The Weanling’s Dilemma Reconsidered: A Biocultural Analysis of Breastfeeding Ecology

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ABSTRACT. Infant feeding practices exert recognized effects on infant survival and command close attention from pediatricians, nutritionists, public health workers, demographers, social scientists, and parents. Despite considerable research and public health efforts, models to inform decision-making about timing of supplementation in policy and practice remain unsatisfactory. In the present review, new models are derived through analysis of the weanling’s dilemma. After approximately 6 months, breast milk alone cannot meet the infant’s nutritional requirements for growth, but nutritional supplementation poses risks of illness and malnutrition. Timing of supplementation is conditioned by complex short- and long-term trade-offs among infant and maternal needs and constraints. No formulaic solution can be prescribed for this dilemma, but optimal timing of supplementation can be ascertained from infant-, maternal-, and locale-specific conditions. Models for these determinants and trade-offs are presented and applied to data from longitudinal studies of breastfeeding, infant development, and infant mortality. J Dev Behav Pediatr 19:286–296, 1998. Index terms: breastfeeding, supplementation, growth, infant diarrhea, human ecology.

Breastfeeding confers human mothers and infants with a universal predilection, namely the weanling’s dilemma. Breastfeeding undoubtedly benefits infants, fulfilling their nutritional, developmental, health, and psychosocial needs. The predilection arises because, by approximately 6 months, breast milk alone cannot meet both the infant’s expanding nutritional requirements and maintain normal growth rates, while the nutritional supplementation introduced to avoid compromising infant growth may also be contaminated or nutritionally inadequate, and thus raise risks of illness, malnutrition, and consequent growth faltering. Prolonged exclusive breastfeeding is not a panacea ensuring long-term infant well-being, and the weanling’s dilemma emerges in the infant as the antithesis benefits of breast milk are weighed against potential detriment to future growth and the potentially high maternal costs of lactation. The management of infant feeding and the optimization of infant well-being are issues that confront infants and mothers in all nations, both developed and developing. However, the poverty and endemic infectious disease of developing nations make the resolution of the weanling’s dilemma a critical public health issue primarily in these contexts.

Breastfeeding now constitutes a focus for research and policy in reproductive ecology, maternal-infant health, and demography. Initial work by anthropologists on breastfeeding and birth spacing was inspired in part by recognition that this phenomenon, by its very nature, requires comparative biocultural analysis. Despite considerable progress in unpacking the complexities of breastfeeding ecology, the full potential for a biocultural perspective remains to be realized. In this end, the present analysis applies a biocultural, ecological, life-history framework to a reconsideration of the weanling’s dilemma. We critically evaluate the local trade-offs involved in breastfeeding and propose a biocultural ecological model for the proximate determinants of the timing of supplementation, with implications for infant and maternal well-being.

THE BIOECOLOGICAL DETERMINANTS OF EXCLUSIVE BREASTFEEDING

Because the weanling’s dilemma revolves around the difficulty of establishing a feeding strategy that optimizes infant development and survival under competing constraints, infant growth and health are used as benchmarks for the efficacy of child care in a given population. Infant growth faltering may arise through the confluence of nutritional needs and pathogen exposure, but the prime mover of the weanling’s dilemma is pathogen risk. Infectious disease has been labeled the “pri-
exclusive breastfeeding are least likely to suffer from early-infant diarrhea, partial breastfeeding demonstrate intermediate risks, and infants receiving no breast milk at all have highest risks. 

**The Underlying Nutritional and Immunological Advantages of Breast Milk**

Breast milk provides a rich source of nutrients and immunological factors that are crucial for infant health. Breast milk contains high levels of proteins, fats, and carbohydrates that are easily digestible and absorbed by the infant. It also contains a variety of immune factors, such as antibodies, immune cells, and hormones, which protect the infant from infections and disease. Breast milk also contains growth factors, such as leptin and insulin, which are important for childhood growth and development.

**Breastfeeding and Child Growth**

Breastfeeding has been shown to have a positive impact on child growth and development. Infants who are breastfed for the first six months have lower rates of mortality and morbidity than those who are formula-fed. Breastfeeding is also associated with lower risk of obesity in later life. Breastfeeding has been shown to have a beneficial effect on neurodevelopment, with breastfed infants showing higher scores on developmental tests than formula-fed infants.

**Breastfeeding and Maternal Health**

Breastfeeding has been shown to have a positive impact on maternal health. It can reduce the risk of postpartum depression, reduce the risk of breast and ovarian cancer, and reduce the risk of obesity and type 2 diabetes in later life. Breastfeeding also increases the bond between mother and child, which is important for emotional development.

**Breastfeeding and the Environment**

Breastfeeding is an environmentally friendly option. It requires no preparation, storage, or refrigeration, and it does not produce any waste or pollution. Breastfeeding is also a cost-effective option, as it eliminates the need for baby formula and other infant feeding products.

**Breastfeeding and Public Health**

Breastfeeding has been shown to have a positive impact on public health. It can reduce the incidence of infectious diseases, such as diarrhea and pneumonia, and it can also reduce the incidence of obesity and type 2 diabetes. Breastfeeding has been shown to be an effective way to promote good nutrition and healthy growth in infants and young children.

**Breastfeeding and Economic Benefits**

Breastfeeding can also have economic benefits. It reduces the cost of infant feeding products and the need for medical care for infants who are formula-fed. Breastfeeding can also improve maternal employment prospects and reduce the cost of infant care.

**Breastfeeding and Social Benefits**

Breastfeeding can also have social benefits. It promotes a strong bond between mother and child, and it is a way to connect with other mothers and families. Breastfeeding can also be a way to build community and social support.
after 3 to 6 months and 5 months, respectively, and stabilize at under 85 and 91% of reference in the second year. Parallel to growth faltering, motor development slows after 6 months.

Recent studies in well-nourished Western populations suggest that breastfeeding has implications for the pattern of infant growth and argue for growth standards based on breastfed infants. However, the breastfed infants in these studies are not exclusive breastfeeders, and consume, after age 4 months, significant amounts of liquid and solid supplemental foods that prevent the degree of growth faltering manifested in the Amole. Comparison of Amole to American breastfed infants' results in a just slightly improved evaluation of their status and yields a similar pattern of declining weight-for-age and weight-for-length from equivalence to reference at birth, to 92 and 97%, respectively, at 3 to 6 months, to stabilization at 86 and 94% of reference in the second year. In agreement with these studies, we recognize that breastfed infants may follow divergent growth patterns that are not "abnormal," but we are focusing here on the growth faltering that ensues after prolonged exclusive breastfeeding. In recognition of the potential costs of prolonged exclusive breastfeeding, the American Academy of Pediatrics designates breast milk as a complete food for the first 6 months of life but recommends supplementation by 4 to 6 months to avoid nutrient deficiencies. The World Health Organization makes similar recommendations for populations around the world. Prolonged, intensive, exclusive breastfeeding, therefore, is not an antedote for the waning infant's dilemma.

Prolonged intensive breastfeeding exacts costs on the mother as well. Breast milk is an energy-rich substance, packing approximately 0.72 kilocalories in every gram. Lactating mothers produce 550 to 850 grams of milk each day, at greater than 80% efficiency, imposing an estimated energy cost of 333 to 719 kcal daily that exceeds the calorie demands of pregnancy and lactation, and is not recoverable by women who supplement their diets with energy or nutrients at this stage of life.

FIGURE 1. Left panel: Daily volume and energy of milk intake by Amole infants during the first 2 years. Amount of milk consumed per unit body weight declines with age, as a function both of biological limits on maternal milk output and infant intake, and of rapid infant growth, particularly in the first 6 months of life. Right panel: Percent of total energy intake consumed as breast milk, contrasted with total energy intake in kilocalories per day, and as percent of the Food and Agriculture Organization/World Health Organization estimated energy requirements.

FIGURE 2. Growth and nutritional status of Amole infants to age 3 years, compared with National Center for Health Statistics reference values. Based on averaged by-sex data. Height-for-age reflects linear growth, weight-for-age indicates present and past nutritional states, and weight-for-length represents acute nutritional status.
of pregnancy. Increased food consumption covers only a fraction of this energy debt, forcing lactating women to metabolize fat reserves, reduce physical activity, and/or lower basal metabolic rates to cover the balance.40,45

In addition to the energy demands, breastfeeding constrains maternal activity and consumes valuable time. As such, mothers may be motivated to supplement as early as possible, without immediately jeopardizing the survival of their infants. The interests of the infant and its mother may conflict with regard to the duration of exclusive breastfeeding. The reality of this conflict is old news to evolutionary biologists46,47 but has yet to be seriously considered in the literature on breastfeeding.

Figure 3 models the biocultural variables that define the proximate determinants of supplementation. Arrow length represents the respective magnitudes of pathogens risk and breastfeeding costs in a given context, whereas pathogens risk favors delayed timing of supplementation, and burdens of breastfeeding favor its acceleration. Timing of supplementation establishes a compromise between these opposing forces and configures the extent to which developmental consequences for the infant tend toward either optimal growth, or suboptimal growth, morbidity, and mortality. This biocultural model of the proximate determinants of supplementation predicts that the timing of supplementation is responsive to pathogens risk prevalent in a given environment. Higher pathogens risk should prolong exclusive breastfeeding. The absence of such a relationship should be reflected in poor infant outcomes. Obviously, the model suggests that the maternal costs of breastfeeding should be related to the timing of supplementation, an expectation that would be refused if maternal outcomes are insensitive to breastfeeding duration.

CULTURAL-ECOLOGICAL DETERMINANTS OF EXCLUSIVE BREASTFEEDING

The cultureless model introduced in Figure 3 is an intentional oversimplification to highlight the proximate variables affecting the timing of supplementation and the consequences for infant morbidity. Obviously, culture largely determines pathogen exposure and breastfeeding behavior. This section provides a brief overview (summarized in Table 1) of the cultural ecological variables reported in the public health and ethnographic literature to shape infant diarrhea risk and breastfeeding activity.

Table 1. Variables Affecting Pathogen Risk and the Cultural Ecology of Breastfeeding

<table>
<thead>
<tr>
<th>Pathogen risk</th>
<th>Exposure</th>
<th>Vulnerability</th>
<th>Breastfeeding supports and constraints</th>
<th>Physical ecology</th>
<th>Social ecology</th>
<th>Ideology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality and quantity</td>
<td>Human waste disposal</td>
<td>Infant developmental status</td>
<td>Availability of adequate supplementation</td>
<td>Phases of human lactation</td>
<td>Expectations</td>
<td>Belief about milk and alternatives or peer norms</td>
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<tr>
<td>Human waste disposal</td>
<td>Household density</td>
<td>Infant nutritional status</td>
<td>Opportunities for breastfeeding, constraints of material work</td>
<td>Prenatal manipulation of fertility</td>
<td>Social support, infant care, and child care practices</td>
<td>Norms of motherhood and marriage</td>
</tr>
<tr>
<td>Domestic animals</td>
<td>Food handling</td>
<td>Infant nutritional status</td>
<td>Infant nutritional status</td>
<td>Social influence, formula feeding</td>
<td>Gender relations</td>
<td>Understanding of child development</td>
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<tr>
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<td>Childrearing</td>
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FIGURE 3. A biocultural model of the proximate determinants of the timing of supplementation. Pathogen risk prolongs the optimal period of exclusive breastfeeding, whereas the costs of exclusive breastfeeding encourage earlier supplementation. The resulting process between these two forces has implications for infant health and growth.
The Cultural Ecology of Disease Exposure

Water Quality. Each of the major enteropathogens associated with infectious diarrhea can be transmitted in infected water, which becomes a critical factor in infant exposure to pathogens. Water improvement projects in developing nations are associated with up to 90% reduction in diarrheal morbidity and 41% reduction in mortality. The sources, quantity, and processing of available water are critical determinants of pathogen exposure.

Human Waste Disposal. Exposure to human waste products is a critical determinant of pathogen burdens. Lack of access to latrines, unsanitary stool disposal, and the presence of feces in the family compound increases pathogen risks. Cultural constraints on infant movement, such as constant carrying or swaddling, may limit exposure to human wastes, thereby modulating pathogen risk.

Crowding. Predictably, because population density facilitates pathogen transmission and exacerbates problems of water availability and waste disposal, crowding is directly related to the risk of infant diarrhea. Household size is positively associated with the incidence of infant diarrhea, as is having more than three people share a bedroom. Exposure to a household member or another child with diarrhea raises infant risk by a factor of 4.4 and 14, respectively.

Food Handling. Food ingestion is a major vehicle for infection that is minimized by exclusive breastfeeding. When supplementation does occur, the use of unrefrigerated food or dirty feeding bottles and utensils is associated with an increased incidence of infant mortality. The specific types of foods given, how they are prepared and stored, and how they are served to the infant in specific cultural contexts modulate pathogen risk.

Domestic Animals. Domestication brings humans into close contact with a range of potential disease vectors. Domestic chicken, dogs, and cats are associated with elevated rates of infant diarrhea caused by Campylobacter jejuni. Domestic animals also indirectly increase pathogen exposure through bringing animal and human feces from outside into the household and by supporting large populations of flies.

Climate and Seasonality. Infant diarrhea has multiple viral, bacterial, and parasitic etiologies that thrive in different climates and during different times of the year. Seasonality may also indirectly alter pathogen risk through its effects on water quality and sanitation and through seasonal exposure to domesticated animals and crowded living conditions.

The Cultural Ecology of Breastfeeding

The physical, social, ideological, and political ecologies that define a given culture all modulate maternal decisions about the duration of exclusive breastfeeding. They are articulated in the present study for heuristic purposes, but, in reality, they mutually constrain domains overlap in seamless whole.

Physical Ecology. Physical environments inhabited by mothers, along with their material-biological co-occurrents, influence infant feeding patterns by affecting workload, subsistence and settlement patterns, physical risks, and reproductive gain.

Subsistence Patterns. Subsistence mode influences the quantity, quality, and variability of food. Availability of ade-

quately supplemented breastfeeding is an obvious necessity for the termination of exclusive breastfeeding. However, local cultural definitions of "adequate" can differ significantly from the biomedical definition, since breast milk substitutes range from nothing more than sugar water to small volumes of adult foods. Availability is frequently defined by income or opportunity costs. In the periurban squatter settlements of Manila, costs of formula feeding consume approximately one third of the average poverty-level income per family, serving as a significant deterrent to its use, and reductions in the price of infant formula have been associated with shorter durations of exclusive breastfeeding in the Philippines.

Materiland Workload. Women's work is linked to subsistence and residence patterns and frequently limits breastfeeding opportunities. This fact is reflected in a survey of breastfeeding and women's participation in subsistence activities in 81 societies: women who exclusively breastfed for more than 1 month contribute less to subsistence than women who introduce supplementary foods prior to 1 month.

Location. Up to 35% of all women are thought to be physically capable of lactation postnatally, but numerous factors influence success in establishing and maintaining lactation. Failure to produce an adequate supply of breast milk requires compensatory supplementation to meet the infant's nutritional needs. Indeed, milk insufficiency is the most frequently cited reason for the early termination of breastfeeding. Anxiety, stress, and pain have all been shown to limit milk production, most likely due to the inhibition of myoctic release and interference with the milk let-down reflex. Despite the energy demands of milk production, maternal nutritional status does seem to be a material limiting factor, although current studies are inconsistent.

Patterns of breastfeeding modulate milk production. When compared with five daily, regularly scheduled feedings, on-demand breastfeeding is associated with greater milk production. Early postnatal initiation of breastfeeding and more frequent feeding induce accelerated milk output and may extend the duration of lactation for several months. Frequent nipple stimulation promotes milk production, whereas relatively infrequent scheduled feedings are associated with nipple soreness, breast overstimulation, and more blurred physiological responses to suckling.

Reproductive Patterns. The causal chain linking breastfeeding, suppressed ovarian function, and birth spacing is well documented. Indeed, regulation of fertility may actually be an independent variable that motivates breastfeeding behavior.

Many cultures implicitly recognize the energy demands of pregnancy and lactation, as a subsequent pregnancy appears to be a commonly accepted reason for weaning. Consequently, for the breastfeeding infant, a mother's pregnancy often heralds the onset of supplementation.

Social Ecology. Social networks can help overcome otherwise formidable impediments to exclusive breastfeeding. Like many Muslim cultures, Bedouin Arab mothers in Israel
observed 40 days of separation with their newborn infants after birth. During this period, mothers are surrounded by patri-

109. Efforts to decrease perinatal mortality by encouraging hospital delivery combine with the traditional practices of maternal infan
ternal care to discourage breastfeeding and, ironically, to con-
tribute to increased maternal mortality risk. Women in rural Kenya who give birth in hospital are twice as likely to feed their
infants formula, and women in the small Mexican village Tepetitlán believe that the midwives and health workers in hospitals prefer
milk substitutes. Consequently, those women supplement, on aver-
age, 3.5 months earlier than women in the neighboring village of Amamayu that has not so closely associated with Western medicine.
Indeed, hospital deliveries frequently separate infants from their mothers, and formula may be the infant's first source of food. Health professionals in hospitals indi-

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city frequently advise women to supplement earlier than in traditional practice.

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111. Similarly, breastfeeding may be associated with marital
relations in Turkmenistan, where acceptance of the mother's presence in the child's life is considered part of the woman's legitimacy, and a woman cannot terminate breastfeeding without consulting her husband or male relatives. Conversely, among the Mende, where sex is separate from a man's father, they believe it tantamount to infant death to not breastfeed properly. The Mende wives report that the woman's role in breastfeeding is more important. Furthermore, breastfeeding is considered important for the child's health. In Turkmenistan, women are more likely to breastfeed exclusively for the first year of life. In contrast, for American, husband expectations for Infan-
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allowed their breasts to be "ruined" by the sucking infant.100 Here, breastfeeding conflicts with a woman’s sexuality and is not central to her role as a mother. Detwyler12 attributes similar ambivalence toward breastfeeding in the United States to the "sexification" of the female breast. In Mali, where breast are believed to exist solely for the purpose of feeding children, women frequently wear no clothing above the waist and breastfeed in public with impunity. Mali women are either bemused or horrified by the sexuality associated with breasts in the West.112

Political Economy. The phyisical, social, and ideological ecologies that surround breastfeeding decisions are not locally pristine, but are part of a larger global system. For instance, before 1975, infant formula manufacturers initiated a marketing campaign that blancketed third-world airwaves with slogans such as "Give your baby love and lactogen," translated into more than 70 languages.113 Concern over the contribution of formula use to rising rates of infant mortality in the developing world spawned the Infant Formula Action Coalition in the United States, which promptly organized an international boycott of Nestle—the world’s largest formula manufacturer.114 In turn, the World Health Organization approved a resolution in 1981 regulating the promotion and use of infant formula.115 Despite these efforts, parents around the world were continually encouraged to replace breast milk with infant formula. Pictures of healthy, fat babies on formula labels filled market shelves,116 and advertising themes such as “when breast milk fails” or “when nature is inadequate” promoted the perception of milk insufficiency.117 Posters on the walls of clinics and day-care centers and infant care and feeding books distributed by formula manufacturers attempted to incorporate formula into the ideology surrounding motherhood and child care.118 Advice of health care providers associated formula with progress, technology, and health. UNICEF also distributed supplemental foods as rewards for clinic visits, and the U.S. Peace for Peace program supplied communities with free powdered milk.119,120

In response to global economic and political pressure, formula manufacturers, agencies, and health care institutions have reduced or eliminated practices inhibiting breastfeeding. Regardless, the legacy of this history endures, since early supplemental feeding has been absorbed into the ideologies of many preindustrial communities. Thus, the global political economy has had drastic effects on the cultural ecology of breastfeeding around the world.

SYNTHESIS: A BIOCULTURAL MODEL OF THE PROXIMATE DETERMINANTS OF BREASTFEEDING

The matrix of variables that define the cultural context of breastfeeding complicate the association between pathogen risk and the timing of supplementation proposed in Figure 3 and suggest a more realistic, less simplisticly dyadic model of the complex ecological determinants of maternal behavior and pathogen risk that powerfully shape supplementation decisions (Fig. 4). In Figure 4, heavy dark arrows represent...
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the balance between the supports and constraints of a given cultural system for breastfeeding mothers. The ideological, social, and physical environments experienced by a woman are mutually informing structural factors that shape the proximate determinants of supplementation decisions and their consequences. These factors, and their informing political economy, influence differential pathways to exclusive breastfeeding and vulnerability: they construct women's roles and statuses that determine workable, social demands (including reproductive performance), and access to material and social resources; and they inform the supplies for and barriers to breastfeeding, including beliefs about infant need and benefits, maternal rights and responsibilities, and social arrangements that restrict, accommodate, facilitate, or require breastfeeding.

In Figure 4, the arrow describing pathogen risk is thickened to indicate that pathogen burden may not be a culturally acknowledged and salient variable in the supplementation equation. This remains an empirical question, for the current ethnographic literature does not consider whether mothers and their surrounding cultures are cognizant of the degree of infant pathogen exposure. However, pathogen risk is biologically salient in its effect on infant health. To the extent that maternal supplementation decisions expose infants to pathogen risk, they open a window of morbidity and developmental costs that can be viewed as a product of the cultural conditions that inform the decisions themselves. Where pathogen risk is low, the margin of infant morbidity can be narrow, even when supports for breastfeeding are weak; constraints are high, and weaning is easy. This is the case in postindustrial societies such as the U.S.-States, where early supplementation occurs with relatively minor pathogen risk, resulting in a narrow margin of morbidity, as reflected by the low levels of infant diarrhea. Sustained, high-quality supplementary feeding supports strong infant growth. Conversely, where pathogen risk is high, the margin of infant morbidity will be wide, unless constraints on breastfeeding are weak and support is strong. In many preindustrial contexts, high rates of infant morbidity, mortality, and stunting elide the consequences of physical, social, and ideological constraints on breastfeeding that encourage early supplementation despite high local pathogen risks. The model predicts that prolonged exclusive breastfeeding in these situations will narrow the wide margin of morbidity. But without adequate supplementation, the immunological benefits of breastfeeding may come at a cost to growth, as exemplified earlier by the Amis.

This model yields a number of empirically testable hypotheses. First, it predicts a positive cross-cultural correlation between pathogen risk and the duration of exclusive breastfeeding. Cultures with poor water resources, inadequate sanitation, domestic animals, and crowded living conditions should delay supplementation. In such cases, ethnographic analysis may reveal cultural ideologies and social ecologies that support exclusive breastfeeding, if the surrounding cultural environment acts to maximize infant survival. This cannot always be assumed, however, for in certain contexts, limited resources and competing demands may constrain caregiving behavior.108,109 Second, the model predicts that infant health and growth will be optimal in populations where the correlation between pathogen risk and breastfeeding duration is strongest. Infant health will be poorest in populations where this relationship is weak. High rates of infant morbidity and mortality indicate a poor fit between the duration of exclusive breastfeeding and high pathogen risk. Maternal relationship can also be considered within cultures, as subcultural practices and socioeconomic stratification create differential pathologies to breastfeeding and trade-offs.

MATERIAL FACTORS IN BREASTFEEDING AND SUPPLEMENTATION

Consistent with the literature on infant feeding and survival, our discussion of breastfeeding and the timing of supplementation has privileged the infant's needs and well-being and considered maternal constraints only in as far as they affect infant interests. Such models leave a glaring gap where maternal needs and well-being are concerned; to be complete, an analysis of breastfeeding ecology requires systematic inclusion of the maternal perspective. In this study, we advance a model that reconceptualizes the previous discussion of the costs and benefits of breastfeeding or risk to maternal outcomes.

Energetic and Nutritional Costs

Net maternal costs increase with duration of breastfeeding, not only in terms of energy expenditure and lost biomass, but also in micrometabolites such as estrogens.118,119,121 Progressive deterioration of maternal nutritional status from the cumulative impact of nutritional demands of reproduction, especially through prolonged lactation, can lead to a "maternal deprivation syndrome" when maternal ability to recover expended nutritional reserves is limited and/or interbirth interval is short.120,121,122 Maternal deprivation syndrome jeopardizes not only maternal health, but maternal mortality. Maternal undernutrition during pregnancy compromises the infant's birthweight,123,124 and maternal survival affects child survival.125 Maternal undernutrition in the current child jeopardizes the well-being of existing and future children. Cultural practices that support infant spacing often explicitly recognize these linkages.123

Reproductive Costs and Benefits

Prolonged lactation increases the risk of maternal depletion at the same time that it offers the major benefit of spacing births, although both involve lost reproductive potential, valued by different units. Longer interbirth interval lowers fertility and positively predicts survival not only of the new infant, but also of the previous one.124,125 Duration of breastfeeding represents the principal variable component of interbirth intervals.126 International health policy advocates breastfeeding largely because of its infant survival-enhancing value via birth spacing.5 Sustained intensive nursing maintains lactation and depresses reproductive function by driving neuroendocrine mechanisms that prolong the period of postpartum amenorrhea and dampen reproductive function most intensively when resumed. Energy deficits from lactation may further supress reproductive functionality through the associated loss of body fat, because weight loss and low body-fat have been linked to impaired ovarian function or amenorrhea in both lactating and nonlactating women.126,127 Furthermore, the
physical load of carrying nursing infants can diminish repro-ductive function both directly through physiological effects of workload,121 and, indirectly, by contributing to energy deficits. The cumulative suppressive effects of prolonged lacta-tion on ovarian function also confer the health benefits of a significantly decreased risk for reproductive cancers because of reduced exposure to ovarian hormones.122 Spacing births allows mothers to recuperate and replenish energy and macronutrient stores, but nutritional drains of lacta-tion hamper this process. Mothers, therefore, face a trade-off between the maintenance of lactation to delay the next reproductive cycle and the introduction of infant supple-mentation to diminish maternal lactation load and speed maternal nutritional recovery. Furthermore, where high fer-tility is valued, the fertility-suppressive effect of sustained breastfeeding can represent an unwanted source of lost repro-ductive potential that rationalizes earlier weaning.123

Productivity Costs

Time and other maternal costs compounded with prolonged breastfeeding, since breastfeeding competes with time and energy for other tasks and goals. Besides increasing time required to deliver increasing milk volume with infant age, efforts to maintain protracted required for breastfeeding exac-erbate the infant grows heavier to carry, more active and diffi-cult to retrieve, and less interested in breastfeeding as it demands increasing supplementation. For instance, carrying a breastfeeding infant contributes to the heavy loads hauled by ypeparastalitist Tampang mothers in Nepal (up to 114% of body weight) and adds an extra 10 minutes of rest time per hour of work for weaning.124,125 and foraging efficiency is con-sistently lower among breastfeeding Ache and Huvi foragers of South America.126 Type of labor can also determine the degree to which output is hindered by breastfeeding. Depending on the nature and importance of women’s pro-ductivity for domestic economy, pressure to maintain work output and then to wean early may be strong.

Social Costs

As noted above, the social value of maternity may be very high and may also be supported by practices that provide nursing mothers with the energy and time resources to sup-port sustained intensive lactation. Similar as maternal well-being depends on social status accrued through productive output, then mothers may be willing or obliged to incur high reproductive costs. But demands of breastfeeding can impose social costs. Nursing mothers may incur labor debts or erode labor reciprocities for domestic, production, communal, and social socializes, and they may be less able to pursue social activities that maintain status and supportive networks. Among nomadic Turkana mothers, for instance, depth of social network correlated with breastfeeding frequency.128 Particularly where intercourse is suppressed during lactation, sustained breastfeeding may erode marital intimacy and hus-band influence, and diminish reproductive potential at the same time that it spaces births. In this sense, breastfeeding is a source of social values and expectations with practical constraints on women’s roles as well as mothers will determine the severity of maternal trade-offs among these demands.

Diminishing Infant Benefits

A further complication to trade-offs involved in breast-feeding and supplementation arises from the fact that the ben-efts and costs of breast milk are time-dependent. Exclusive breastfeeding entails diminishing benefits to the infant that must be weighed against the cumulative or escalating costs to the mother. Developmental processes and changes in the infant make its needs and vulnerabilities a moving target over time. As infant biomass and activity expand with age, breast milk increasingly fails to meet these needs, thereby devolv-ing the maternal unit cost of milk production, which scarcely declines with time. This cost is partially offset by the diminis-hing volume and energy content of milk produced with extended lactation, but other costs (in risk to future repro-duction) escalate with time. Furthermore, the immunologi-cal benefits of breast milk attenuate as the infant develops; SlgA concentrations are highest in postpartum colostrum, and undergo a three-to-four fold drop in breast milk during the first 3 months of the infant’s life, and similar declines in lymphocyte, macrophage, and lactoferrin concentrations have also been reported.129 In contrast, lymphocyte appears to be the key immune factor produced at higher concentrations during this same period. When breast milk consumption and infant body mass are considered, the growing infant receives gradually diminishing doses of SlgA and lactoferrin each day through the first 4 months of life.130

Superimposed on these time-dependent changes in breast-milk composition is the maturation schedule of the infant’s own immune defenses. SlgA in saliva reaches its peak early at 6 weeks and remains stable until early childhood; serum immunoglobulins rise gradually from infancy through late childhood; and systemic inflammatory, phagocytic, and spe-cific lymphocyte-mediated subunits come on line during the first year.131,132 As noted earlier, breastfeeding reduces infant diarrhea in a dose-response manner. Nevertheless, this protective effect wanes off after 6 months, and disappears after the first year of life,133 partly because of developing infant Immunocompetence that devalues the relative mater- nal breast milk contribution.

A MATERNOCENTRIC MODEL OF THE PROXIMATE DETERMINANTS OF SUPPLEMENTATION

Reorganization of our earlier bicultural model of infant feeding to foreground maternal outcomes (Fig. 5) shows that trade-offs influencing the timing of supplementation and infant outcomes also pertain to “maternal burden,” defined as the physical and reproductive debts incurred by exclusively breastfeeding mothers, as elaborated above. As in the previ-ous model, culturally structured supports for breastfeeding extend the period of exclusive breastfeeding, whereas con-straints limit breastfeeding and encourage earlier supple-mentation. Pathogen risk was previously emphasized as a support for breastfeeding, but here it is subsumed as “a sup-port,” while maternal burden appears as a force encouraging supplementation. As with pathogen risk shown in Figure 4, maternal burden is represented by a dashed arrow to indicate that it may not be a culturally recognized and salient vari-able in the supplementation equation, despite its biological
Inconsistency between maternal burden and the culturally defined timing of supplementation opens up a "margin of depletion," leading to maternal depletion, reproductive risk, morbidity, and mortality. Where maternal burden is low, the margin of depletion may be narrow, even when infant benefits and social supports are strong. Contrasts on prolonged breastfeeding are weak, and breastfeeding is prolonged. This appears to be the case among the Am tele, strong social supports for breastfeeding delay the timing of supplementation, but maternal workload is low and nutritional status is relatively good. Therefore, the low maternal burden keeps the margin of depletion narrow despite the costs of prolonged breastfeeding. Conversely, Am tele women show no decline in weight or anthropometric measures during the course of lactation nor does maternal weight decline with parity. Observations when maternal burden is high, the margin of depletion will be wide, unless contrasts on breastfeeding are strong, supports weak, and breastfeeding is abbreviated. For instance, Guaj women of highland Papua New Guinea suffer pronounced maternal depletion despite late marriage and first birth (21.2 yr and 25.5 yr, respectively), and low and widely spaced births (total fertility, 4.3 live births; interbirth interval, 4.3 yr), because they breast very heavy workloads, experience marginal micro- and macroconsist in balance, and practice intensive prolonged breastfeeding (38.5 mo). The extent to which breastfeeding and supplementation practices and decisions privilege infant needs over those of the mother determines the margin of maternal depletion.

The degree to which infant benefits, local cultural supports for, and constraints against breastfeeding are consistent with maternal burden becomes an interesting ethical question, with real implications for maternal well-being. The maternocentric model provides testable hypotheses to complement those suggested by our earlier infanocentric model. First, it predicts that if cultures do operate in react to major challenges to well-being, then maternal burden will be an independent variable moderating any cross-cultural relationship between pathogen-risk and durations of exclusive breastfeeding. Under conditions of high maternal-risk, cultural ideologies and practices should support earlier supplementation, particularly where maternal productive or future reproductive potential is highly valued. Second, the optimal timing of supplementation from the maternal viewpoint may not coincide with and may actually differ substantially from the optimal timing for the infant. Where maternal and infant interests diverge most, greatest input will be required to implement effective improvements in infant care that minimize risks to infants and mothers. The models suggest that parallel comparative evaluation of both sides of maternal-infant breastfeeding equation (breastfeeding duration, pathogen risk, infant morbidity, maternal burden, and maternal depletion) should reveal that cultural and ecological trade-offs set the relative margins of risk for infants and for mothers.

CONCLUSION

The weaning dilemma remains immutable; our models demonstrate that there can be no universal prescription to remedy the weaning dilemma. We have attempted to elucidate this dilemma by constructing a biocultural framework that identifies both the costs and benefits associated with the duration of breastfeeding and their consequences for infants and mothers. Mothers and their babies share a commonality
of interest that informs the long-term intensity of emotional and material care that distinguishes the relationship.\(^{14}\) Ne-oethics, conflict between maternal and infant needs is a reality, and health outcomes are inevitable. Local cultural ecologists shape the parameters for these trade-offs and, ultimately, determine the patterns of breastfeeding and infant and maternal outcomes.

Our analysis reveals the complexity of the weaning concept and suggests a more realistic conceptualization of breastfeeding and weaning behavior. Weaning involves the introduction of supplemental foods but has been variously defined as the initial introduction of non-breast milk substances, the onset of regular supplementation, or the introduction of solids. Weaning is also often conflated with termination of breastfeeding or cessation. Modeling breastfeeding ecology underscores the embeddedness of supplementation in ongoing breastfeeding. Specific weaning practices thus represent a particular mix of breastfeeding and supplementation.\(^{15}\) In addition to the timing of introduction of solids, the breast milk-supplementation ratio and the pace of transition from exclusive breastfeeding to solids are significant variables that can affect infant outcomes.

The models of breastfeeding behavior outlined above highlight the implications of weaning ecology for the timing of infant supplementation. The epidemiological literature has long documented the relationship between breastfeeding and infant morbidity, and anthropologists have emphasized on the sociocultural contexts that shape patterns of child care. This article attempts to bring these perspectives together to consider another risk factor critical that is constructed by culture and that has the potential to shape culture and behavior in turn. The emphasis on breast milk and infant morbidity also highlights the infant in the breastfeeding scenario. Exclusive breastfeeding is the focal decision-making process that influences the implications of these decisions for infants in different contexts. The infant, after all, is the one who suffers from diarrhea, or whose growth is stunted from inadequate supplementation. The benefits of breast milk cannot be fully understood without a consideration of the trade-offs experienced by the infant with respect to the local disease ecology.

Conversely, exclusive focus on infant outcome denies the finiteness that breastfeeding exists significant costs on maternal physiology and autonomy. By ensuring maternal burden in our intersocietal model of the determinants of supplementation (Fig. 3), we highlight these costs and emphasize their potential consequences for maternal, and ultimately, infant, well-being. Obviously, the best-case scenario is prolonged breastfeeding by a well-nourished mother in a low-pollution environment with appropriate supplementation. But ideal conditions seldom prevail, and any health intervention that seeks to evolving exclusive breastfeeding needs to consider the consequences of maternal depletion and mobilize to limit maternal burden.

Last, these models can guide interventions into the interactive impact of specific ecologies on breastfeeding behavior and infant health. Does the cultural ecology surrounding breastfeeding minimize the timing of supplementation with respect to infant health? Do culture obscure this perception? In which aspects of the physical, social, ideological, and political ecologies are infant outcomes to supplementation decision? Such questions not only guide research, but suggest the most effective avenues of intervention.

We conclude that there is no simple formula ideal solution to the weaning dilemma that could be uniformly applied by all (or most) mothers in all (or even) populations. Rather, the optimal solution for question of exclusive breastfeeding, and infant supplementation schedule, varies according to specific ecological conditions and must be sought through holistic modeling of these conditions. That a universal solution is unavailable does not preclude the use of a general method for deriving locally appropriate resolutions to this dilemma. Our models provide a framework for making rapid in situ assessments of which variables have the highest local salience and should, therefore, receive priority in designing programs or interventions. Current models in public health privilege infant needs, whereas those in reproductive ecology underscore maternal reproductive outcomes. Both focus closely on maternal infant process at the expense of neglecting political, economic, ideological, or sociocultural structural factors that may place mothers and infants at risk. Maternal and infant morbidity and outcomes are mutually defining, yet not synonymous; if we aim to promote infant and maternal well-being, then these complexities can only be understood through integrated models that weigh construction, support, and risk for both parties, and point to their structural bases. We hope the models presented here will stimulate that process.

REFERENCES


