



# **SPLASH!®** milk science update February 2017 Issue



This month's issue features the potential of milk to treat pre-term and ill infants, the healing properties of milk, the connection between cows' immune systems and milk production, and a cultural look at colostrum.

## **Milk's Bioactive Ingredients Help Wounds Heal Faster**

- **Milk contains biologically active ingredients, including white blood cells, antimicrobial proteins, and cell-signaling molecules, that influence immune function.**
- **Milk from various mammals, including humans, has demonstrated positive effects in animal models on healing lesions of skin and eyes by stimulating and enhancing the body's immune response.**
- **Topical application or oral ingestion of immunologically active cow's milk components, such as whey protein, may be particularly important for diabetics that have slow wound repair.**
- **Bioactive components from human and cow's milk offer promise as nutritional adjuvants for wound healing.**

They say time heals all wounds. But can milk help those wounds heal faster? Noting milk's ability to stimulate and support the development of an infant's immune system, researchers posed the simple, but elegant, hypothesis that milk could accelerate the healing process by enhancing the body's immune response. A growing body of studies with animal models provides strong support. From lesions of the corneal epithelium to lacerations of the skin, milk-treated groups healed faster than controls, and milk helped slow-healing diabetics match their healthy peers [1-5]. Importantly, these differences can't be chalked up to just nutrition. Blood samples from groups supplemented with milk (or milk-derived proteins) had significant changes in immunologically active molecules implicated in wound healing. Milk's ingredients influenced the way their immune system operated—for the better. Milk may be a beverage, but it clearly shows great promise as medicine.

### **Wound Healing 101**

Skin is the body's largest organ, and it is also an integral part of the immune system. Skin keeps the outside, and all of its potential pathogens, out. The same is true for the epithelial lining of the eyes, mouth, and all other potential portals that antigens can breach. These surfaces constitute our best defense against the germs of the outside world. Anything that compromises their ability to do their job has to be dealt with immediately.



From a small paper cut on the thumb to a major laceration of the leg, the healing process is the same: inflammation, proliferation, and remodeling. Inflammation usually has a negative connotation when it comes to human physiology, but it is a necessary and critical first step in wound repair. Immediately after injury, the immune system sends white blood cells to clear the denuded area of potential pathogens, such as bacteria. These same white blood cells also are responsible for releasing chemical messengers, called cytokines, to orchestrate the inflammatory and subsequent phases of wound repair. Some of these cytokines are referred to as pro-inflammatory because they help orchestrate the inflammatory response. Others are anti-inflammatory, helping to ensure the inflammatory phase comes to an end.

The balance between the two types of messenger molecules during the inflammatory stage is critical—too many inflammatory cytokines may prolong the inflammatory phase, but too many anti-inflammatory cytokines may keep that phase from occurring at all. The importance of these cytokines, and their relevant concentrations, is clearly demonstrated when wound healing is modeled in diabetic animal models [1,2]. Diabetic rats have higher levels of anti-inflammatory cytokines than their healthy peers, resulting in a delayed inflammatory stage and a subsequently slower healing process [1,2].

Following inflammation, epidermal cells migrate to the wound site and undergo rapid mitosis to replace the damaged cells and fill the space (hence, proliferation). Importantly, barking orders to begin this stage also come from white blood cell-secreted cytokines. These chemical messengers are responsible for telling cells where to go, when to make copies of themselves, and perhaps most importantly, when to stop making copies of themselves. And during the final phase of wound repair (remodeling), these same cytokines are responsible for telling cells to make collagen proteins, the glue that holds the skin cells together.

## Milk's Healing Ingredients

For wound healing to proceed in a timely and efficient manner requires many different types of immune factors (neutrophils, macrophages, antibodies) to each send the correct message (make copies, eat the bacteria, make collagen) at the correct time. Delays increase the body's risk of infection, so it is not surprising that clinicians are very interested in identifying wound-healing adjuvants—substances that enhance the body's immune response.

Milk is an obvious choice to use as an adjuvant. One of its primary objectives is to stimulate and support the development of the infant's immune system, and it is well known that it contains biologically active proteins such as lysozyme, lactoferrin, and antibodies, as well as pro- and anti-inflammatory cytokines. But the magnitude of ingredients that play a role in wound healing was only recently elucidated [3]. Performing a detailed molecular analysis of bovine colostrum (the milk produced during the very first days of lactation), Altomare and colleagues identified over 1700 different proteins in colostrum. When these proteins were clustered based on biological function, 93 proteins related to one or more of the stages of wound repair (e.g., inflammation, tissue-remodeling, collagen synthesis, blood vessel formation) [3].

Colostrum is known to have a higher concentration of immune components than mature milk, so the number of active proteins may be lower in other lactation stages. Total protein number may also differ in milks from different mammals (for example, human milk may have more immune factors than cow's milk). However, Altomare et al. [3] highlight the high homology (structural similarity) between the proteins identified in bovine milk and those produced by humans. Structural similarity may mean functional similarity, suggesting these proteins can have positive effects on wound healing in humans despite originating from a cow. While using human milk on humans may be the ideal, cow's milk (which is available on a much larger scale) may be sufficient to get the job done.

## Putting Milk to the Test

Rodent models support the hypothesis of functional similarity across species. Human, cow, and camel milk have each demonstrated positive effects on wound healing in rats [1-3, 4]. For example, human milk used as eye drops for rats with corneal epithelial wounds resulted in faster healing than either artificial tears or autologous serum drops (drops made from the patient's own blood) [5]. Artificial tears lack any factors that promote healing, but autologous serum drops were believed to be the closest to real tears because of the presence of growth factors and antibodies that occur naturally in serum. Milk, however, may be the best tear alternative, providing a greater number of factors—such as lactoferrin, fibronectin, and epidermal growth factor—that enhance epithelial wound healing [5].

Importantly, those three very same ingredients, and many more, can also be effective in wound repair when they are added to the diet. In two related experiments, Abdel-Salam and colleagues [1,2] investigated how supplementation with camel milk whey proteins influenced wound healing in diabetic rats. They selected the whey fraction of camel milk because, like all mammal milks, it contains bioactive proteins, pro- and anti-inflammatory cytokines, and cytokines that modulate cell migration and cell adhesion. In both studies, diabetic rats supplemented with camel milk proteins had faster healing skin lesions than did diabetic controls, and actually matched the healthy controls in progression from each stage of healing.

At first read, one could suggest that the supplemented rats healed faster simply because the extra protein gave them a nutritional boost. But chemical analysis of their blood tells a different story. Rats receiving whey protein had distinct cytokine profiles—higher levels of inflammatory cytokines (e.g., interleukin 6) and lower levels of anti-inflammatory cytokines (e.g., interleukin 10) than did diabetic controls. In effect, camel milk whey supplementation “normalized” the rats' cytokine profiles [1,2].

Interestingly, the immune boosting effects of camel milk proteins occurred only in groups supplemented during the healing period; supplementation before wounding the study animals did not alter cytokine profiles or accelerate healing. This suggests the biologically active proteins and other molecules in milk interact with the host immune system immediately after ingestion and cannot be stored for a rainy (or wounded) day. As a potential adjuvant for wound healing in human diabetics, this is good news. Supplementing after an injury as part of a treatment plan is much easier to implement than requiring patients to take supplements daily just in case of a wound.

## Milk in the Medicine Cabinet

But how likely is it that milk (or whey) supplementation will help human wounds heal? This question has yet to be systematically addressed, but there are several reasons to be optimistic. First, similarities in cytokines, proteins, and other bioactive components used for wound healing between rats and humans (and really, across all mammals) offer promise for similar positive health outcomes. Indeed, whey proteins from cow's milk in particular, and cow's milk products in general, are associated with improving health in diabetic humans, including increasing the body's sensitivity to [insulin](#). Second, the amounts of whey protein needed to produce the changes in cytokine profiles in the diabetic rats were well within the limits for human protein supplementation (e.g., 100 milligrams whey per kilogram of body weight). People hoping to build muscle through whey supplements, or clinical studies that investigate the effects of whey on body composition often supplement with one gram (or 1000 milligrams) of protein per kilogram of

body weight. It is not yet known how much whey would be needed in humans to obtain similar results to those seen in rats. But if the amounts are comparable, the safety of the supplementation has already been established.

It is certainly exciting to think that the carton of milk setting in your refrigerator, or the cylinder of whey protein in your pantry has the ingredients to enhance your body's immune response during injury. Maybe someday in the near future, milk will become a fixture in our medicine cabinets.

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## Milk for Ill and Pre-Term Infants

- **Human milk contains various constituents that stop infants from getting sick.**
- **Infants born very early or born with certain medical problems can benefit from compositional modifications to the milk they consume.**
- **Medically appropriate human milk modifications include increasing the concentrations of all major macronutrients, raising the concentration of particular nutrients, and reducing the odds that specific proteins in the mother's diet get into her milk.**

Unadulterated, fresh, and straight from the breast, experts agree that human milk is the best option for healthy infants. Not only does it provide the macronutrients essential to fuel and build young bodies, it actively stops infants from getting sick by dosing them with immunoglobulins and with sugars that are indigestible by humans. These sugars block viruses that otherwise would be able to attach to cells lining the gut, and they selectively feed species of bacteria that prevent nasty bacterial species from causing disease. But what if a young infant is already ill? In a recent review [1], Sara DiLauro and her colleagues from University of Toronto, Canada, The Hospital for Sick Children, also in Toronto, offer a summary aimed at clinicians about how human milk may be modified to cater for the particular needs of pre-term and sick infants.

Why might infants with health concerns benefit from slight alterations to normal human milk? The micro-details of the composition of human milk vary from mother to mother. But the fact that this composition changes little even when a woman is not able to eat enough is surely a strong evolutionary hint that the recipe can't be improved.



One reason that may not always be the case is that young infants with health challenges, which would have spelled certain death for most of human evolution, are today frequently able to survive and flourish, thanks to a broad range of modern medical developments. In other words, there would have been little evolutionary pressure for the composition of the human milk to adapt to sick or premature infants' needs. We know, for example, that the gut of a very-low-birth-weight infant is physiologically immature, meaning that what gets absorbed into the bloodstream is quite different from what gets absorbed from the gut of a normal-weight infant born at term.

Sara DiLauro and her colleagues address four human milk modification strategies. The first among them are standard strategies to raise the energy concentration of milk from about 20 kcal per ounce (0.68 kcal/ml) to

whatever level is deemed appropriate. This may be appropriate for infants with unusually high metabolic demands. Such demands can arise, for example, from the development of infections like sepsis, having an atypically high resting heart rate (tachycardia), or having a lot of red blood cells per volume measure of blood—a condition called polycythemia, which can develop in response to chronic hypoxia. The authors report that an infant with congenital heart disease often does better when supplied human milk of 24–30 kcal per ounce, which can be created by adding either liquid fortifiers or powdered formula to milk. The authors also warn that differences in the osmolality of the milk mixture—compared with unmodified human milk—should be carefully monitored; if the osmolality gets too high, infants may have trouble tolerating the modified milk.

In some cases, increasing the concentration of a particular human-milk component, rather than that of many macronutrients in one go, may be worthwhile. The first step in “target fortification,” as this is known, is to analyze the macronutrient content of a sample of human milk that the needy infant is consuming, so it’s clear exactly how much protein, fat, and carbohydrate he or she is getting. Then the exact amount and kind of additional nutrients can be calculated to meet individual requirements. Where it has been tried, this approach has led to more consistent growth among pre-term infants, the authors report. Nonetheless, target fortification can be expensive and logistically complicated.

Occasionally—about 2% to 3% of the time—infants show signs of an allergy to cow’s milk protein (CMPA). The percentage with this problem is much smaller among infants who are breastfed. CMPA can cause all kinds of diverse symptoms, from mucus in an infant’s stool to breathing difficulties. Among formula-fed infants, the offending source proteins come from the cow’s milk that was used to manufacture the formula; the solution to their woes, therefore, is simply to switch to a soy-based formula, assuming that breastfeeding is not an option and that the infant is not also allergic to soy, which they are about 14% of the time. Among breastfed infants, the problem is likely to be whey and casein proteins consumed by the mother and passed on in her milk. In these cases, the mother should be advised to avoid eating the sources of these proteins and see if the infants’ symptoms abate.

The last topic that the authors discuss is the modification of fats in human milk. Globules of structurally diverse fats do wonders for the healthy development of infants and appear to play a role in healthy brain development. Fats also provide up to half of the raw energy content of human milk. However, there are a few, rare medical disorders in which the provision of the usual suite of fats causes problems. Some infants, for example, have a condition called chylothorax, meaning that their thoracic duct is incompletely developed, and a substance called chyle, which is rich in triglycerides, can build up in their chests.

The methods for managing infants with chylothorax are far from perfected. Although researchers have started to study ways of removing and replacing the fats in human milk, and a few specialist hospitals have offered milk with modified fat to infants with chylothorax, there are still no recommendations for the optimal milk fat level for these infants.

DiLauro and her colleagues suggest chylothorax management as an area of focus for future research. And there are many more illnesses on that list. Moreover, little is known about how populations of different species of bacteria shift over time in infants born prematurely—those who start life with physiologically immature guts. Another review, published in 2014, made a direct plea for more premature infant microbiome studies [2].

Information gathering through diligent lab work and careful trials will hopefully push the best medical advice forward substantially in the years ahead. But it is just that—medical advice intended for deliberation by qualified medical practitioners. Without their recommendation, human milk in its natural form is the optimal foodstuff for infants—unadulterated, fresh, and straight from the breast.

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## The Energy Cost of Immune Cell Victory

- **The immune system of livestock can be frequently stimulated by disease challenges and gut inflammation caused by heat stress and dietary changes.**
- **Activated immune cells preferentially use glucose as an energy source.**
- **Energy in the form of glucose is prioritized for use by the activated immune system at the expense of milk production.**
- **A single acute immune cell response within a lactating dairy cow costs the energy equivalent of at least one kilogram of glucose.**

Immune cells are strange beasts. Their favorite occupation, like a child nearing the end of a long summer vacation, is just hanging around looking for something to do. Usually, they just cruise the body in the blood, sometimes detouring into tissues seemingly just because they can. All is good.

During this time, immune cells have only one major function—surveillance. Their immediate job is to identify invading bacteria and viruses that may cause illness. Detection of these foreign microbial agents by the immune cells then causes their activation and the initiation of a robust defensive battle that ultimately destroys the invading micro-organisms. Most battles are victorious, but there is a cost of success—the diversion of chemical energy away from the maintenance of everyday events, like animal growth and milk production, to fuel the defensive immune cell battle.

Production animals are faced with frequent immune system challenges that include not only microbial infections such as mastitis but also chronic gut inflammation caused by feed changes and heat stresses. The energy cost of fueling these immune cell responses has

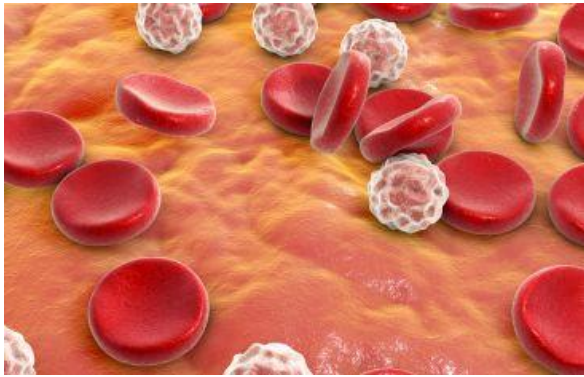
been difficult to calculate and even its approximate magnitude has been unclear.

Recently, a team of researchers from Iowa State University led by Lance Baumgard performed intriguing experiments using lactating Holstein cattle to determine the magnitude of the energy cost of an immune response[1].

The researchers selected lactating Holstein cattle and subjected them to three treatments. The first animal group received an intravenous control treatment consisting of a saline solution. The second group received a small amount of a very potent bacterial cell wall component, lipopolysaccharide or LPS, which is known to induce a strong immune response in nearly all animals, including cattle. The LPS was used to trick the cattle immune system into a robust response to a phantom bacterial infection. The third group also received the LPS but additionally, glucose was continuously infused into the blood to maintain a constant blood glucose level. The cattle were then intensively monitored for a period of twelve hours during which they were fasted to avoid the confounding effects of different feed intakes.

In both of the groups receiving LPS compared with the control group, there were increases in blood proteins characteristic of infections, a striking 80% reduction in milk yield, an approximate 11% reduction in milk lactose percentage, and many diagnostic signatures often accompanying an infection—including mild hyperthermia—but only in the first 1.5 hours after treatment. In the animals that were only infused with LPS there was initially a substantial though transient 84% increase in the blood glucose level in the first 2.5 hours following the LPS treatment. This was likely the result of glucose mobilization from the liver to fuel the energy hungry immune cells activated by LPS in the blood. However, for the remaining experimental time, there was a sustained 30% decrease in blood glucose (severe hypoglycemia, suggesting that glucose resupply from the liver was exhausted. Correspondingly, there was a 160% increase in blood lactate levels (hyperlactemia). The decreased blood glucose combined with increased lactate levels point toward the activation of a biochemical pathway that directly metabolizes glucose to generate energy.

Immune cells preferentially obtain their energy supply from glucose [2-6]. Hence, the amount of glucose infused into the blood of the LPS-treated cattle (the third cattle group) to maintain a constant blood glucose level plus the glucose associated with the reduction in total milk lactose production (lactose is synthesized from glucose) over the twelve-hour period was used as a proxy for the total amount of glucose consumed by the immune cells activated by the LPS.



The researchers concluded that a single acute immune cell response costs the energy equivalent of burning at least one kilogram of glucose over a twelve-hour period [1]. This is a lot of energy unable to be used for direct production purposes! Tellingly, the authors also list a number of biological and technical reasons why this number is likely to be an underestimate.

The study also dramatically demonstrated that lactation was rapidly and severely sacrificed presumably to spare glucose for directly fueling the activated immune cells. The authors hint that this is an evolutionarily conserved response in mammals that strongly prioritizes animal survival over lactation. Thus, the lactation and immune cell activation biological systems are intimately intertwined. The detailed mechanism underpinning the severely decreased milk output after the introduction of LPS into cattle

may also involve adverse direct and indirect effects of LPS on the mammary cells synthesizing milk.

Maximizing livestock productivity requires the optimal partitioning of energy resources between competing and often differently prioritized biological systems. Farm animals that have frequently activated immune systems will divert energy resources away from production traits to prioritize immune responses, thereby potentially decreasing productivity. The study of Baumgard and colleagues has now quantified the minimal energetic cost of an activated immune system [1]. The cumulative energy requirements of multiple microbial challenges, dietary changes and heat stress throughout the life of a farm animal are likely to be large. Thus, emphasis on herd management in these areas may yield big rewards.

Clearly, immune defense wins the day (protection from disease), but there is an energy cost to pay.

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## Colostrum Through a Cultural Lens

- **Perinatal mammary secretions, known as colostrum, are rich in immune molecules and complex sugars.**
- **Five-hundred years ago, experts in medicine and animal husbandry cautioned against feeding colostrum to newborn animals and humans.**
- **Many cultures practice “denial of colostrum.”**
- **Successful public health campaigns incorporate cultural identity.**

In the first hours and days after a human baby is born, mothers aren't producing the white biofluid that typically comes to mind when we think about milk. They synthesize a yellowish milk known as colostrum or “pre-milk.” Colostrum is the first substance human infants are adapted to consume, and despite being low in fat, colostrum plays many roles in the developing neonate [1]. Historically and cross-culturally, colostrum was viewed very differently than it is amongst industrialized populations today.

### Colossus Colostrum

A colossus is not just something large, it can be “something of great power, influence, or importance.” Colostrum, the smallest drops for the tiniest tummies, effectively fits this definition because of its substantial effects on organizing the infant's health, metabolism, and microbiome. At birth, babies are first appreciably exposed to maternal and environmental microbes while they have relatively naïve and immature immune systems. During this neonatal period, infants have permeable intestines that facilitate transport of maternal-origin hormones into circulation.



Immune proteins are particularly enriched in colostrum compared with mature milk. Macrophages, a type of white blood cell, are enriched in colostrum, and function to engulf and “digest” microbes [2] like *E. Escherichia coli* [3]. Immunoglobulin A (IgA), secreted at mucosal surfaces, defends against ingested pathogens [4] and is a particularly prominent immunofactor in colostrum [5]. Complex sugars attach to proteins, such as IgA [6] and lactoferrin, that influence microbes that colonize the infant's intestinal tract [7]. In one study, exposure to colostrum via mouth swabs in very-low-birth weight, premature infants in a Neonatal Intensive Care Unit changed microbial colonization of the oral cavity [8]. Additionally, the

concentrations of growth factors in colostrum are higher than in mature milk [9-10] and underlie “lactocrine programming” of infant development during ephemeral windows of sensitivity [11].

In these ways colostrum is a medicine and a signal for the neonate while providing food for the microbes. During early neonatal days, infants lose weight as they mobilize fat deposited during fetal life to sustain energy [12], particularly among breastfed infants [13], until their bacterial buddies are on board to assist digestion and transitional milk is delivering more calories.

### Colostrum in Historical Context

Modern scientific understanding of the role of colostrum for the neonate stands in stark contrast to the Western historical perspective of this “pre-milk” substance. In 1577, Heresbach's 4-book series on animal husbandry, translated by Googe, provides an early record of the use of the term “colostrum” in English [14]. As the book cautioned, “you must be sure to milke out the fyrst milke called Colostra... for this, except some quantitie be drawn out, doth hurt the Lambe.” Before being called colostrum, early milk was called “bystings,” “biestings,” or “beestings” and was met with similar skepticism. Thomas Newton translated from Latin the 1577 health guide of Guilielmus Gratarolus that claimed “the thicke and curdie Milke... commonly called Biestings, is very dangerous” [15].

Indeed, throughout pre-industrial Europe, colostrum was perceived as dangerous, unhealthy, or harmful to the baby [16]. Some of the perceived disgust with colostrum likely originated due to the yellowish, viscous features shared with another fluid rich with immune cells—pus. Although such fluid at the site of an active infection is due to the substantial concentration of dead white blood cells, colostrum is packed with the richness of living immune cells that protect the infant and entrain the immune system [17].

Within Europe, this cautionary disdain for colostrum persisted for hundreds of years, but by 1737 Henry Bracken stated in his handbook on midwifery that “The Colostrum or first Milk is a medicinal Nourishment which Nature hath prepared for the Purpose that it should moderately nourish” [18].

## No Country for Colostrum

Despite the scientific advances in decoding colostrum, across many human cultures, anthropologists and other ethnographers have documented colostrum taboos. In 1966, Dr. Dana Raphael's doctoral thesis [19] explored what was then known cross-culturally about the timing of initiation of breastfeeding. Using the [Human Relations Area Files](#), (HRAF), a database of cross-cultural information "to promote understanding of cultural diversity and commonality" established in 1949, Raphael identified 32 different societies in which breastfeeding was initiated 3–7 days after the infant's birth. Expansion of the HRAF database has increased the number of societies known to have some degree of colostrum taboo. Of the 120 different cultures for which information about timing of breastfeeding initiation was available, in 50 cultures, 41%, initiated breastfeeding after 2 days post-partum [20].

In previous generations, initiating breastfeeding several days after parturition was reported as customary among many peoples across the globe—from the Dard, Burusho, Gujaratis people in regions of Afghanistan, Pakistan, and India, to the Nupe and Hausa people of West Africa, to the Mongo of Central Africa, the Khoikhoi of Southern Africa, the Tuareg people of the Sahara, among the Tübatulabal, Ojibwa, Creek, Navajo, and Tarahumara of North America, and the Jivaroan peoples along the Marañon River in South America, the Manus of Papua New Guinea, and among Pacific Islanders from Samoa, Marquesas, and Marshall Islands [21]. Dr. Mel Konner, having conducted extensive research among the Zhun/Twasi (known among Westerners as the !Kung), reported in 1972 that "the infant is not put to the breast until the colostrum has run out" [22]. Among Mithila, women in India within the Ayurvedic tradition state that "A mother's 'real' milk is not ready at the time of her child's birth; rather it comes 2 or 3 days later when heat in her body transforms 'water' into milk" [23].

Colostrum taboos reflected the perception that colostrum was dangerous—the Aka people of Central Africa caution that "'First milk,' contaminated liquid from pregnancy, can make infants sick and die" [24]—or problematic—as warned by the Marquesan Islanders "if a mother nurses her infant immediately (after birth), the child will be difficult to raise" [21]—or disgusting—"colostrum is a foul substance that oozes from the breasts... like pus" [23]. In some cultures, postponement of nursing is to afford mothers time to recover from the exertions of labor and delivery [20,23].

Within some of these traditional contexts, during the period in which the neonate was denied colostrum, infants would be breastfed by another woman [21]. Among the San people of Southern Africa, lactating women who were producing mature milk would suckle the neonate [21]. In Iran, a woman who was rearing an infant of the same sex as the neonate would provide milk [19]. Among the Iatmul of Papua New Guinea, a woman who recently delivered a baby, and who was likely synthesizing transitional milk, would breastfeed the newborn during the colostrum taboo [19]. British Colonel John Biddulph traveled widely in the Himalayas and reported in 1880, that among the Ashimadek clans in the Chitral region of modern day Pakistan, infants were nursed by all lactating women in the community [25]. In this way, the denial of colostrum in many cultures was made possible by allomaternal-nursing and cooperative care of infants [26-27]. Although milk sharing has received increasing research effort [28-29], biocultural studies of allo-maternal nursing have remained rare [30].

When milk from another woman was not available, or allo-maternal nursing was not practiced, other milks or gruels were commonly prepared for the infant [19-21]. In pastoralist cultures that have colostrum taboos, the newborn can be fed cow's or more often goat's milk. In other cultures infants were, and sometimes still are, fed a specially prepared gruel consisting of water mixed with mashed, ground, pounded, or stewed solids such as sugar, molasses, butter, coconut, flour, breadfruit, maize, herbs, pollen, acorn, piñon, seeds, taro, or roots [20-21]. These newborn gruels reflect the subsistence practices and local ecology of the respective peoples [20].

Seemingly less common, but occasionally observed, are cultural practices in which newborns are provided only water [21,24] or nothing at all [21]. Of greater concern are cultural practices in which neonates are provided purgatives that increase risk of dehydration [20-21].

Relatively limited biomedical research effort has been allocated to directly investigating the health consequences of colostrum taboos among traditional societies. One rare example found that children in Gujarat State, India who were denied colostrum were significantly more likely to be two standard deviations below weight for age and height for age than were infants who breastfed shortly after birth [31]. Without more such studies, the primary option is to extrapolate from studies in which infants are exclusively breastfed or exclusively formula-fed from birth in industrialized populations, which may poorly approximate the context, ecology, and dynamics that characterize an appreciable proportion of human cultures. The immediate concern is the impact on infant immune, microbial, and gut function and maturation. Additionally, given that milk flow through the mammary gland during the first post-natal days influences milk production weeks later [32], colostrum taboos may lower capacity for milk production later in lactation. The health implications of these cultural practices are myriad, and the magnitude of the consequences remains poorly understood.

## Public Health in the Context of Colostrum Taboos

Across every human society, motherhood and childhood are deeply embedded within social relationships and cultural identity [33]. For those communities characterized by traditional cultural practices that include colostrum taboos, advocating for optimal breastfeeding practices or public health interventions presents challenges [34]. Many of the populations discussed here are in

nations that have relatively higher infant mortality [35] and traditional communities may experience even greater pathogen risk and more limited access to health care. Such conditions increase the impetus to motivate people to adopt best practices for the neonatal period. In order to productively achieve these public health goals, building partnerships within the community and demonstrating cultural competence are essential [36-37]. Morse and colleagues recommended that health care practitioners “should determine the mother’s beliefs and cultural practices concerning colostrum and early infant feeding” and determine whether education can be used to sustainably shift cultural practices [20]. Importantly, mothers who decline to breastfeed during the immediate post-partum period due to colostrum taboos may actually have every intention to breastfeed subsequently.

Notably, many of the citations presented in the present essay reflect cultural practices of previous generations, rather than a cross-sectional snapshot of current prevalence. Indeed, using the search term “colostrum taboo” time restricted from 2006–2016 in Google Scholar yielded no articles. Other search approaches suggest that global health efforts are having an impact. Fewer than 20% of Turkish infants were denied colostrum for the first 24 hours after birth [38]. Among women in Gujarat State, India more infants are nursing in the first post-natal hours, and fewer than 25% of infants are denied colostrum, a substantial improvement from earlier studies [31]. However, elsewhere in India, denial of colostrum remains prevalent [39] and is still practiced among some traditional societies [24].

Many scholars and clinicians, especially at the forefront of promoting and facilitating skin-to-skin and early latch, are likely doing a double take reading about these cultural practices. Many may have encountered them due to human migration and cultural diasporas. Morse and colleagues caution medical health practitioners that assessment is essential before interventions [20]. Attempts “at ‘correcting’ a cultural belief may alienate the mother from the caregiver or the health care service” and ultimately do harm. Moreover, depending on household composition and power dynamics, messaging about optimal practices for infant health may require including grandmothers and aunts who are socially enforcing traditional customs [34,39]. Addressing these issues has been and will be most effective at the intersection of the life sciences, social sciences, and global health practice.

In memoriam for [Dr. Dana Raphael](#) 1926–2016.

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