge and interest in promoting and supporting breastfeeding throughout the country. By adopting many of the approaches used in the lactation management edu-

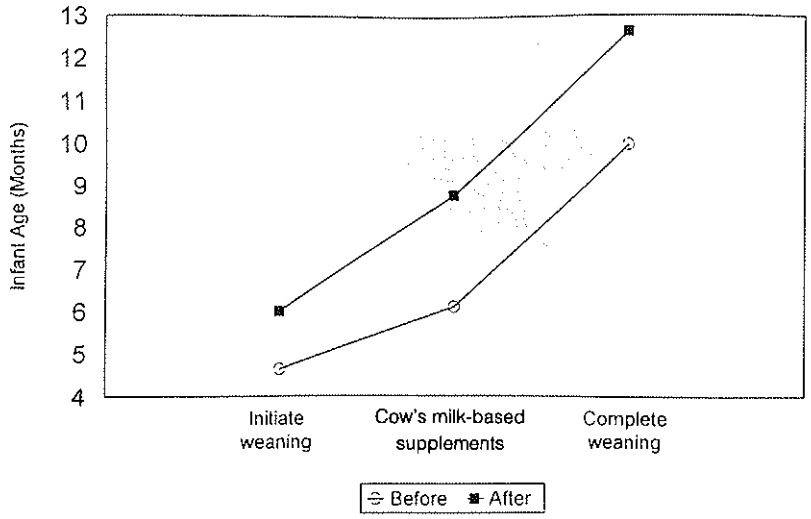

FIG. 4. Recommended ages for initiating weaning, introducing cow's milk-based supplements, and completing weaning before and after health professionals complete breastfeeding education course

YEAR	TRAINERS TRAINED	ADDED CASCADE TRAINING
1992	33	300
1993	67	1000
1994	75	4500

FIG. 5. Numbers of health workers trained in Baby-Friendly Hospital Initiative workshops in Chile 1992–94

cation programme, Chile developed its own cascade effect. In 1992, after the Innocenti Declaration and the World Summit for Children, the Chilean government created a National Breastfeeding Commission to develop a National Breastfeeding Programme. As part of that programme, the Baby-Friendly Hospital Initiative was launched in Chile with the support of UNICEF. The main emphasis and activities of the National Breastfeeding Programme, with the participation of the six Wellstart associates, have been educating health-professional teams on breastfeeding and developing teaching materials to help them disseminate that training. In 1992, 34 professionals, including teams from three hospitals, participated in the first Baby-Friendly Hospital Initiative Training for Trainers Workshop. These teams received teaching materials such as slides, videos, books, and syllabi to replicate the teaching at their institutions. Since then two new workshops have been developed, attended by 142 new trainers who are now teaching the health teams in their own and neighbouring institutions. By the end of 1994, more than 4,500 health workers had been trained throughout the country in replicated, 18-hour courses (fig. 5). Eleven hospitals have been designated as Baby-Friendly owing to their supportive practices for breastfeeding. In 1994 approximately 290,000 infants were born in Chile, with 52,000 of these births occurring in Baby-Friendly Hospitals.

A national survey carried out at the end of 1993

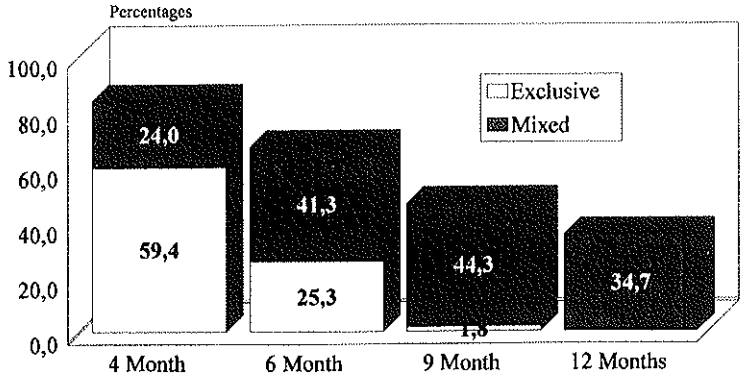

FIG. 6. Percentage of children exclusively and partially breastfed in Chile in 1993 according to age. Source: Ministry of Health National Breastfeeding Survey

showed that the prevalence of exclusive breastfeeding at six months had increased from 2% in 1985 to 25% in 1993 (fig. 6). In areas of the country where health workers in hospitals and community clinics have been trained, the percentage of exclusive breastfeeding at six months is more than 60%. These results show that there actually was a lack of knowledge among health workers on how to promote and support breastfeeding [17, 18], and that when they learn, they change their practices, which then have an impact on the prevalence and duration of breastfeeding in the community.

The next step is to make this effort sustainable and cost-effective. The only way to do this is to change what is taught at the university level and to include the scientific basis and clinical management of breastfeeding in the curricula of health-professional schools [19, 20]. This effort has already begun in many countries. A curriculum guide for medical, nursing, and nutrition training programmes has been developed by Wellstart and is beginning to be used in several universities in the United States, Latin America, and Africa. In Latin America two subregional workshops were held for this purpose, one in Guatemala and another in Paraguay. A national pre-service curriculum workshop was held in the Pontifical Catholic University in Chile as the first activity of the National Breastfeeding Training Centre. The participants included representatives from schools of medicine, nursing, midwifery, nutrition, pharmacy, and dentistry from all the Chilean universities. In Africa a similar process is under way with the participation of 10 countries in east, central, and southern Africa.

Health-professional education is critical to making any kind of long-term change in the way breastfeeding is promoted, supported, and protected. When health professionals are convinced that a breastfed child has the best start in life and really understand how breastfeeding works, they will send the right messages and give the needed support. Only then will the impact on the community be sustainable and something as natural as breastfeeding be preserved.

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Discussion of paper by Valdés and Schooley

Professor Howie

I suggest that factor X is important, and it almost comes back to the sort of things that Dr. Van Esterik was talking about. It is the whole culture and atmosphere, and I was very impressed with that picture of the maternal support group. It was the warmth and the smile of the health professional in the middle of the group that really made an impression on me, and I don't know if the other people in the group felt the same thing. I felt that she was exuding a very large dose of factor X. The real challenge is how to get everybody exuding factor X. It has to do with smile and atmosphere and less to do with the mechanics of the videos and the material. I suspect that factor X is the key to the sort of things that you are achieving.

Dr. Valdés

I think the important thing is that factor X is contagious. Once you learn the style, you can't make a traditional, boring course. Now, people get there and they are received maybe with candy, maybe with some touching things. That's the only place where working women come and charge their batteries. The doors are open, they sit, they chat. We have become sexual psychologists because all their concerns come to us and they are heard. I think that's the reason they come back to the programme. They follow us, and they believe us.

Dr. McNeilly

When Professor Howie and I set up the first breastfeeding study in Edinburgh, we were aiming to recruit 200 women. We assumed the average time of breastfeeding was four months, so there would not be a problem. We would finish the study in two years. We had to have a meeting after four months, because none of the 20 women who had entered the study at that point had even thought to stop breastfeeding. We couldn't understand why, but the reason was that the research nursing sister who was recruiting them, Mary Houston, talked to these women about problems with breastfeeding, children, anything. They kept going because they would save their problems up, and she would visit them every two weeks, and they would keep going until she arrived and pour out their hearts to her. She would fix it, and they would carry on. Now, having subsequently done a study on that, we found that the difference between the women who gave up and the women who carried on was not that they had fewer problems or anything like that; it was just that they had somebody whom they could rely on to discuss their problems with, and Mary Houston certainly had factor X. So, I think that from our point of view, we stopped at 45 women rather than 200 because factor X interfered with the programme.

Dr. Garza

I enjoyed the presentation. It obviously shows what one can do with a good system. But I was struck by the complexity of what is needed, because we have dismantled the family structure that used to support it, and in some ways there are parallels with formula. Whenever we try to replace a natural system with an artificial one, we keep discovering that many things are missing. I'm wondering what you are doing to get yourself out of business. Because that would be our ultimate success; that is, when we wouldn't need those very complex systems to replace a family structure.

Dr. Valdés

I'm trying hard to get out of business. First, by including breastfeeding in the medical curriculum so we don't have to retrain professionals. I think the next step would be to include breastfeeding in the schools and change what children are taught in

school. I have now gone to my children's school because I'm horrified at what they teach them. That would be another step. When you see that 60% of the mothers are breastfeeding, these children will have had the opportunity to have seen breastfeeding in action. So, I think we are reversing the situation.

Dr. Lawrence

A very nice presentation. I would add that before we change things completely, we have to go back to the school system. In New York State we have created, with the Department of Education, a curriculum for kindergarten through high school that is currently on trial in one part of the state. Our aim is to educate all children, not just girls, that breastfeeding is normal and to put it into the curriculum: not to have them take a course in breastfeeding, but to have it as part of the curriculum. The second piece is the education of the health-care professional, and that, too, needs to be part of the total curriculum and not something you can choose or not choose. We have tried a model programme doing that as well, in which our first-year medical students get something about the value of human milk in their nutrition course. They get the anatomy and physiology of the breast in their second-year course on women's health, and in the third year all of our students spend a week in the newborn nursery, seeing mothers, helping them breastfeed, and learning what the practical questions are. But, in response to Dr. Garza's comment, we have to weave it into the normal curriculum for everybody in their culture, plus the health-care professional.

Dr. Valdés

I completely agree, and it is important that it be present in all of the schools to send the same message.

Dr. Pérez

I discovered Veronica Valdés in 1985, and because we had to start a research project, I asked her to go to Wellstart. She stayed there a little over a month. When she came back, the first thing she did was to give us a one-day workshop on breastfeeding. There were 18 obstetricians and gynaecologists from Catholic University's Department of Obstetrics and Gynaecology. Some of us have been in this department almost 40 years, several of us have a lot of experience, and some of us have some background in breastfeeding research. After the one-day workshop, we could not believe how much we had learned about very simple breastfeeding techniques. I'm sorry Dr. Valdés didn't talk about how to teach a woman to breastfeed, because she knows a lot about that, and she is a genius about that very simple thing. We, with 40 years of practice, did not understand that, and she, after being in Wellstart, taught us in a fantastic way. I believe this first step of Dr. Valdés in our university is a very important step in any breastfeeding programme, which is to teach the health team.

Dr. Valdés

Thank you, Dr. Pérez. It was quite a challenge, because we had to teach our teachers.

Summary of the Workshop

Scientific experts in fields concerned with the health and well-being of children and their mothers recognize breastfeeding as the best way to nourish infants and to promote the post-partum and possibly the longer-term health of women. This consensus led the world community more than 20 years ago to recommend that infants be breastfed exclusively for four to six months, with continued breastfeeding for two years or longer.

Benefits to the infant

The benefits to the infant fall into three broad categories: nutritional, immunologic, and behavioural. Reviews of the world's scientific literature by the Working Group reaffirmed the strength of the conclusions regarding the nutritional and immunologic benefits and led to an acknowledgement of the potential for significant behavioural advantages.

Nutritional benefits

It is clear that the nutritional benefits to infants extend through the periods of exclusive and partial breastfeeding and possibly beyond the latter period. The high nutritional value of human milk conferred by the high bioavailability of its nutrients, the balance of specific nutrients, and other characteristics is of significant advantage to all infants. It is of most value, however, to infants of families with low economic resources. Human milk substitutes accessible to those infants generally are unsafe because of their inferior nutritional quality and frequent contamination with potentially fatal infectious agents.

The bacteriologic safety and high nutritional value of human milk argue strongly for maximizing the intake of human milk, especially among infants of the poor. This is especially important when other foods are added to the infant's diet. Added foods are of inferior quality, are often bacteriologically contaminated, and generally displace human milk, thereby raising the risk of infection and malnutrition in children living in unsafe environments. Although there are recent data that support the extension of exclusive breastfeeding beyond six months among some infants, the published data remain too limited to conclude that the period of exclusive breastfeeding should be extended universally beyond the current recommended period of four to six months. There is no controversy, however, regarding the important role of human milk in supplying essential nutrients to the child during the period of mixed feeding.

The major possible exceptions to the full adequacy of exclusive breastfeeding relate to vitamins K, D, and B_{12}. Although there is some disagreement, most medical scientists continue to recommend vitamin K supplementation at birth for all infants, regardless of feeding mode, to prevent haemorrhagic problems in the newborn. Infants with limited exposure to sunlight, or those whose mothers had low vitamin D stores because of low vitamin D intake or limited sun exposure, should receive vitamin D supplements. Infants of strict vegetarians who do not eat eggs or milk products also run the risk of vitamin B_{12} deficiency and should be provided with an exogenous source of this essential nutrient.

Maternal malnutrition also may result in abnormally low levels of some nutrients in human milk. Generally, however, even women living under very harsh conditions will provide sufficient milk of adequate quality to breastfeed infants exclusively for four to six months. More importantly, circumstances that lead to maternal malnutrition almost uniformly result in malnutrition and serious infectious morbidity among non-breastfed infants. The mortality rates of non-breastfed infants in these circumstances are estimated to be 12 times higher than those of breastfed infants.

The contamination of human milk by xenobiotics may present safety concerns in some circumstances. Situations in which environmental pollutants, such as heavy metals and organohalides, may contaminate human milk should be evaluated carefully; how-

ever, attention must always be given to the benefits and risks presented by the exclusion of human milk and the use of its substitutes. In these circumstances exposure of the infant obviously begins *in utero*, thus making it more imperative to attend to the contamination of the environment.

The major biological xenobiotic of concern is the human immunodeficiency virus (HIV), which is responsible for the acquired immunodeficiency syndrome (AIDS). Although it is clear that human milk may carry HIV, controversy remains as to the conditions that determine the infectivity of HIV in human milk. There is no controversy, however, that the benefits of human milk are much greater than the risks presented by HIV in areas characterized by high rates of infant mortality and malnutrition.

Immunologic benefits

In addition to serving as the most reliable, safe, and nutritious food for infants, human milk provides unique immunologic benefits, which result in decreased rates of infection and other desirable outcomes. In the recent past, scientific evidence was limited to the likelihood that human milk conferred passive protection; that is, protection against infectious disease occurred because of the direct interaction between specific milk components and potential pathogens that threaten the infant. However, there was little evidence to support the hypothesis that human milk alters the development of the infant's immune system to provide active as well as passive protection. Data reviewed by the Working Group support the idea that both active and passive mechanisms likely account for the decreased infectious morbidity observed in infants in both economically developing and fully industrialized nations. Of particular interest were data from the United Kingdom demonstrating that breastfeeding for at least 13 weeks had protective effects against gastrointestinal and, to a lesser degree, respiratory infections that lasted beyond weaning.

Recent studies have demonstrated that breastfeeding enhances responses by the infant to infectious challenges. Enhanced responses were noted following the administration of parenteral vaccination with diphtheria and tetanus toxoids and Hib (*Haemophilus influenzae* type b)–protein conjugate, oral poliovirus, and "natural" infections with respiratory syncytial virus. The mechanisms responsible for these responses are the subject of intensive investigations. It is likely that both the high nutritional quality of human milk and its complex immune components (e.g., various growth factors, cytokines, and anti-inflammatory factors) are responsible for the improved immune function of breastfed infants.

The combined nutritional and immunologic protective effects of human milk against diarrhoeal disease result in a reduced incidence and severity of the disease. As a consequence, breastfeeding protects strongly against diarrhoeal mortality, especially in young infants. Although partial breastfeeding is protective, maximal protection is achieved with exclusive breastfeeding. A reduction in the incidence of respiratory disease is less clearly established, but breastfeeding does appear to reduce the severity of respiratory illness, as reflected by hospitalization rates and mortality. There also is fairly consistent evidence that breastfeeding protects against otitis media, but the effect is less than that seen for diarrhoeal diseases. Evidence for protection against other infeetious diseases is less clear, but nonetheless suggestive. Theoretieal mathematical projections based on data obtained from the World Health Organization indicate that a 40% reduction in the prevalence of non-breastfeeding would result in a 50% reduction in respiratory deaths and a 66% reduction in diarrhoeal deaths worldwide in children 18 months old or younger.

Evidence also was reviewed which suggests that the immunologic benefits may last for a longer term. Investigators have reported that for years after breastfeeding has ceased, breastfed infants have a significantly lower risk than bottle-fed infants of developing type I diabetes, Crohn's disease, and lymphomas in childhood.

Behavioural benefits

Behavioural benefits are more difficult to document. Although it is highly plausible that specific constituents of human milk enhance the infant's neural development and that suckling at the breast promotes desirable emotional ties between mother and infant, objective experimental evidenee in support of the hypothesis that breastfeeding directly enhances the infant's behavioural development is limited. The usefulness of most published investigations is restricted by inadequate study designs, inappropriate evaluation tools available to or selected by the researchers, and an overly narrow focus on developmental outeomes, such as IQ scores and psychomotor indices. The narrowness of the focus excludes consideration of interactions between feeding mode and other potentially important modulators of behavioural development (such as reductions in morbidity) and disregards the *processes* that underlie development. Furthermore, very little attention has been given to the alternative possibility that breastfeeding may limit mental development through, for example, the transfer to the child of toxic substances in milk. This alternative is complicated by the confounding likelihood that the infant's exposure to

toxicants is initiated during gestation, the period of maximal vulnerability.

Even when these caveats are acknowledged, previously breastfed children appear to have an advantage over bottle-fed children in developmental scales, IQ tests, and assessments of other specific cognitive outcomes. Among the most provocative observations are the positive effects on IQ of feeding human milk to premature infants. Although the workshop participants acknowledged controversial aspects of those observations, the need to replicate such studies was recognized widely. The consistency of the evidence argues strongly for evaluations with more robust designs and evaluation tools. Such investigations should permit inferences regarding the nature, degree, and persistence of the potential effects of breastfeeding or human milk feeding on behavioural development and the assessment of the modulation of putative effects by social, economic, and other environmental factors.

Benefits to the mother

Maternal benefits also fall into three broad categories: reductions in fertility, health benefits of a non-behavioural nature, and positive behavioural outcomes. The Working Group examined the first and second categories in greater detail than the third.

Generally, lactation is expected to help women maintain a healthy body weight when sufficient quantities of adequate food are readily accessible and to enhance the physiological efficiency of nutrient utilization under nearly all conditions. The hormonal changes that accompany lactation are expected to influence maternal behaviour in ways that support breastfeeding and promote mothering behaviours. Investigators also have suggested that successful breastfeeding is important to maternal self-efficacy and possibly social empowerment. These expectations likely are most relevant when maternal nutritional and social needs are met.

The mother's responses to breastfeeding have been studied much less than those of the infant. A principal limitation is that lactation seldom has been studied in the context of the complete reproductive cycle, which includes the nulliparous period, pregnancy, lactation, and the non-lactating, non-pregnant state that precedes a subsequent pregnancy. The significance of this omission stems from the likelihood that biological strategies for maintaining maternal well-being through the life cycle rely on a healthy physiological preparation for reproduction and adequate pregnancy intervals for maternal repletion. Interactions among the contiguous and interdependent stages within reproductive cycles and the biological effects of the distinct socio-economic, demographic, and environmental conditions in industrializing, newly industrialized, and post-industrialized settings are expected to modulate maternal responses to lactation.

Health consequences

Insufficient data were available to the Working Group for an assessment of the effects of lactation on the prevention of maternal obesity and nutrient depletion. Although obesity is of most concern in fully industrialized and newly industrialized nations, it is, ironically, a growing problem among some developing countries with large numbers of undernourished women of reproductive age. Similarly, the paucity of data makes it difficult to assess the global impact of lactation on nutrient depletion of the mother and its potential consequences for maternal and infant health.

Issues related to longer-term health outcomes, that is, osteoporosis and breast cancer, were addressed more confidently. Concerns that lactating women may be at greater risk of osteoporosis because of loss of calcium in milk have not been supported by recent studies conducted largely in affluent countries. Current evidence supports a preventive effect of breastfeeding against pre-menopausal breast cancer, but no association has been found between breastfeeding and post-menopausal disease.

Fertility

Data reviewed by the Working Group reaffirmed the suppression of fertility by breastfeeding. The duration of the mother's infertility is directly dependent on her infant's suckling activity. Breastfeeding is most effective in decreasing fertility (and thereby facilitating longer, more desirable interpregnancy intervals) when infants are breastfed on demand and are provided no other sources of food or water. There also are data suggesting that the use of pacifiers may lessen the effects of breastfeeding on fertility by decreasing the infant's suckling activity.

The mean anovulatory period for non-breastfeeding women appears to be approximately 50 days. In breastfeeding women, anovulation may persist well into the second year post-partum. Infertility appears to be maintained by a suckling-induced disruption of the normal pulsatile pattern of luteinizing hormone (LH) release (essential for ovulation) and facilitated by an increased hypothalamic sensitivity to the negative feedback effects of oestradiol. The mechanisms responsible for these maternal responses to lactation have not been identified but are sufficiently reliable to have led a group of investigators to conclude that when women fully or nearly fully breastfeed and remain amenorrhoeic, breastfeeding provides more

than 98% protection from pregnancy in the first six months post-partum. The programmatic implementation of this conclusion is known as the lactational amenorrhea method (LAM) of natural family planning.

Any biological or social factor that either promotes or interferes with the infant's suckling activity (such as a delay in the introduction of complementary foods or the inappropriate or premature introduction of supplementary or complementary infant foods) will, respectively, prolong or shorten the duration of infertility. Discussions on the control of milk synthesis were particularly relevant to these considerations. It is clear that milk synthesis is under autocrine (local) control. The frequency and degree to which the breast is emptied are the principal determinants of the quantity of milk that is produced. Generally, interference with the suckling activity of infants will be reinforced by a subsequent decrease in milk production. Under such conditions, feedback mechanisms will lead to progressive decreases in suckling, which, in turn, will disable mechanisms that disrupt pulsatile release of LH and eventually result in an earlier return of ovulation.

Demographic effects of breastfeeding

The Working Group examined the demographic effects of the impact of breastfeeding on fertility and infant mortality. It reviewed the impact of breastfeeding on one of the two principal proximate determinants of fertility, the rate of births. The other proximate determinant, the reproductive span (the interval between a woman's first ovulation and the time she either dies or becomes infertile), was not considered, because breastfeeding is not thought to influence it.

The effects of breastfeeding on the dynamics of birth intervals may be examined by dividing the birth interval into three parts: the post-partum period (the time between delivery and the resumption of both ovulation and sexual intercourse), the time between the end of the post-partum period and the next birth, and the period of the pregnancy associated with a live birth. Endocrine responses that make lactation possible prolong post-partum anovulation and amenorrhoea through mechanisms that have been reviewed briefly in the preceding section and regulate other reproductive functions (such as luteal function) through mechanisms that are understood less comprehensively. A semi-quantitative assessment of the impact of these effects on fertility suggests that a woman's lifetime fertility may be reduced as much as 50% by prolonged breastfeeding.

The demographic impact, however, also will be influenced by the effect of infant-feeding practices on child survival. Unlike the semi-quantitative assessments of the effects of the proximate determinants of fertility on population growth, the impact of the proximate determinants of child mortality on population growth has been more difficult to estimate. Six types of factors have been identified among the principal determinants of child mortality: maternal characteristics, environmental contamination, nutrient deficiency, injury, personal illness control, and the gestational age and development of the newborn. The first three are influenced greatly by breastfeeding.

The relations among breastfeeding, fertility, and child mortality are confounded by the socio-economic changes that often accompany changes in breastfeeding patterns. The socio-economic conditions that traditionally have led to decreases in the incidence and duration of breastfeeding tend, over the long term, to have a beneficial effect on the six factors listed above and to diversify and increase the use of contraceptive strategies for birth control. Nonetheless, if socio-economic changes are ignored and the positive impact of breastfeeding on fertility and child mortality on population growth is assessed, it appears that long-term breastfeeding (i.e., breastfeeding into the second year of the child's life) is likely to have only a limited effect on population growth. This, however, does not diminish the health benefits to both mother and infant anticipated from increased birth spacing and the nutritional and immunologic benefits discussed previously.

Current worldwide breastfeeding trends

The Working Group also reviewed data from demographic and health surveys conducted from 1990 to 1993. It is alarming that under-five mortality remains excessive by any measure in much of the world. For example, in 13 African countries for which data are available, mortality among children between one and four years of age ranged from 318 per 1,000 live births in Niger to 83 per 1,000 in Namibia. As in all regions, infant mortality in those 13 countries generally accounts for an increasing proportion of under-five mortality as the under-five mortality rate drops.

It is very likely that improved breastfeeding practices will have a significant impact on child mortality in nearly all economically developing countries. The term "breastfeeding practices" deserves emphasis, because the percentage of children born in the last five years who were ever breastfed ranged from 95% to 97% in the same 13 African countries for which mortality data are available. The percentages of children ever breastfed were similarly high (greater than 90%) in the Asian, South Pacific, and Latin American countries for which data are available.

In most developing countries that were surveyed,

substantially more than 50% of all infants were breastfed up to 12 to 15 months of age, and more than 25% were breastfed up to 20 to 23 months. The median duration of breastfeeding among children born in the last three years ranged from 17 to 28 months in the African countries that were surveyed. No economically developing country in the regions surveyed had a mean duration of breastfeeding below six months, and in most countries the mean durations were substantially above that level. Yet, consistently across all countries surveyed, the mean duration of breastfeeding was from 5% to nearly 100% greater in rural than in urban areas. In most countries, a minority of infants were fed only human milk through four months of age, although rates varied widely among those countries surveyed. For example, 90% of Rwandan infants were reported to receive only human milk through four months of age. The rates in Tanzania, Kenya, Madagascar, and Namibia ranged from 17% to 47%, and the rates in Burkina Faso, Ghana, Malawi, Niger, Senegal, Nigeria, Zambia, and Cameroon ranged from 1% to 13%. Rates were similarly divergent in other regions of the world. The percentages of infants whose diets were restricted to only human milk aud water were similarly divergent among countries but were substantially higher than the percentages of those receiving only human milk.

Sociocultural factors affecting breastfeeding

Breastfeeding is a learned, not an instinctive, behaviour. Desirable breastfeeding practices must be actively promoted and supported. Successful breastfeeding, therefore, is dependent upon social and cultural factors. Major shifts iu breastfeeding practices in fully industrialized countries over the last 30 to 40 years and rural–urban differences in most economically developing countries provide the best evidence of the great influence of sociocultural factors on breastfeeding. The best predictors of breastfeeding practices in fully industrialized countries are sociocultural rather than biological. This also is increasingly true in the industrializing countries, especially in those that are urbanizing quickly. However, recognizing the importance of sociocultural factors in determining infant-feeding practices does not lessen the difficulty of understanding how specific sociocultural factors operate or may be measured adequately to explain variations within and between different infant-feeding patterns.

The sociocultural factors that have been examined most often are those that can be integrated easily into biomedical and epidemiologic models, such as religion, martial status, education, and kinship pattern. These often are included in assessments of knowledge, attitudes, and beliefs. Yet because infant feeding, and breastfeeding in particular, represents a wide range of highly emotional issues, it is often difficult to obtain reliable and valid data from informants in most studies.

Other factors are less commonly studied, because they are more difficult to assess. For example, factors reflective of values, attachment, nurturance, and sexuality require interpretation from social science paradigms and are not as amenable to reductionist models. Nonetheless, all of these factors probably contribute significantly to the links among what people say they know, what they know, and what they practise.

As long-term, detailed ethnographic analyses have become increasingly available, a conceptual model has emerged that describes culture as an interaction between *style* and *structure*. Style refers to the manner of expression characteristic of an individual, a time, and a place. The application of this model is expected to increase understanding of the influence of sociocultural factors on breastfeeding. Infant-feeding styles communicate fundamental values, attitudes, and beliefs reflected in the interaction between mother and infant during feeding, in how breastfeeding is accomplished, and so forth. These styles of feeding are part of dynamic trends and fashions.

Styles in turn are in a dynamic interaction with defined organizational and institutional structures, such as those related to health care, the economy, and governments, each with its own potential influence on iufant-feeding choices. An improved understanding of relevant styles and structures should enhance our ability to predict how infant-feeding choices will be affected by changes in sociocultural factors.

Despite these limitations, a comparison of the effects of biological and sociocultural factors on measures of breastfeeding success (for example, prevalence and duration) strongly suggests that breastfeeding is biologically robust but highly susceptible to positive and negative sociocultural influences. The principal basis for this conclusion is that breastfeeding is sustainable under the wide range of biological conditions characteristic of affluent women in economically developed countries and of poor women in harsh environments in less economically developed areas. This is not true when breastfeeding is considered under an analogously wide range of sociocultural conditions relevant to breastfeeding. Although it would be a mistake not to recognize the cost that this characteristic presents to poor women (that is, to their biological well-being), it is equally fallacious to conclude that adequate breastfeeding can be accomplished only when all biological needs are optimally met.

Resources needed to protect, support, and promote breastfeeding

The information reviewed by the Working Group did not allow a prioritization of resources needed to protect, support, and promote breastfeeding. It did allow the group, however, to identify resources that would enhance the likelihood of successful lactation in nearly all settings. The paucity of quantitative information available to assess the relative importance of resources needed in specific settings represents a major research gap. The resources identified by the group fell into three broad categories: time, space, and sociocultural/economic support.

The physiological and sociocultural information reviewed by the group documented clearly that breastfeeding requires time of the mother. The two principal sources and sinks of time are the family and, when the mother also is employed outside the home, her employer. Because milk production is sustained by physiological processes dependent upon the regular removal of milk, time constraints that result in decreased or inefficient suckling will have a negative impact on milk production and eventually on the sustainability of adequate milk production. Time constraints imposed by employers have marked negative impacts on breastfeeding success because of adverse effects on suckling. Employment policies that recognize the importance of maternal leaves, temporary part-time employment options that do not adversely affect longer-term full-time employment opportunities, and opportunities for breastfeeding in the workplace represent complementary strategies to help establish and sustain adequate lactation.

Space is required to breastfeed. Differing perceptions of physical modesty, hygiene, and other concepts dependent upon cultural norms and relevant to infant feeding and maternal well-being will make diverse demands on the characteristics of spaces best suited for the protection, support, and promotion of breastfeeding. These demands apply to family residences, places of employment, and various sites where communities congregate, such as places of worship, businesses, and entertainment.

Sociocultural and economic support fall into two subcategories, tangible and intangible support. Examples of the types of tangible support needed to obtain full benefits of breastfeeding are safe and adequate food for the mother and complementary infant foods for the period of mixed feeding when foods other than human milk are introduced to the infant's diet; fair labour compensation that recognizes the needs of families; and adequate housing and related services that protect, support, and promote the hygienic well-being of the family.

Examples of intangible support tended to centre around five social sectors: government, business, community, health professions, and educational and research institutions. Those which centre around government represent a wide range of issues. They extend from laws and policies that govern parental leaves to those that lead to differing urbanization trends. Parental leave policies are of obvious relevance; urbanization trends influence family support structures and employment patterns, which affect the protection, support, and promotion of breastfeeding.

Although the Working Group recognized the significant influence that the commercial sector plays in determining parental and family leave policies of specific countries, the negative impact of both overt and subtle inappropriate marketing practices by producers of infant foods received more focus. Strategies that have a negative impact on breastfeeding appear designed to decrease suckling at the breast, thereby causing decreased milk production, with increased dependence on human milk substitutes, and undermining maternal confidence in the ability to breastfeed and the general social support of breastfeeding. These strategies are implemented by such diverse activities as direct advertisement to the public and the now discredited distribution of human milk substitutes at little or no cost in health-care settings or directly to family residences. Other issues relevant to the commercial sector's employment policies and the impact of these policies on the time mothers have to breastfeed have been discussed previously.

The issue common to communities-at-large, health professions, and educational and research institutions is recognition of breastfeeding as the *expected* mode of feeding for all infants and, its corollary, the use of human milk substitutes only when specifically indicated. Although all agencies and institutions with interests in infant health recommend exclusive breastfeeding for at least the first four to six months, these recommendations are not commonly reflected in the practices of communities, health professionals, and educational and research institutions. Examples of the consequences of failing to make practices conform with recommendations are inappropriate management of lactation by health professionals who have received inadequate training, poor knowledge and attitudes of many young families relative to breastfeeding because of inattention to lactation in primary and secondary education, and a poor knowledge base for the improvement of lactation practices because of inadequate research support.

Conclusions and recommendations

The data reviewed by the Working Group provide a strong scientific base for the present recommenda-

tions. The present benefits of breastfeeding in all countries and the benefits that are projected when international recommendations are implemented more broadly are of great significance to individuals and organizations responsible for the implementation of scientific knowledge that is highly pertinent to infant and maternal health.

The Working Group urges the active protection, support, and promotion of breastfeeding by governments, communities, the commercial sector, educational and research institutions, voluntary organizations responsible for the promotion of maternal and infant health, and, in particular, health professionals and facilities. Especially relevant to this recommendation is the resilience of lactation in the face of harsh biological conditions and the fragility of breastfeeding in the face of inadequate sociocultural and economic support. These characteristics impose a special responsibility on all societies to safeguard the well-being of women by ensuring their access to a safe and adequate food supply throughout their life cycle and to provide adequate time, space, and sociocultural and economic support to women and their families to maximize the health of all children from infancy and the health of women throughout the reproductive cycle.

Books received

Basic calculations for chemical and biological analyses. Bassey J. S. Efiok. AOAC International, Gaitersburg, Md., USA, 1993. (ISBN 0-935584-51-X) 135 pages, paperback. US$45 (USA, Canada, Mexico), US$55 elsewhere.

This book is neither new nor explicitly nutrition-related, but it is exceedingly convenient and useful for the kind of calculation that every nutrition or food scientist is required to make from time to time. It contains the information necessary for calculating the amount, concentration, and preparation of reagents, buffers, spectroscopy, enzyme assays and activities, and radioactivity. Anyone still concerned in any way with calculations of laboratory data will find this inexpensive paperback invaluable.

Carcinogens and anticarcinogens in the human diet. A comparison of naturally occurring and synthetic substances. National Research Council. National Academy Press, Washington, D.C., 1996 (ISBN 0-309-05391-9) 417 pages, paperback. US$44.95.

Plants contain chemicals that have medicinal stimulatory, hallucinatory, and narcotic effects, so it is not surprising that they also contain chemicals that are protective against or contributory to cancer. The US National Research Council committee responsible for this report was charged with examining the occurrence, toxicological data, dosage, mechanisms of action, and potential role of natural and synthetic carcinogens and anticarcinogens in food. Despite their enormous number in the food supply, the great majority of naturally occurring and synthetic chemicals in the diet are present at levels below those at which any significant adverse biological effects are likely. Moreover, a varied and balanced diet contributes significant protection. The committee concluded that natural components in the diet may prove to be of greater concern than synthetic components with respect to cancer risk. Even though human epidemiologic data indicate that diet contributes to a significant portion of cancer, it is extremely difficult to assess human cancer risk from individual natural or synthetic compounds, because the diet is such a complex mixture and interactions among components are largely unknown. The report documents and discusses these conclusions.

Trace elements in human nutrition and health. World Health Organization, Geneva, 1996. (ISBN 92-4-156173-4) 343 pages, paperback. SwF 85/ US$76.60; SwF 59.50 in developing countries.

This book provides authoritative recommendations concerning nutritional requirements and safe ranges of intake for 19 trace elements important to human health, based on a consensus of international experts. It combines the latest scientific knowledge about the consequences of specific dietary intakes with practical advice on how to identify the effects of deficiencies and excesses of trace elements. Recommendations for individual elements are presented in the form of safe ranges of intake for population groups and represent the limits of adequacy and safety for the mean intakes of whole populations. The final chapters provide detailed guidelines for the design and interpretation of research on trace elements for human consumption. These include analytical methodologies, dietary surveys, environmental supplies of trace elements, and the differences between population averages and individual intakes.

This book is essential for every nutrition library; it is unfortunate that it cannot be made available even more cheaply for developing countries. A French edition is in preparation.

Vitamin A and the immune function. Edited by Chris Kjolhede and William R. Beisel. Haworth Medical Press, New York, 1996. (ISBN 1-56024-757-6) 156 pages, hardback. US$29.95.

This is the report of a 1993 symposium that dealt broadly with vitamin and immune function from basic biochemistry to applied epidemiology and clinical practice. It includes basic information on the metabolism and mechanisms of action of vitamin A, with special reference to infection and immunity, the effects of vitamin A on B-cell and T-cell function, and the complex relationship of vitamin A status, supplementation, and immunocompetence. A comprehensive historical overview by Dr. Beisel provides valuable background. In addition to its authoritative summary of current knowledge, the book will be useful for the design of future in-depth investigations.

Note for contributors

The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy on the inside of the front cover). Submission of an article does not guarantee publication—which depends on the judgement of the editors and reviewers as to its relevance and quality. All potentially acceptable manuscripts are peer-reviewed. Contributors should examine recent issues of the *Bulletin* for content and style.

Language. Contributions may be in English, French, or Spanish. If French or Spanish is used, the author should submit an abstract in English if possible.

Format. Manuscripts should be typed or printed on a word processor, **double-spaced**, and with ample margins. Only an original typed copy or a photocopy of equivalent quality should be submitted; photocopies on thin or shiny paper are not acceptable.

When the manuscript has been prepared on a word processor, a diskette, either $3\frac{1}{2}$-inch or $5\frac{1}{4}$-inch, should be included with the manuscript, with an indication of the disk format and the word-processing program used.

Length. Ordinarily contributions should not exceed 4,000 words.

Abstract. An abstract of not more that 150 words should be included with the manuscript, stating the purposes of the study or investigation, basic procedures (study subjects or experimental animals and observational and analytical methods), main findings (give specific data and their statistical significance if possible), and the principal conclusions. Emphasize new and important aspects of the study or observations. Do *not* include any information that is not given in the body of the article. Do not cite references or use abbreviations or acronyms in the abstract.

Tables and figures. Tables and figures should be on separate pages. Tables should be typed or printed out double-spaced. Submit only original figures, original line drawings in India ink, or glossy photographs. Labels on the figures should be typed or professionally lettered or printed, not handwritten.

Photographs. Ideally photographic materials should be submitted in the form of black and white negatives or black and white glossy prints. Photographs will not be returned unless a specific request is made.

Units of measurement. Preferably all measurements should be expressed in metric units. If other units are used, their metric equivalents should be indicated.

Abbreviations. Please explain any abbreviations used unless they are immediately obvious.

References. References should be listed at the end of the article, also double-spaced. Unpublished papers should not be listed in references, nor should papers submitted for publication but not yet accepted.

Number references consecutively in the order in which they are first mentioned in the text. Identify references in the text and in tables and figure legends by arabic numerals enclosed in square brackets. References cited only in tables or figure legends should be numbered in accordance with the first mention of the relevant table or figure in the text. **Be sure references are complete.**

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1. Alvarez ML, Mikasic D, Ottenberger A, Salazar ME. Características de familias urbanas con lactante desnutrido: un análisis crítico. Arch Latinoam Nutr 1979;29:220-30.

—corporate author:

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119-25.

Book or other monograph reference

—personal author(s):

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—corporate author:

4. American Medical Association, Department of Drugs. AMA drug evaluations. 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

—editor, compiler, chairman as author:

5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

—chapter in book:

6. Barnett HG. Compatibility and compartmentalization in cultural change. In: Desai AR, ed. Essays on modernization of underdeveloped societies. Bombay: Thacker, 1971:20-35.

Identification. Please give the full name and highest degree of all the authors, the name of departments and institutions to which the work should be attributed, the name, address, and fax number of the author responsible for correspondence about the manuscript, and sources of support for the work. If the material in the article has been previously presented or is planned to be published elsewhere—in the same or modified form—a note should be included giving the details.

Manuscript copies. The contributor should keep a duplicate copy of the manuscript. Manuscripts will not be returned unless specifically requested. Proofs will be sent to the authors only in exceptional circumstances.

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La rédaction du *Food and Nutrition Bulletin* recherche des articles traitant de sujets correspondant à ses thèmes (voir au vérso de la couverture la politique éditoriale de cette revue). La remise d'un manuscrit ne signifie pas sa publication, qui dépend de l'opinion de la rédaction et des réviseurs sur son intérêt et sa qualité. Tous les manuscrits susceptibles d'être acceptés sont révisés par des pairs. Les auteurs sont invités à se pencher sur les récents numéros du *Bulletin* pour prendre connaissance de son contenu et de son style.

Langues. Les manuscrits peuvent être rédigés en anglais, en français ou en espagnol, et dans ces deux derniers cas, l'auteur ajoutera, si possible, un résumé en anglais.

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Résumé. Un résumé de 150 mots maximum doit accompagner le manuscrit. Il devra donner les buts de l'étude ou des recherches, les procédures de base (sujets de l'étude ou animaux expérimentaux et méthodes d'observation et d'analyse), les principaux résultats (fournir des données spécifiques et indiquer dans la mesure du possible leur importance statistique) ainsi que les principales conclusions. Veuillez mettre en relief les aspects nouveaux et importants de l'étude ou des observations. Prière de *ne pas* inclure des informations qui ne figurent pas dans le corps de l'article. Dans le résumé, ne citez aucun ouvrage de référence et n'utilisez ni abréviations ni sigles.

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5. Medioni J, Boesinger E, editores, Mécanismes éthologiques de l'évolution. París: Masson, 1977.

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