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Mother–Infant Cosleeping, Breastfeeding and Sudden Infant Death Syndrome: What Biological Anthropology Has Discovered About Normal Infant Sleep and Pediatric Sleep Medicine

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ABSTRACT Twenty years ago a new area of inquiry was launched when anthropologists proposed that an evolutionary perspective on infancy could contribute to our understanding of unexplained infant deaths. Here we review two decades of research examining parent–infant sleep practices and the variability of maternal and infant sleep physiology and behavior in social and solitary sleeping environments. The results challenge clinical wisdom regarding "normal" infant sleep, and over the past two decades the perspective of evolutionary pediatrics has challenged the supremacy of pediatric sleep medicine in defining what are appropriate sleep environments and behaviors for healthy human infants. In this review, we employ a biocultural approach that integrates diverse lines of evidence in order to illustrate the limitations of pediatric sleep medicine in adopting a view of infants that prioritizes recent western social values over the human infant's biological heritage. We review what is known regarding infant sleeping arrangements among nonhuman primates and briefly explore the possible paleoecological context within which early human sleep patterns and parent–infant sleeping arrangements might have evolved. The first challenges made by anthropologists to the pediatric and SIDS research communities are traced, and two decades of studies into the behavior and physiology of mothers and infants sleeping together are presented up to the present. Laboratory, hospital and home studies are used to assess the biological functions of shared mother–infant sleep, especially with regard to breastfeeding promotion and SIDS reduction. Finally, we encourage other anthropologists to participate in pediatric sleep research using the unique skills and insights anthropological data provide. By employing comparative, evolutionary and cross-cultural perspectives an anthropological approach stimulates new research insights that influence the traditional medical paradigm and help to make it more inclusive. That this review will potentially stimulate similar research by other anthropologists is one obvious goal. That this article might do so makes it ever more possible that anthropologically inspired work on infant sleep will ultimately lead to infant sleep scientists, pediatricians, and parents becoming more informed about the consequences of caring for human infants in ways that are not congruent with their evolutionary biology. Yrbk Phys Anthropol 50:133–161, 2007. © 2007 Wiley-Liss, Inc.

"Telling mothers and fathers how to bring up their children in books is arguably as silly as sending false teeth through the post and hoping they fit" (Hardyment, 1983, p. 15).

One aspect of evolutionary medicine with which most biological anthropologists are familiar (and in which some of us are actively engaged) examines the potential incompatibilities between the lifestyles and environments in which humans currently live and the conditions under which human biology evolved (Nesse and Williams, 1994; Trevathan et al., 1999, in press). Researchers that explore the health implications of "western lifestyle" on conditions such as diabetes, obesity, ovarian function, reproductive cancers and degenerative chronic disease (to name a few) have tested hypotheses derived from an evolutionary paradigm and advanced our understanding of the mechanisms by which a mismatch between current behavior (e.g., diet, activity, and timing of reproduction) and physiological mechanisms that evolved under very different living conditions (e.g., patterns of fat storage and attrition of ova) have come into conflict (Pollard, in press; Trevathan et al., in press). Encompassed by this umbrella, evolutionary pediatrics considers the consequences to

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infant and child health of the adoption by western societies of untested and historically novel care-giving practices for which infants are not necessarily biologically designed (Ball, in press). We recall Barash's (1986, p. 60) observation regarding the overall stability and constancy of human infant biological needs relative to the fast-changing culture around them. He states as follows: "... there would be little if any difficulty exchanging a Cro-Magnon and a modern infant, but great incongruity in making the same switch with adults of both cultures."

Similarly, Bruner (1972, p. 687) reflected on the likely limitations, in this case, of western child learning models that forego any evolutionary considerations. He suggested that "... it would be a mistake to leap to the conclusion that because human immaturity makes possible high flexibility in later adjustment, anything is possible for the species ... we would err if we assumed a priori that man's inheritance places no constraint on his power to adapt." We view this as a central concept in examining the potential mismatch between certain contemporary Euro-American infant care practices, and our infants' ability to accommodate these practices—and suggest that we are pushing infant adaptability (and indeed maternal adaptability) too far, with deleterious consequences for short-term survival and long-term health.

Drawing upon cross-species, cross-cultural, historical, and physiological evidence, evolutionary pediatrics makes it clear that notions about what human infants need and why, especially as regards nighttime sleep and feeding patterns, seems to reflect far more about what societies want parents to be and infants to become (self-sufficient and independent) rather than what infants actually are—exceedingly dependent, and unfinished "extero-gestates" to use Montagu's (1986) description. Indeed, especially in early human infancy—and from an evolutionary point of view—reference to the mother's body is critical to understanding not only what infants need but what they can and cannot do and why. After all, as Hrdy (1999, p. 69) aptly puts it: "For species such as primates the mother IS the environment ..." meaning that practically nothing about a human infant makes sense except in light of the mother's body. Consider, as an illustration, that the delivery of breast milk and the context of its delivery create continuous sensory maternal–infant exchanges involving touch, smell, movement, sound, and taste. Altogether these sets of interactions function as the only physiological and behavioral regulatory microenvironment to which an infant is adapted (also see McKenna and McDade, 2005). This perspective does not mean to imply the existence, now or in the past, of some near-perfect original set of conditions from which all evolutionary reconstructions and functional interpretations of current infant care must flow; but it does force a reconsideration of the limitations of an exclusively culturally based rationale for nighttime infant-maternal separation which, it can be argued, places both breastfeeding mothers and infants at odds with their respective biological needs for contact and the mother's most optimal way to deliver her infant food.

We explore here whether or to what degree western infant care practices have pushed too far the notion of the human infant's physiological independence from the mother. Except by way of mother's body which acts as a buffer human infants are not at all biologically prepared to respond as autonomous individuals to the selective pressures of the larger environment. Evolutionary perspectives on infancy often begin with work on the evolution of human birth (Trevathan, 1987; Rosenberg and Trevathan, 1995) that explores the unique development of human infants in the context of evolutionary constraints imposed by the voyage of a large-brained hominin through the relatively small birth canal of a bipedally adapted pelvis. This evolutionary compromise has resulted in truncated gestation relative to brain growth and delivery of a part-altricial part-precocial infant with only 25% of its adult brain volume to a mother who requires social assistance during birth (Trevathan, 1987; Martin, 1990). Contemplation of the birth process from an evolutionary viewpoint provides important insights into the way in which intrapartum care is delivered, ranging from the positions in which women labor and deliver, to the relative benefits of birth management by midwives and doulas vs. obstetricians (Jordan, 1980; Trevathan, 1987; Rosenberg and Trevathan, 1995).

It is no less than an anthropological axiom that the conflict between the architectural changes in the human pelvis subsequent to bipedalism followed by accommodation of increasing brain size made childbirth amongst humans anything but a casual event. It placed huge burdens on parents to invest substantially in the survival of their under developed and vulnerable infants. But insofar as the specific form of infant care-giving that follows birth is concerned it would seem that evolution played an odd trick: the same selective forces that so undeniably constrained prenatal processes including fetal sensitivity to the quality of the environments into which it will be born (Kuzawa and Adair, 2003; Pollard, in press) and the biology of birth itself (Trevathan, 1987) apparently put far fewer constraints on what parents actually do with, or for, their infants postnatally. Care-giving activities such as feeding, sleeping arrangements, patterns of social affiliation, communication, and the general patterns of parent–infant attachment, appear at times due to cultural reasons to wander far away from any original range of economic, social and physical conditions that might have produced them. The question the research described here sheds light on is whether, or to what degree, contemporary (and in some cases "recommended") care-giving patterns expose today's human infants to environments that are so far removed from those within which infant development evolved that maternal and infant health are compromised as a consequence.

One might think that with so much at stake (i.e., with energetically costly mating effort, gestation, lactation and parental investment effort to "raise" an infant to reproductive maturity) selection might have tightened its grip on what kinds of care could occur. That primate maternal care obviously finds expression even without specific genetic "programming" as to what precise form it should take permits flexibility such as that afforded by various patterns of allocare observed among nonhuman primates and human groups (e.g., Ross and MacLarnon, 2000; Sear et al., in press). In a contemporary technological context this flexibility in maternal care options appears to have become disadvantageous, as evidenced over the past half a century when urban western women became persuaded that an artificially synthesized cow's-milk based formula fed to infants via bottles was as good as or better than the species-specific milk their own bodies produced and could feed to their infants directly. That human infants accepted this alternative food source and survived was taken as evidence of its appropriateness and desirability, but uncritical acceptance of an alternative feeding strategy for human infants was premature. Although it is well-known to anthropologists that feeding artificial infant formula is hazardous in parts of the world that lack access to clean water and refrigeration, leading to high infant mortality rates from gastrointestinal infection, it has long been assumed that artificial formula feeding in affluent societies is a benign infant-care choice (Greer and Apple, 1991; Walker, 1993). However, a recent epidemiological study conducted by Chen and Rogen (2004) in the United States, where infant deaths from infectious diseases remain low even without breastfeeding, yielded an important finding. They conclude that in the United States 720 infant deaths between 28 days and a year might be prevented annually by breastfeeding. Human species-specific milk, therefore, continues to matter a great deal even where infants are born into affluent and highly sanitized environments. Moreover, it is also likely that many western women over the last 50 years succumbed to a range of reproductive cancers (cervical, breast or ovarian) and suffered other reproductive impairments potentially due to the loss of protection afforded by breastfeeding (see Pollard, in press; Collaborative Group on Hormonal Factors in Breast Cancer, 2002).

Of course, breastfeeding is not the only infant-care practice in western industrialized cultures that has been replaced by other more technologically based or socially acceptable infant care innovations with deleterious results. For solitary sleeping infants, for example, being placed prone (on their stomachs) in cribs was recommended universally throughout the 1970s and 80s, as this was observed to reduce sleep-related infant movements and promote more uninterrupted deeper sleep (a cultural goal of infant care) (Douthitt and Brackbill, 1972), but in the 1990s it became apparent that this recommended infant sleep position was associated with thousands of unexpected deaths of western infants (SIDS) for reasons still unknown (Kahn et al., 2002). Presently mother–infant sleep contact in the form of bed-sharing is recommended against by pediatric authorities (e.g., American Academy of Pediatrics Statement, 2005). This latter recommendation is, in our opinion, also highly problematic given (as will be demonstrated in what follows) the intertwined physiology of the sleeping human mother–infant dyad.

This review aims to enhance appreciation of the importance of examining parent–infant relationships from an evolutionary and cross-cultural viewpoint, which emphasizes the effects of assumptions and practices in critical areas of infant care, such as physical contact, sleep location, feeding, and weaning on infant health and development. We discuss these issues in the light of infants' evolved needs, physiological expectations and behavioral capabilities. Evolutionary pediatrics therefore aims to apply evolutionary understanding of infant development and care-giving practices to investigating the iatrogenic (unintentionally induced) effects of biomedically driven changes in infant care and the discordance between parental care-giving instincts, infant developmental needs, and culturally sanctioned practice in postindustrial societies.

Twenty years of research and publication by a growing cadre of biological and cultural anthropologists, pediatricians, midwives, physiologists and psychologists in exploring infancy and infant care from an evolutionary perspective has challenged the accepted views of sleep medicine and helped clarify the meaning and deficiencies of epidemiological findings in understanding infant sleep and nighttime patterns of human infant care. In so doing these researchers have defined a new agenda for critically evaluating public health messages regarding more optimal or appropriate infant sleep behavior and nighttime infant care. We begin by tracing the development of this area of inquiry from the initial hypotheses posed by McKenna regarding the relationship between infant sleep location and sudden and unexpected infant deaths. We review the process of establishing the technical and analytical methods for the first sleep studies to simultaneously monitor two sleeping partners (mother and baby) and discuss the outcomes of these studies; we explore briefly infant sleeping arrangements among nonhuman primates as far as has been reported, which is minimal, and explore the possible paleoecological context within which early human sleep and parent–infant sleeping patterns and arrangements might have evolved. Finally, a thorough discussion of our changing historical–cultural perceptions of infants in western societies is used as a background to fully understand the controversies surrounding the issue of cosleeping in the form of bed sharing in western cultures, a child care practice that has never been considered nor explored on anything even closely resembling a level scientific playing field by pediatric sleep medicine.

THE STARTING POINT: WHAT IS THE PROBLEM WITH INFANT SLEEP?

We begin in a particular time (the late twentieth century) and space (Anglo-American family homes). Our imagined families are new couples with their first baby, and it is nighttime. The dominant expectation for these initial months is parental sleep deprivation—their infant's sleep patterns do not match their own, and parents, desperate for a "good night's sleep," seek the magic solution for achieving a somnolent baby. Baby's grandmother advises a large bottle of formula at bed time so that baby will not wake to be fed in the night. Others suggest adulterating the formula with baby cereal for greater infant satiation or medicating baby with proprietary infant pain killers or colic remedies containing alcohol (or occasionally even alcohol itself) to "knock the baby out." Friends sing the praises of "Ferberizing the baby" or similar infant sleep training programs employing an oxymoron known as "controlled crying." Parents, who feel all else has failed, resort to the painful approach of "crying it out"—and while their infant screams alone in an adjacent room, they lie awake racked with guilt, forcing themselves to resist responding, reassuring each other "it is for his own good"—until the infant eventually collapses from exhaustion into sleep.

Anthropologists are uniquely privileged in being trained to view the behavior of contemporary humans through a lens that permits a particularly broad and comparative perspective. In employing this lens we can scrutinize the "management of infant sleep" as a cultural feature of the parenting behavior of our own societies and ask: What's wrong with this picture? How have several generations of new parents in western postindustrial countries been influenced to treat their babies in this way? And why did it come to be considered "normal?"

In this section of our review we provide some comparative background, drawing upon cross-species, cross-cultural, and historical evidence regarding the ways in which parents and infants sleep, and we speculate on the factors that influenced the development of the view of infancy characteristic of our own societies as portrayed above. This background, we hope, will set the scene for presenting the research of biological anthropologists into the effects of different infant sleep environments and permit contemplation of their consequences.

Human infant sleep in contemporary world cultures

. . . we must accept that the modern Western custom of an independent childhood sleeping pattern is unique and exceedingly rare among contemporary and past world cultures. (Crawford, 1994, p. 46).

One of us (Ball, 2007) recently conducted a cross-cultural review of contemporary infant sleeping environments for a volume on cross-cultural child rearing. In summarizing previous overviews she drew on two large-scale cross-cultural surveys: Barry and Paxson's (1971) report has often been cited as defining the normative pattern of infant sleeping arrangements worldwide. This review of 127 cultural groups for whom ethnographic reports were available attempted to code and quantify sleeping arrangements for infants based on ethnographers' descriptions and found that in 79% of the societies examined infants normally slept in the same room as their parents, with 44% sharing the same bed or sleeping surface. A more recent study conducted using the HRAF probability sample (Nelson et al., 2000) uncovered references to sleep contact in 25 of 53 societies for which infant care information was available and reported that placing infants in separate rooms at night was unusual (although no data were provided). Surveys of ethnographic descriptions have their obvious limitations, (such as their unsystematic nature, the biasing element of the ethnographers' interests, and the fact that private sleeping arrangements do not necessarily fall within the realm of the "anthropological gaze;" however, they do provide a crude means of gaining a quantifiable cross-cultural overview.

Jenni and O'Connor (2005) recently summarized the literature on culture and children's sleep in industrialized and complex modern societies, concluding that private bedrooms for children were actually the exception, not the norm, in contemporary world cultures. Although it might be assumed that parental attitudes to infant sleep may be similar in those societies with a strong Euro-American influence, researchers have noted interesting intercultural differences between parenting attitudes. Italian parents, for instance, who prefer to have infants sleep in their rooms, were reported by Wolf et al. (1996) to consider the American norm of putting children to bed in separate rooms to be "unkind"—echoing Morelli's finding that Mayan mothers were shocked to learn of the sleeping practices of American infants, arguing that to separate an infant from its mother for sleep was abusive or neglectful treatment (Morelli et al., 1992).

The practice of prolonged physical contact with the caregiver is a common theme in reports of infant care cross-culturally, particularly during the transition from wake to sleep and during sleep. In Mayan families, infants commonly fell asleep in someone's arms and were taken to bed with their parents, sleeping with their mothers from birth to 2 or 3 years of age or until the birth of their next sibling (Morelli et al., 1992). In Balinese society, Margaret Mead (cited by Jenni and O'Connor, 2005) reported that infants were held continuously day and night and that being alone for even brief periods of sleep was undesirable at any age but that infants and children were particularly vulnerable to spirit risks during sleep. More recent ethnographic reports reinforce similar themes. Liamputtong and Naksook's (1998) examination of child rearing practices among Thai mothers in Australia revealed that infants were routinely in the presence of adult company, particularly at nighttime, with 80% sharing their mother's bed. Likewise for Brazilian Terena children sleeping in the same bed with family members was customary practice and reflected the high values attributed to family links in the Terena culture (Reimao et al., 1998). Even within societies where Euro-American parental aspirations for infant independence may dominate, cultural subgroups still persist with traditional infant sleep practices that run counter to the dominant child-rearing ideology. Abbott's (1992) study of rural Appalachian families in Eastern Kentucky in the US, for instance, emphasizes how family solidarity is reinforced by physical sleep contact during infancy and childhood.

In contrast to the tendency in the postindustrial West to cast the role of the care giver as promoting and fostering infant independence, in Japan the converse perspective prevails. Here, the infant "is seen as a separate biological organism who from the beginning, in order to develop, needs to be drawn into increasingly interdependent relations with others. In America, the infant is seen more as a dependent biological organism who, in order to develop, needs to be made increasingly independent of others" (Caudill and Weinstein, 1969: 72). In re-examining the sleep practices in US and Japanese families, Latz et al. (1999) discovered that many more Japanese than US children (aged 6–48 months) regularly slept with their parents (59% vs. 15%, $P < 0.001$). Likewise, in Korean (Lee, 1992) and Chinese (Nelson and Chan, 1996) families parent–infant sleep contact is normal and common.

Within societies where western postindustrial infant care ideologies dominate, stark contrasts can arise between the infant sleep practices of indigenous cultural groups and those of the majority culture. Within the New Zealand cultural landscape, the issue of infant sleep was explored for Maori, Tongan, Samoan, Cook Island, Niuean and Pakeha (European) cultural groups in Aukland by Abel et al. (2001). They found that Pacific cultural groups favored sleep contact with infants while European-derived New Zealanders favored infants sleeping alone; however, there were differences and tensions between island-raised and NZ-raised Pacific care givers in their practices. The underlying cultural ideals regarding healthy personal development in early life were particularly crucial to understanding the desirability of shared or separate sleep environments for infants: Pakeha parents favored Western notions of increasing the independence and autonomy of their infants, while Pacific parents generally favored interconnectedness as the best means for fostering an infant's physical, moral and spiritual development (Abel et al., 2001). Similar contrasts can be observed by comparing infant care practices of immigrant groups in Northern Europe with those of resident Europeans. Even within a relatively small nation such as the UK, much cultural variation in infant sleep exists due to both the diversity in cultural practices of immigrants to the UK and variations in parenting style within the majority UK population. Gantley et al. (1993) documented the diversity of infant care practices in Cardiff between Bangladeshi and Welsh mothers. Bangladeshi infants were consistently cared for in a sensory rich environment, including sleeping close to other people both day and night. In contrast, Welsh infants experienced alternating periods of intense sensory input and deprivation with long periods of lone quiet sleep emerging as a culturally desirable goal for infants—as was encouragement of sleep independence at an early age.

A cross-cultural comparison of Sami and Norwegian children (Javo et al., 2004) challenges the belief that solitary sleep is positively correlated with independence. Significantly, more Sami than Norwegian children slept with their parents, yet Sami children were observed to be significantly less demanding of their parents' attention during play than their Norwegian counterparts. Interestingly, a report of the Norwegian SIDS study (Arnestad et al., 2001) documented that since 1993 sleep contact has emerged as a more common mode of sleep for Norwegian infants and attribute this to a campaign at the beginning of the 1990s to increase breastfeeding in Norway. In Sweden, 23% of 3-month-old Swedish infants were found to regularly sleep with their parents (Lindgren et al., 1998); 25.9% of exclusively breastfed infants were regularly sleeping in the same bed as the parents compared with 11.3% of formula-fed infants ($P = 0.001$) while 20.3% of partially breastfed infants regularly slept in the same bed as the parents. This relationship between breastfeeding and close sleep contact has repeatedly emerged in many studies as mothers in Western postindustrial societies that had lost a tradition of breastfeeding and sleep contact with their infants rediscover their importance and their interconnectedness (see sections "Significance of UC Irvine Studies;" "Interview studies in North-east UK;" "How breastfeeding changes the bed-sharing environment;" "The importance of early sleep contact on breastfeeding initiation.")

Human infant sleep in a historical and postindustrial western context

Historical contributors to the notion that infants should sleep alone. As we have seen, in the majority of contemporary world cultures mothers and fathers do not appear to expend time nor energy reading about different philosophies underlying their choice for social rather than solitary sleeping arrangements for their infants or debating how to get the baby to fall or stay asleep. In fact, the idea of placing the infant to sleep alone, and expecting it to fall asleep away from the comfort and safety of its mother's body, is alien for the majority of parents. Yet, in the postindustrial west, "modern, healthy, normal" infant sleep means solitary sleep. So, how did our view become so estranged from that of the rest of the world? Why is solitary infant sleep so heavily endowed with a sense of medical and moral value and protection for western infants?

The answers are not simple. The definitive beginnings of the story of solitary infant sleep are hard to pin down, as so many cultural, religious, economic, and political factors are involved. It may, at least in part, stem from a time in western history when impoverished urban mothers with no access to other forms of family limitation, were compelled to sacrifice some of their children in order that the rest might live. For example, historians have documented during the last 500 years that poor women living in cities such as Paris, Brussels, Munich and London, confessed to Catholic priests of having deliberately overlain their infants in order to control family size (Flandrin, 1979; Kellum, 1974; Stone, 1977). Led by horrified priests who threatened excommunication, fines or imprisonment, infants were "banned" from parental beds (Stone, 1977). The legacy of this period in western history appears to have converged with other changing social mores and customs, such as values favoring privacy, self-reliance, and individualism, to sculpt the philosophical foundation upon which contemporary cultural beliefs about sleeping arrangements are built. This particular foundation makes it far easier to assume there are dangers inherent in mother–infant sleep contact than to assume there are benefits.

In turn, the proliferation of the idea of "romantic love" throughout Europe also contributed to the separation of the infant from its mother during sleep hours, as it was thought the infant might intrude on the conjugal bond (Stone, 1977; see Fildes, 1986). Likewise, Freud (1908) promoted the idea that infants should not be exposed to the sexual acts of their parents for fear of far reaching psychological impairment—although recent research has found no evidence that primal scene exposure in early childhood has harmful consequences for later life (Okami et al., 1998). Furthermore, with the rise of the father as the authoritarian, fathers were encouraged to limit affectionate physical contact with their children in favor of providing discipline (Stone, 1977). These events were all contributory factors in the development of a cultural climate which promoted separate sleeping quarters for western children and subsequently the formulation of "knowledge" about healthy infant sleep (see Table 1).

Throughout the last century the notion of infants sleeping apart from their parents has become embedded in "expert" parenting advice and assumed to be the preferred scientific context for studying infant sleep and generally thought to be simpler and more compatible with western social values, which favor individualism and autonomy (e.g,. see Thoman, 2006). In the United States we can point to L. Emmett Holt (1894) a pediatrician whose "catechism" promoted strict feeding and sleep schedules for children, while King (1921) performed the same role in Great Britain (Hulbert, 2003; Hardyment, 1983). John B. Watson, who introduced behaviorism to psychology, lent his considerable professional standing to support infant separation and independence on both sides of the Atlantic (Watson, 1928). It is widely reported that Watson believed no child could have too little affection; "Never hug and kiss them. Never let them sit in your lap. If you must, kiss them once on the forehead when they say goodnight. Shake hands with them in the morning. Give them a pat on the head if they have made and extremely good job of a difficult task" (Watson, 1928, quoted by Hardyment, 1983, p. 175). As silly as this may sound, Watson's views contributed significant support to what was already a powerful cultural belief that for infant physical, psychological, and intellectual health parental cuddling, affection, and even touch should be avoided.

Benjamin Spock's (1946) 50-year influence on US baby boomers must not be overlooked either, although his approach to childcare challenged the orthodoxy of the day as he encouraged parents to treat infants and children as individuals. Nevertheless, he recommended that for parents to avoid being bothered by the wails of their

TABLE 1. There is no single reason why the solitary sleeping, bottle-fed or formula-fed infant came to be thought of as "normal," "healthy," and/or "desirable;" rather, the convergence of a variety cultural and historical processes and/or factors unique to Western industrialized societies such as these altogether contribute to an explanation

Historical factors/forces influencing emergence of western solitary infant sleep ideology

- notion of infant's "original sin" need for imposed self-discipline, fear of spoiling;
- fear of infants/ children observing sex, masturbation by wet nurses, fear of affection or touching;
- Catholic church bans "bed-sharing" due to infanticide confessed (in confessionals) by starving mothers;
- values favoring individualism, independence, autonomy, self discipline and self-sufficiency;
- re-location of parental decision making to outside of home to external "authorities" . . . rise of child care experts . . . pediatricians, as "authoritative medical" knowledge comes to dismiss acquired parental knowledge of infant;
- emphasis on "romantic" nature of "husband-wife," conjugal relationship to exclusion of children;
- emphasis on superiority of "technology" as a substitute for mother's body and what her body provides (cow's milk rather than breast milk), stimulating "objects or swings" rather than mother's sensory exchanges achieved through contact;
- switch to bottle feeding from breastfeeding.

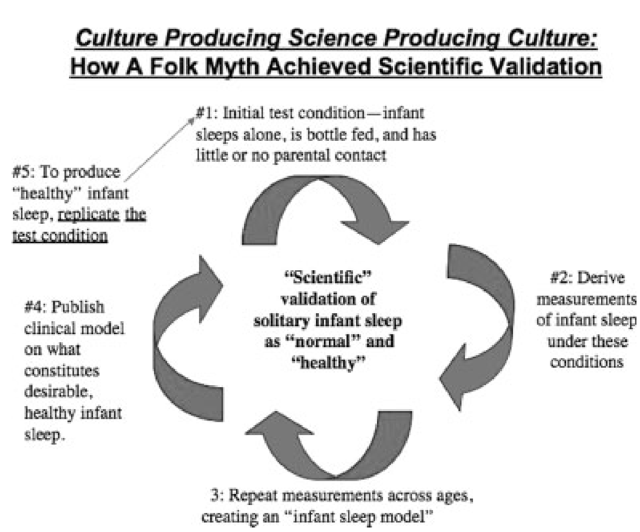

Fig. 1. How the western folk beliefs concerning the appropriateness of infants sleeping alone achieved scientific validation. The production of a model of allegedly "normal" infant sleep derived exclusively from measurements taken from a solitary, bottle fed infant means that the only way parents can induce in their infants clinically "normal and healthy" infant sleep is to replicate the conditions within which the sleep architecture data were derived, that is, placing bottle fed infants alone to sleep. Adapted from McKenna and McDade (2005).

infants at night the latter should be trained from the birth to sleep alone in their rooms, advising that placing towels around the nursery door to block out the sounds of infant sobs was highly effective. The ubiquitous sleep training programs, popular around the end of the twentieth century, advocating variants of "controlled crying" in which parents leave their child alone for longer and longer periods (with intermittent parental visits) to condition them to fall and stay asleep on their own represent what Ball and Klingaman (2007) identify as modern descendants of Watson's authoritarian approach to nighttime infant care, epitomizing in the late twentieth century Anglo-American cultural landscape what the infant's nighttime experience should be (e.g., Hiscock and Wake, 2002; Ferber, 1986; Ford, 2002). In fact, while these individuals pursued a similar nighttime strategy in advocating separate sleep quarters for infants, with strict, controlled, nighttime breastfeeds or contact, their influence suggested moral authority not only over the infants but over the parents who should comply with expert advice rather than relying on their own knowledge and experience of their infants' needs. The legacy of this western reliance on "authoritative knowledge" (Jordan, 1980) continues to negatively impact parents and to make them question their own emotions and tendencies when it comes to caring for their babies—a rather strange and unique handicap associated with western cultural history (Hulbert, 2003; Hardyment, 1983).

Historical contributors to the notion that infant sleep should be undisturbed. It is an unfortunate act of history that the development of sociocultural-folk perception of formula feeding and solitary sleeping in infancy as normal and healthful preceded the technological capacity to study infant sleep. At the time electrophysiology became available for infant sleep studies US breastfeeding rates were at an all-time low. Consequently, researchers, operating within their own contemporary cultural context, used solitary-sleeping formula-fed babies as their model for measuring and quantifying "normal" and "healthy" infant sleep (see Ball, 2003; McKenna and McDade, 2005) (see Fig. 1). The parameters for infant sleep development that were defined by these studies became widely disseminated in both pediatric textbooks and parenting manuals, and the first reference point for ascertaining appropriate infant development became enshrined as the age at which an infant began to "sleep through the night." It is in this historical context that the social myths about the importance and normalcy of solitary infant amongst bottle-fed infant achieved "scientific" validation.

Up until the 1980s, when anthropologists began challenging the notion that solitary infant sleep was healthy, and/or normal, nearly all infant sleep research operated under the premise that uninterrupted, solitary infant sleep was the gold standard by which infant sleep patterns must be measured and quantified (Ball, 2003). In consequence, infants who could not "measure up" to expectations became patients potentially in need of a behavioral or clinical "cure." Presently over 71% of US infants are at least initially breastfed (Li et al., 2005), and as feeding method is a variable exerting significant impact on infant sleep patterns, it is highly unlikely that breastfed infants will sleep in ways which match the infant sleep patterns found in the clinical and parental manuals. Compared with formula-fed infants breastfed infants wake more frequently, develop consolidated sleep later (Elias et al., 1986), and more frequently sleep in close proximity to their mothers (Ball, 2003). Altogether this chain of events helps to explain how questions concerning what constitutes a safe infant sleep environment, that is, "the bed-sharing debate" has been turned on its head: species wide and biologically normal and protective infant sleep environments (mother–infant sleep contact) is assumed to be inherently lethal while solitary crib sleeping is assumed to be healthy, beneficial, and always safer.

HUMAN SLEEP BEFORE WESTERN HISTORY

Sleep among the nonhuman primates: a social event, but where have all the data gone?

Field and laboratory studies of nonhuman primates provide data with which to evaluate the possible evolutionary roots of human behaviors by means of either homology or analogy. Although several evolutionary biologists have recently tackled issues regarding the function of sleep across various taxonomic groupings (Frank and Heller, 2003; Siegel, 2005), the precise function(s) of sleep is still a source of speculation and debate (e.g., see Dement and Vaughn, 1999), which makes it difficult to confirm explanations for the sleep pattern of any one primate species, including our own (Worthman and Melby, 2002; Worthman, in press). Still, studies of the resting and sleeping behavior of nonhuman primates both from the field and laboratory provide a rationale for evaluating infancy and parenting from a comparative background and provide compelling evidence for acknowledgement of the importance of mother–infant proximity during sleep, and its overall importance throughout the extended development of all primates. This is a noncontentious proposition for biological anthropologists, especially when considered in the context of nonhuman primate mother–infant separation studies which demonstrate that, due to the primate infants relative immaturity at birth and delayed maturity, even short-term separations between the mother and her offspring are known to have lasting, and potentially devastating, physiological consequences (see Reite and Field, 1985 for reviews). Pioneering research conducted on the underlying physiological aspects of attachment was begun by Harlow (1958, 1959; see also Blum, 2002) and further investigated amongst bonnet macaques, squirrel monkeys, pigtail monkeys (Seiler et al., 1979; Coe and Levine, 1981; Laudenslager et al., 1982; Coe et al., 1985; Reite et al., 1989). These researchers demonstrated exquisitely that short-term separations of infants from their mothers (for sleep or for other daytime periods) leads to an array of potentially life-threatening physiological changes such as adrenal-cortisol surges, immune dysfunction, and breathing abnormalities, while leaving infants alone to sleep induced serious impairments to sleep architecture, and amongst some infants cardiac arrhythmias, as well as a variety of depressive syndromes and immune deficiencies. Although not specifically focusing on nighttime sleep behaviors or arrangements, these studies provided the basis for beginning to question the cultural justifications for claiming that nighttime separation of the human infant from the mother is ultimately beneficial, given the fact that the human infant is born the least neurologically mature primate of all, the most reliant on the mother, for the longest period of time (Konner, 1981; also see Konner and Super, 1987).

In addition to laboratory-based physiological studies of nonhuman primates, an array of (fairly limited) data can be found relating nonhuman primate sleep patterns to ecological pressures. These include risk of predation, patterns of food distribution and the ways in which social structure may influence nighttime sleeping subgroups (see Anderson, 1984 for review). However the breadth of research focused on nonhuman primate sleep, and especially mother–infant sleep patterns has, until very recently, remained narrow and largely elusive. Nocturnal prosimians were long known to cache their infants in nests to sleep, or "park" them on branches while the mothers forage (e.g., Nash et al., 1989), however recent reports indicate that the daytime sleeping behavior of these species appears to be social, with groups of females and infants sleeping in close contact, and, in some species, including males (see Muller and Thalmann, 2000). In Anderson's (1984) extensive review of monkey and ape sleeping patterns, the focus of attention was the social organization of sleeping units which apparently, for many species, can remain exceedingly fluid. There appears to be no general principle by which primate species affiliate with particular sleeping sites either, except where food across the short or extended season is more predictable through time (Milton, 1980). One generalization following a synthesis of Old World (*Catarrhine*) sleeping activities is that: "Even in the relatively widely spread gibbon or patas group, for example, mothers will sleep huddled with their infants" (Anderson, 1984, p. 203); continuing, "... with increasing independence the youngsters spend increasing amounts of waking time away from the mother but still return to sleep with her at night;" "Among great apes, offspring may share the mother's nest until up to 5 years of age, even if the mother has a young infant" (Anderson, 1984, p. 203). Anderson's most recent synthesis (2000) probably constitutes the most complete review of nonhuman primate sleep to date, and the paucity of information therein on mother–infant sleep patterns and nighttime feeding behaviors is sadly indicative of the lack of research relevant to human sleep ecology (see "Paleo-ecology of maternal–infant sleep and adult hominin sleep" section below). While Anderson mentions the utility of social sleeping to infant (and older) primates in nighttime thermoregulation and postural stability, there still appear to be few observational reports available on mother–infant nighttime interactions (Anderson, 2000). Somewhat more data are available on the duration of mother–infant sleep contact in various species, which indicate that even though infants begin to leave their mothers' bodies to explore the environment during daylight hours as they mature, they persistently return to sleep in close contact with their mothers at night (Anderson, 2000). Great ape infants share their mother's sleeping nest until around 5 years of age even if the mother has a subsequent infant, and Anderson notes that juvenile tantrums are observed when attempts to nest with their mothers are rebuffed (p. 363).

Papers mentioning nonhuman primate sleep environments or behaviors published throughout the nineties made only brief reference to the mother–infant dyad and did not devote much space to discussing sleep in a larger developmental context. For instance, Ansorge et al.'s (1992, p. 276) study of sleeping clusters in Barbary macaques refers to choice of sleeping partners, and states, "Females with newborns avoided additional sleeping partners, whereas those without newborns favored clusters with more than one partner." Likewise an anecdote included in Zhang's study of brown capuchin monkeys reads, "A clear sleeping event of the core individuals of the group was observed once: the adult male was in the middle, with two reproductive females on each side, and the respective young of each female beside its mother" (Zhang, 2005, p. 335). These articles are not unlike many primate field reports that include reference to sleeping patterns, with little detail provided beyond a simple acknowledgement that infants and juveniles sleep in maternal contact. Anderson and McGrew (1984, p. 7) analyzed the composition of sleeping huddle groups of guinea baboons and in so doing excluded infants because "they always huddled overnight with their presumed mothers." Likewise in reference to huddling they mention, "... an adult female often had an infant ventrally," and "Infants usually slept clinging to adults."

A notable and more recent exception to the general lack of nonhuman primate cosleeping research is a study conducted by Fite et al. (2003) examining the ways in which parent–infant cosleeping affects the sleeping patterns of *Callithrix kuhlii*. Interestingly, the authors note, "Parent–infant cosleeping occurs in human and nonhuman primates, yet studies on the impact of cosleeping on parental sleep patterns have been limited to human mothers," later referring to the studies that McKenna and Mosko (1990) conducted on this subject (Fite et al., 2003: 1268). This further underscores the need for expanded research covering both proximate and long-term social and physiological aspects of sleep and sleep development among nonhuman primates.

In reviewing the extant literature on nonhuman primate sleep research our primary point is not the relative dearth of publications on mother–infant sleep, but rather that this arrangement is the norm and expected for primates of all shapes, sizes, social structures, and ecological settings. It is plausible that primatologists have failed to devote copious amounts of research time and effort to cosleeping, which is imperative to the health, growth, and safety of primate infants, not because it lacks importance but because it is ubiquitous and therefore does not necessitate the explanation afforded to more variable sleep behaviors. Thus, the absurdity of the notion of a nonhuman primate mother putting her vulnerable infant to rest alone, away from the safety of her proximity and care, throws into sharp relief the fact that this same notion is perceived as healthy, practical, and logical for human infants in many western societies.

Paleoecology of maternal–infant and adult hominin sleep

"Sleep studies are quite untroubled by any fossil record and it seems unlikely that it (sic) ever will be" Meddis (1983, p. 57).

Definitive evolutionary evidence regarding the form and patterning of human-hominin sleep behavior or ecology is nonexistent. But anthropologists are not afraid to explore what the human fossil record may yield about the evolution of human sleep in ways that might behoove clinicians and sleep study practitioners to take notice. It is an anthropological axiom that the reconstruction of any kind of behavior is far from easy. Indeed in some cases, without archaeological materials and data, it is all but impossible, particularly when the behavior leaves no lasting and visible mark on either the landscape or anatomy, as is the case for sleep. Nonetheless attempting a reconstruction of the contours and context of human sleep behavior, including likely infant sleeping arrangements, is an important exercise. Nobody in recent years has done this better than Carol Worthman, who initially conducted a broad and informative global overview of the ecology of human sleep (see Worthman and Melby, 2002) and has recently proposed a revolutionary view of the origins and evolution of human sleep (Worthman, in press). In her most recent paper Worthman takes as her starting point the following deductions: a) the morphological changes occurring concomitantly with a shift from quadrupedalism to bipedalism would reduce the feasibility of arboreal habitation during sleep; b) the loss of body hair, which precludes infants from clinging to mothers' ventrums, would increase the risk of arboreal sleeping; and c) the lack of insulation resulting from loss of body hair would create a need for external heat sources or protective covering to compensate for heat lost during sleep (Worthman, in press), a point made previously by McKenna and Mack (1992). This logic infers that the sleep environment of early hominids is likely to have been terrestrial. However, such a sleep location would have involved increased predation risks for our vulnerable ancestors. Consequently, Worthman suggests that ground-sleeping hominids must have utilized tools, social groups, and, later, fire and physical constructs as compensatory means of preservation. The debate surrounding the first uses of fire is far from settled, but even assuming that the earliest estimates for fire use and shelter building as protection from predation are accurate, these advances occurred late in the evolution of human sleep ecology. Consequently human sleep physiology evolved in an environment of great risk and, Worthman argues, one would expect human sleep traits to have been selected accordingly.

Although the exact role sleep fulfills biologically is not fully understood, one cannot deny that it is vital to the maintenance of well being. But, says Worthman, long-term well being is of little value if an individual faces death as a predator's meal. Thus, she argues, the need for sleep and safety must be mediated biologically, and the seemingly contradictory needs of short- and long-term preservation manifested in behavior. Worthman argues that security for ground sleeping hominids came in the forms of both cooperation in social groups together with vigilance and responsiveness while sleeping. She points to the architecture of human sleep, particularly the stages of sleep (Stages 1–4 NREM sleep, REM) that exhibit wide ranging differences in their reversibility and sensitivity to external cues, from the largely responsive, easily awakened sleep of Stage 1 to the deep stages of slow wave sleep (Stages 3 and 4) and REM as evidence of such adaptation. Worthman argues that continuous sleep cycles lasting ~90 min, during which shallower stages of slow wave sleep predominate (Stage 1: 2–5%; Stage 2: 45–55%) over the deeper stages of slow wave sleep (Stage 3: 3–8%; Stage 4: 10–15%), minimize the duration of sleep periods during which vigilance is low, and maximize the opportunities for reversibility. Similarly, other sleep researchers argue specific EEG configurations are indicative of microarousals that act as momentarily altered thresholds of responsiveness for the purpose of evaluating external stimuli and, if need be, facilitating transitions out of sleep (Halasz et al., 2004 cited in Worthman, in press).

Such sleep architecture, which prioritizes light over deep sleep, with heightened vigilance and responsiveness that Worthman argues quite possibly describes much of nighttime sleep throughout human evolution is also, of course, precisely what we observe in the sleep of modern human mothers when sleeping in contact with their infants (see sections "Infant sleep architecture;" "Maternal sleep architecture;" and Mosko et al., 1996; Mosko et al., 1997c). The sleep patterns of breastfeeding bed-sharing mothers can be said to reflect a likely ancestral pattern lost recently by other adult humans sleeping in the 21st century exclusively in a western context, changes that from a health point of view remain for the most part largely unexplored.

WHY COSLEEPING STUDIES: MOTHER–INFANT COSLEEPING IN A SIDS RESEARCH CONTEXT

SIDS is "The sudden and unexpected death of an infant under one year of age with the onset of the lethal episode apparently occurring during sleep, that remains unexplained after a thorough investigation including the performance of a complete autopsy, review of the circumstances of death and clinical history" (Willinger et al., 1991, p. 361).

McKenna (1986) suggested that the western human infant who sleeps separated from the physiological regulatory effects of its mother's body is sleeping in an environment for which it is not designed biologically and therefore may be at increased risk for SIDS (see also McKenna and Mosko, 1990, 1993; McKenna et al., 1994; McKenna and Mosko, 1994; McKenna, 1995). At the time the hypothesis was proposed two to four infants per 1,000 live births in the Euro-American industrialized world were dying from the unknown causes classified as SIDS (Guntheroth, 1989). In many Asian societies, even in industrialized populations such as Hong Kong and Japan, SIDS deaths occurred at a fraction of the rate found in the west (Lee et al., 1989; Watanabe et al., 1994). Today, while the SIDS rate has been reduced to a low of 0.5 infants per 1,000 live births in the United States it still remains the leading cause of infant deaths from 28 days to one year, constituting about 85% of all sudden and unexpected infant deaths between the age of one month and one year (American Academy of Pediatrics, 2005).

Epidemiological studies in the late eighties identified that the single most significant risk factor for a SIDS death was an infant being put down to sleep in the prone position, that is, on its stomach (Mitchell et al., 1992). This finding overturned several decades of pediatric sleep advice that advocated the prone position as a strategy to promote deep sleep amongst infants. This advice became prevalent at a time when formula feeding was the norm for infants and separation of the infant from the parents at night was a culturally sanctioned and desirable practice (Guntheroth and Spears, 1992). As we approach the close of the first decade of the 21st century it is increasingly recognized that each of these practices and pediatric recommendations (prone sleep, formula feeding, and nighttime mother–infant separation) have altogether cost the lives of hundreds of thousands of babies in the western world (from illnesses, asphyxial accidents, or as SIDS) (Fleming et al., 1996; Carpenter et al., 2004; Chen and Rogan, 2004; Ip et al., 2007). Since western countries initiated "back-to-sleep" campaigns in the early nineties, however, world SIDS rates in all groups have been reduced at least by one half—but the pathophysiology of SIDS remains unexplained, and SIDS is considered a "diagnosis by exclusion," a category invoked when, after a complete, autopsy all explanations for the cause of the infant's death are excluded (American Academy of Pediatrics, 2005). Epidemiologists identify maternally related risk factors for SIDS to include smoking during or after pregnancy, maternal age less than 20 years, poor prenatal care, low weight gain, anemia, use of alcohol or drugs, history of sexually transmitted or urinary-tract infections, and membership of a historically underrepresented minority or indigenous group (such as Cree of Canada, Aborigine of Australia, Maori of New Zealand). Infant-related epidemiological risk factors reported by Mitchell et al., (1999) include being male, low birth weight, premature, African American or Native American (in USA), exposed to tobacco and drugs, and sleeping in a prone position. Other less widely acknowledged risk factors associated with SIDS include overheating, sleeping in a separate room, sleeping without a pacifier, and sleeping with an adult on a sofa. There is also a growing body of evidence relating formula feeding to increased SIDS risk (Ip et al., 2007).

As anthropologists we would add two further risk factors normally overlooked by epidemiologists that only become obvious when SIDS is viewed from a comparative evolutionary and anthropological perspective; the biggest risk factors for SIDS are a) being a 2–3-month-old human and b) living in a western postindustrial nation. In a series of papers in the late eighties and early nineties, McKenna (1986; McKenna et al., 1993; McKenna et al., 1994; McKenna, 1995) proposed that the human respiratory system and its underlying neurobiology is a species-specific corollary of human speech production. "Learning to breathe" amongst human infants, he argues, may be more complex and experientially based than is generally appreciated. McKenna's (1986) speculation begins with the observation that there is no animal model for SIDS, that is, it appears to be a species-specific phenomenon for infants to die suddenly and for no apparent reason during sleep, suggesting that anthropological data might best help us to understand what is unique about human infants in making them susceptible to a syndrome suspected to relate to some kind of breathing control error occurring during sleep, during a very narrow developmental period. McKenna's hypothesis centered on the potential role that maternal sensory-bodily exchange with the infant plays in providing the safest possible microenvironment for the neurological development of the exceptionally immature human infant. During early infancy the neonate moves away from strict autonomic control of breathing to a system in which more voluntary, cortically based neurological structures share breathing control with lower brainstem structures (Krasnegor et al., 1987; also see McKenna, 1986 for review). Extensive voluntary control of breathing and the underlying integration of the ascending and descending nerve tracts that permit it develop within the first four months of the infant's life, enabling human infants to switch effortlessly between autonomic and volitional breathing at will. This developmental skill is maturing at the same time that infants are most vulnerable to SIDS, between the ages of 2–4 months, and SIDS remains one of the most age-circumscribed phenomena known. Learning to "speech breath" involves the infant learning how to control air flow rates, subglottal air pressure and release (during both sleep and awake periods), and the volume of breadth that underlies vocalizations which at first involve crying, but then transform into purposeful utterances which lead eventually to speech itself (see McKenna and Mosko, 1989). Within the normal range of developmental trajectories however, infants are not equally capable of compensating for privation and/or environmental assaults, and about 7% of infants are born with neurological deficits (Kagan, 1984). Hence, McKenna and Mosko (1990) hypothesized that breathing control structural abnormalities or maturational asymmetries manifesting themselves during sleep could conspire with environmental stresses such as maternal sensory deprivation to increase vulnerability to SIDS.

This hypothesis was further supported by a variety of psychobiological studies documenting the negative physiological effects to breathing, heart rate patterns and stability, sleep behavior, oxygen saturation levels, susceptibility to diseases, body temperature, cortisol levels, and heart rhythms that primate young exhibit in response to short term maternal–infant separation (see above, Reite and Field, 1985). Furthermore, cross-cultural data especially show the absence of, or substantially lower SIDS rates, in cultures within which mother–infant cosleeping and breastfeeding are the norms (Nelson et al., 2001; Wantanabe et al., 1994; Lee et al., 1989). The confluence of these lines of evidence, together with the nonhuman primate evidence (see above) led McKenna (1986) to conclude that solitary sleeping infants were deprived of maternal breathing signals and/or cues involving touch, vesicular breathing sounds, chest movements and exhaled CO_2 gases. All of these sensory stimuli, he suggested, could induce infant arousals leading to oxygenations and provide practice for arousing (an infant's most powerful defense against respiratory collapse). Without them, he hypothesized, infants born with deficits may more easily experience a breathing control error during sleep such as the kind suspected to be involved in SIDS. One testable prediction from this hypothesis was the expectation that maternal sleep contact would affect infant sleep states by increasing arousal opportunities and preventing long periods of deep sleep. If demonstrated this would serve to provide a protective developmental microenvironment within which the complex, volitional, cortically based breathing pattern and neurology underlying sleep could emerge (McKenna, 1986).

What is cosleeping and bed-sharing? Toward standardizing definitions

Cosleeping takes no single predefined form and is highly variable both with respect to whom aside from the mother, sleeps near to the infant and what types of the surface and/or bedding materials are used (see Worthman and Melby, 2002).

In the context of SIDS and pediatric sleep research, McKenna and Mosko (2001) proposed that in order to understand what kind of cosleeping is taking place and, hence, whether or not it is safe or more risky the term cosleeping be used generically to describe a diverse, generalized class of shared sleeping arrangements in need of further taxonomic categorization. Cosleeping therefore refers to situations when a caregiver and infant sleep alongside each other in some form or another either on the same or a different surface as, for example, when a bassinet is positioned next to the parents' bed, or an infant's hammock is slung above the mother's, or when an infant is in a western adult bed with a supervising adult. What is critical in denoting a "cosleeping arrangement" is the sensory link connecting the infant with the adult committed to its care and protection. In a cosleeping scenario the "dyad" must be able to communicate through multiple, mutually reinforcing, sensory modalities as, for example, through a combination of tactile, visual, auditory, olfactory, or kinesthetic and/or vestibular sensory channels. Usually cosleeping involves almost all of these sensory exchanges.

Under this taxonomic definition of cosleeping, bed-sharing can be viewed as a specific case of cosleeping, where an adult and an infant sleep together in the same adult bed. Likewise sofa-sharing would involve shared sleep on a couch or sofa, with other circumstances treated accordingly. This avoids the confusion caused when epidemiological studies combine together shared adult–infant sleep in beds and on sofas as a single category named "bed-sharing" (e.g., Carroll-Pankhurst and Mortimer, 2001) or when situations of infants sleeping alone on adult beds are termed "bed-sharing" (e.g., Drago and Dannenberg, 1999; Nakamura et al., 1999), or when infants sleeping alone in cribs who have previously shared a parental bed are termed "bed-sharing" (e.g., Tappin et al., 2005).

A cosleeping environment, therefore, must always provide the infant with the opportunity to "sense" and respond in turn behaviorally and/or physiologically to the caregiver's signals and cues, that is, the mother's smells, breathing sounds, speech directed to the infant, sleep or breathing movements, invitations to breastfeed, touches or to any as yet unidentified sensory stimuli. Bed sharing is therefore a specific type of cosleeping, which, like other specific types of cosleeping, can be further taxonomically differentiated into one of two subtypes: safe or unsafe. This issue will be explored further below.

BREAKING NEW GROUND: POLYSOMNOGRAPHIC BEHAVIORAL AND PHYSIOLOGICAL STUDIES OF MOTHER–INFANT INTERACTIVE SLEEP

When McKenna, Mosko and coworkers conducted the first ever studies of mother–infant sleep in the early nineties, little was known about the behavioral and physiological effects of social sleep for adult humans, let alone the nature of the interactions that mothers and infants might have while sharing sleep. Only one previous study had approximated an ethological approach in examining the synchronous movements of a sleeping adult couple (Hobson et al., 1978), while another had pioneered the use of time-lapse video to examine infants sleeping alone in cribs in their homes (Anders, 1978, 1979). McKenna and Mosko's research was, therefore, both methodologically and conceptually novel.

In their first forays into infant sleep research McKenna, Mosko and coworkers redefined the "natural ecology" of human mother–infant sleep by rejecting the dominant cultural notions that a) infants should and do sleep alone, and b) that the solitary sleeping, formula-fed infant constitutes the appropriate research subject and/or context for assessing human infant sleep. Using an evolutionary perspective they constructed an anthropologically informed approach that recognized the human species-wide pattern of mother–infant social sleep and its importance for nighttime feeding and infant regulation and support (McKenna et al., 1990; McKenna et al., 1993; Mosko et al., 1993).

To explore the role that mothers play in influencing their infants' nighttime sleep physiology and behavior two initial pilot studies involving five and three mother–infant pairs were conducted at the University of California Irvine (UCI) Sleep Disorders Laboratory. In the course of these studies McKenna and Mosko devised novel recording methods and analytical tools for quantifying elements of shared sleep and mother–infant nighttime interactions. It is therefore appropriate to summarize the details of these initial studies as the techniques used are unlikely to be familiar to most biological anthropologists. Furthermore the outcomes of these studies spawned a new research area fusing human ethology and developmental biology with pediatric sleep medicine, which has brought the perspectives of biological anthropology to a new audience of clinicians and other health professionals, as well as paving the way for biological anthropologists to begin conducting studies involving nighttime physiology and behavior.

The polysomnography of mother–infant sleep contact: Eight mothers and their babies

For the initial UCI studies, mothers and their 2–5-month-old infants were attached to physiological monitoring devices and observed bed-sharing in the first study, then bed-sharing and sleeping separately in different rooms over successive nights in the second study. No instructions were offered to mothers as to how to position their infants once in bed and recordings began as soon as the infant appeared to be asleep. The technological challenges of monitoring both the mother and infant in the same bed (which had never been attempted before) were significant, but technological obstacles were resolved to record continuous all-night data on maternal–infant interactions and physiology using simultaneous traces on a 12-channel polygraph supplemented with infra-red photography.

The recordings for this and subsequent studies at UCI identified sleep stages in 30-s epochs according to accepted criteria. The Rechtschaffen and Kales (1968) scoring system to track sleep stages and wake periods for young adults was utilized for the mothers, while the sleep scoring system for 3-month-old infants developed by Guilleminault and Souquet (1979) was used for the infants. Sleep-wake patterns were identified using three simultaneous parameters: EEG (electroencephalography), EOG (electro-oculography), and EMG (electromyography). Five sleep stages were recorded for mothers: REM (rapid eye movement sleep or active, paradoxical sleep) and four stages of non-REM or quiet sleep, delineated as Stages 1, 2, 3, and 4. Stages 1 and 2 are collectively referred to as light non-REM sleep; Stages 3 and 4 together constitute slow wave or delta sleep (also called deep sleep). For infants, due to their neurological immaturity, only three stages are defined: REM, Stages 1–2, and Stages 3–4. Further details on sleep staging and the scoring and identification of wakefulness, transient (short) vs. epochal (long) arousals, breastfeeding sessions and infant and/or maternal sleep positions can be found in the original papers (Mosko et al., 1993, 1996, 1997a,b,c).

Pilot study one: exploring the behavior and physiology of bed-sharing. The aim of the first pilot study was to ascertain whether such research was methodologically feasible and to explore the sleep of bed-sharing mothers and infants in comparison with published reports of women and infants sleeping alone. Each of five mother–infant pairs shared a single-sized bed in a darkened sound-attenuated room at the UCI Sleep Lab (see McKenna et al., 1990); over 77 h of behavioral and physiological data were recorded. The data obtained were compared with published reports of comparatively aged mothers and infants sleeping alone. The bed-sharing mothers exhibited significantly less consolidated sleep, and on average experienced four times the number of sleep stage changes (moving from sleep to wakefulness or from one stage of sleep to another) than did solitary sleeping women in published reports. Bed-sharing mothers also exhibited twice the sleep latency (time taken to fall asleep) of solitary sleeping women, and consequently experienced one fewer REM cycle per night. The bed-sharing infants experienced significantly less time in deep sleep (Stages 3–4) and exhibited arousals of greater than 1 min more frequently than reported for solitary sleeping infants, a finding that was to remain consistent throughout all subsequent studies (McKenna et al., 1990).

In the course of this study McKenna and Mosko devised a method to examine the degree of synchrony of maternal and infant arousals by calculating what they termed Simultaneous Activity Times (SATs). Development of this measure arose from the observation that mothers and infants experienced simultaneous brain wave changes often within seconds of one another, and sometimes without any overt behavioral change. The 30-s "epochal" sleep-stage scoring system was used to compute (for each mother and infant) the proportion of sleep time that was spent simultaneously in the same sleep stage as the other member of the pair. Total SAT averaged 46% for the mothers (range 43–48) and 44% for their infants (range 43–45%). It was recognized, however, that the progression of sleep stages through the night has an inherent organization that could contribute to the high percentages of SAT observed. To explore the nature of mother–infant sleep synchrony, therefore, SATs were computed for randomly matched pairings of each mother with every other infant with whom they did not sleep, and found to be significantly greater for comparisons within mother–infant dyads in comparison with randomly matched mother–infant pairs. Calculation of simultaneous overlap for each separate sleep stage (i.e., Stages 1–2, Stages 3–4, REM and Wake) revealed that overlapping sleep states were greater for mothers paired with their own vs. with other infants, but only reached statistical significance for wake after sleep onset (WASO). The same was true when infants paired with their own mothers were compared with infants in randomly matched pairs.

Pilot study two: the effects of varying sleep configuration. In the second exploratory study conducted at UCI, three healthy mothers (18–36 years old) and their full-term infants (two females and one male, 2.5–4 months old) underwent three consecutive nights of polysomnography, alternating between different sleeping arrangements to explore within subject effects of sleeping together or apart. Mothers and infant slept in separate rooms during the first two nights and shared a single size bed on the third night. The first night served as an "adaptation night" due to reported "first night effects" in laboratory sleep studies of both adults and infants (Agnew et al., 1966; Bernstein et al., 1973; Sostek and Anders, 1975). The two rooms used for the solitary-sleep nights were identical in size, layout, and furnishings, and had an adjoining door which was kept open so that mothers were in auditory contact with their infants and were able to perform all caretaker interventions on an *ad lib* basis. The same physiological variables were monitored as in Study 1.

When compared to the solitary nights, infant sleep variables while bed-sharing exhibited three key differences. The number of stage shifts per hour of sleep was (on average) 29% higher when bed-sharing than when sleeping alone; there was a 28% increase on Stages 1–2 (light) sleep, and a 47% decrease in deep sleep (Stages 3–4). This preliminary finding has been consistently replicated in subsequent bed-sharing studies conducted

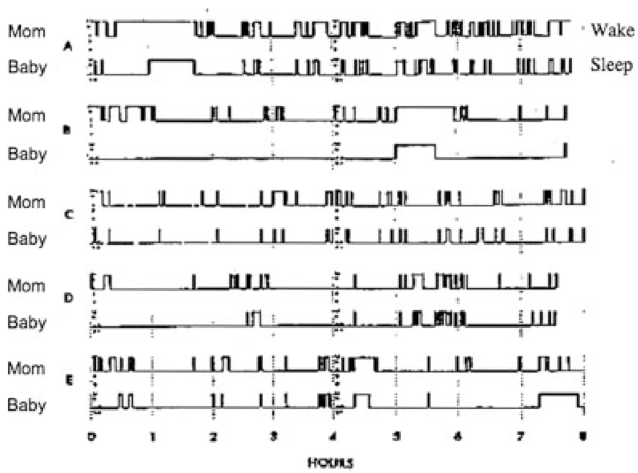

Fig. 2. All night sleep-wake histograms for five (**A–E**) bed-sharing mother–baby pairs. In each pair, the top histogram is the mother and the bottom one is her infant. Each histogram has two positions: the top position designates Waking: the bottom designates all stages of sleep since Stages 1–2, 3–4, and REM are collapsed together in the bottom position. Notice the degree to which brief awakenings of the mother and infant overlap. From McKenna et al. (1994).

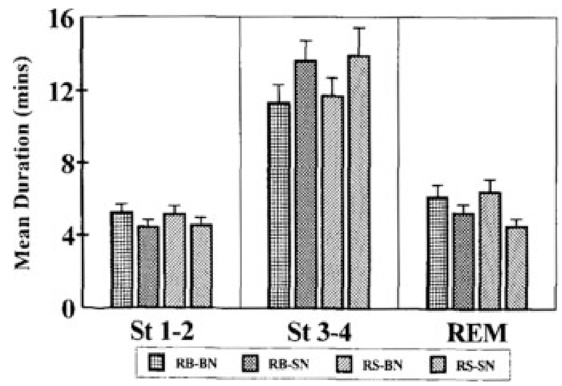

Fig. 3. Mean uninterrupted infant sleep stage duration graphed by group (RB vs. RS) and by night (BN vs. SN). All three stages showed significant effects of night (BN vs. SN). Lines above the bars indicate standard errors of the means. Data are restricted to mothers' time in bed (from Mosko et al. (1996) *Sleep* 19(9):677–684 with permission, © 1996 Associated Professional Sleep Societies LLC).

by both McKenna's team and others (see below). Mothers also showed more stage shifts per hour of sleep during bed sharing (33% increase). Two types of arousals (epochal and transient) were scored and both infant and maternal arousals were expressed as frequency per hour of sleep to allow for within-pair differences in nightly total sleep time. Both mothers and infants exhibited a striking increase in overlapping arousals on the bed-sharing night compared with the solitary night (see Fig. 2) (McKenna et al., 1993; Mosko et al., 1993).

NICHD bed-sharing study at UC Irvine 1991–1993: nighttime polysomnography and behavior of 35 mothers and their babies sleeping apart and together over three consecutive nights in a sleep laboratory

Based on the promise of the physiological findings from the two preliminary studies, funding was secured from the National Institute of Child Health and Development (NICHD) to further investigate the nature of mother–infant shared sleep via a more controlled and statistically robust study design. By this time the research team had identified that social and solitary sleep environments have considerable interactions with both breastfeeding (duration, intervals, frequency of sessions) and infant sleep position (prone, supine, side) and had developed a special interest in the possible connection between breastfeeding and mother–infant arousal patterns and sleep architecture. Although not examined in the preliminary studies, these variables were recognized as crucial for an evolutionary analysis of maternal–infant sleep as well as for the hypothesized relationship between SIDS and the sleep environment and so were included in this subsequent research (Mosko et al., 1996; Richard et al., 1996).

Participants were recruited from the Birthing Unit at the UC Irvine Medical Center. Twenty mother–infant pairs were routine bed-sharers (RB: defined as sleep contact with mother for at least four hours per night, 5 days a week) and 15 pairs routinely slept apart (RS: defined as maternal sleep contact no more than 1 night per week for any part of the night). All mothers who participated in this study were Latina, as bed-sharing is an accepted practice in this cultural group (Morelli et al., 1992), thereby providing a control for potential cultural differences in attitude toward the implementation of bed-sharing. Mothers were required to be under 38-years-old and exclusively or predominantly breastfeeding (no more than one 4 ounce bottle of formula per day and none after 3:00 pm). Infants had to be 11–15 weeks of age (peak age for SIDS) at the time of the sleep studies and in good health. Further details of specific inclusion criteria and study protocol can be found in Mosko et al. (1996, 1997a,b,c) and McKenna et al. (1998).

Mothers and infants were monitored polysomnographically as before (during an initial adaptation night) conforming to the routine home sleeping arrangement, which was followed on the subsequent two nights by a bed-sharing night (BN) and a separate night (SN) in randomly assigned order.

Infant sleep architecture: bed-sharing vs. solitary room sleeping. On the bed-sharing nights infants slept significantly longer (total sleep time), with more light sleep (greater duration and percentage of Stages 1–2) and less deep sleep (shorter duration and lower percentage Stages 3–4) than on the solitary nights, irrespective of their routine sleeping condition. There was no significant group effect for any of the infant sleep architecture variables. Figure 3 shows that infant sleep on the bed-sharing nights was associated with shorter mean episodes of deep sleep than on the solitary nights irrespective of routine sleeping arrangement (Mosko et al., 1996). Results for standard infant sleep architecture variables comparing routine bed-sharing (RB) and routine separately sleeping (RS) mother–infant pairs on their bed-sharing night (BN) and solitary nights (SN) are shown in Table 2 (see Mosko et al., 1996). Total recording time did not differ on the two nights.

Maternal sleep architecture and arousal. On the bed-sharing night mothers experienced more light sleep (Stages 1–2 duration and percentage of total sleep time) and reciprocally less deep sleep (Stages 3–4) than on the

TABLE 2. Results of the ANOVAs for standard infant sleep architecture variables based on 23 routinely bed-sharing mother-infant pairs and 17 routinely solitary sleeping pairs spending consecutive nights in the laboratory sleeping in the bed-sharing (BN) and solitary sleep (SN) conditions

	Group	BN	SN	Group *P* value	Night *P* value	Interaction *P* value
Recording time (min)	RB	475.9	472.8			
	RS	455.4	445.5	0.144	0.136	0.435
Total sleep time (TST) (min)	RB	409.4	389.7			
	RS	390.8	379.3	0.385	***0.017***	0.513
Stage 1/2 sleep (min)	RB	183.1	153.2			
	RS	170.6	161.2	0.852	***0.002***	0.090
Stage 3/4 sleep (min)	RB	85.4	106.7			
	RS	91.6	96.7	0.854	***0.002***	***0.044***
REM sleep (min)	RB	140.9	129.8			
	RS	128.6	121.3	0.202	0.095	0.719
Stage 1/2 sleep (% TST)	RB	44.6	39.1			
	RS	43.5	42.6	0.604	***0.034***	0.115
Stage 3/4 sleep (% TST)	RB	20.8	27.6			
	RS	23.6	25.5	0.906	$<$***0.001***	***0.023***
REM sleep (% TST)	RB	34.6	33.2			
	RS	33.0	31.9	0.342	0.288	0.928
WASO (min)	RB	57.2	66.2			
	RS	51.2	54.3	0.121	0.099	0.415
No. REM episodes	RB	8.9	8.6			
	RS	8.1	7.9	0.095	0.286	0.630
REM cycle (min)	RB	54.3	56.8			
	RS	56.3	59.0	0.342	0.094	0.957

Total recording time did not differ on the two nights (from Mosko et. al. (1996) *Sleep* 19(9):677–684 with permission, © 1996 Associated Professional Sleep Societies LLC). Table entries reflect group means and ANOVA results. Significant findings are in bold italics. BN, bed-sharing night; SN, solitary night; RB, routinely bed-sharing group; RS, routinely solitary sleeping group; REM, rapid eye movement; WASO, waking after sleep onset. Data are restricted to mothers' time in bed.

separate night, irrespective of routine sleeping arrangement. No difference was found in the amount of mothers' REM sleep, but REM latency was shorter and the number of REM episodes was higher for the routinely bed-sharing mothers (both significant). No significant interaction effects were found for any variable examined (see Table 3). Total sleep time and sleep efficiency (ratio of sleep time once in bed to total recording time) did not differ significantly on the two nights.

Independent of routine sleeping arrangement, mothers experienced significantly shorter episodes of both Stages 1–2 and 3–4 sleep but not REM on the bed-sharing night (see Fig. 4), and although routinely bed-sharing and separate sleeping mothers exhibited similar sleep patterns in each of the two conditions, routinely separate sleeping mothers rated their sleep quality and sufficiency significantly lower on the bed-sharing night than did the routinely bed-sharing mothers.

For all mothers, on average, 51% of arousals overlapped one or more infant arousal on the bed-sharing night compared to 21% on the solitary night. Both routinely bed-sharing and separate sleeping mothers experienced more than double the number of overlapping arousals on the bed-sharing night compared to the solitary night, reflecting a significant difference for each group. Furthermore, within group comparisons revealed significant increases on the bed-sharing night for all three types of overlapping arousals (those where the infant aroused first, where the mother aroused first, and where arousal appeared to be simultaneous). However, by far the largest difference was in the number of infant-first arousals on the bed-sharing night compared to the solitary night. Comparison of overlapping arousals across the two groups in their routine sleeping conditions (see Fig. 5) also revealed significant differences indicating that routinely bed-sharing mothers exhibited greater arousal sensitivity and did not habituate to their babies compared with routinely separately sleeping mothers (Mosko et al., 1997c).

Infant arousals in the solitary and bed-sharing environments. As Figure 6 shows, routinely bed-sharing infants on their bed-sharing night experienced significantly more total arousals per hour of sleep than did routinely separately sleeping infants on their solitary night in the lab. Mosko et al. (1997) reported significantly fewer arousals occurring among both groups of infants during deep sleep compared with other sleep stages.

Routinely bed-sharing infants experienced significantly more frequent transient arousals from deep sleep than did routinely separate sleeping infants regardless of laboratory condition (on average 1.6 per hour (or 75.6%) more frequent in the RB group than in the RS group). Furthermore, in deep sleep, epochal wakenings were significantly more frequent on the bed-sharing night than on the solitary night, irrespective of routine sleeping arrangement (Mosko et al., 1997). Finally, for both groups of infants, the number of overlapping arousals with the mothers was roughly doubled on the bed-sharing night (46.4%) compared with the solitary night (23.9%), a highly significant difference for both groups. For routinely bed-sharing infants, within-group comparisons revealed significant increases on the bed-sharing night in all three categories of arousals (as was true when maternal arousals were examined); those where mother aroused first, where the infant aroused first, and where they appeared simultaneous. However the largest increase was where the infant aroused first. On average, routinely bed-sharing infants exhibited 25.3 more such arousals on the bed-sharing night (Mosko et al., 1997).

The relationship of mother–infant sleep contact with breastfeeding. Breastfeeding was examined using

TABLE 3. Maternal sleep architecture variables and ANOVAs showing that similar to their infants while bed-sharing, RB mothers spend significantly less time in Stages 3–4 (deep) sleep than they do when they sleep alone, as do RS mothers when they bed-share[a]

	Group	$\bar{x}$ BN	$\bar{x}$ SN	Group	Night	Interaction
Recording Time (min)	RB	475.9 ± 9.3	472.8 ± 9.4			
	RS	455.4 ± 14.0	445.5 ± 15.1	0.144	0.136	0.435
Total Sleep Time (min)	RB	392.3 ± 10.2	374.2 ± 11.0			
	RS	360.2 ± 17.2	359.6 ± 22.4	0.250	0.188	0.219
Sleep efficiency	RB	0.82 ± 0.01	0.79 ± 0.02			
	RS	0.79 ± 0.02	0.80 ± 0.03	0.604	0.495	0.163
WASO (min)	RB	58.6 ± 6.1	70.0 ± 6.6			
	RS	62.7 ± 8.3	61.5 ± 11.9	0.784	0.553	0.461
Stage 1–2 (min)	RB	220.2 ± 9.5	195.0 ± 8.5			
	RS	208.3 ± 16.1	196.0 ± 18.4	0.753	0.004*	0.298
Stage 3–4 (min)	RB	83.8 ± 5.6	93.2 ± 8.6			
	RS	72.1 ± 7.1	87.3 ± 8.5	0.379	0.009*	0.508
Stage REM (min)	RB	88.3 ± 5.0	86.0 ± 4.6			
	RS	79.8 ± 4.9	76.3 ± 4.1	0.170	0.482	0.881
Stage 1–2 (% TST)	RB	56.0 ± 1.8	52.1 ± 1.8			
	RS	57.1 ± 2.9	53.7 ± 2.9	0.659	0.014*	0.833
Stage 3–4 (% TST)	RB	21.4 ± 1.3	24.8 ± 2.2			
	RS	20.7 ± 2.4	25.5 ± 2.8	0.991	0.001*	0.527
Stage REM (% TST)	RB	22.5 ± 1.2	23.1 ± 1.1			
	RS	22.2 ± 1.0	20.7 ± 1.6	0.340	0.680	0.344
REM latency (min)	RB	66.8 ± 3.7	77.0 ± 7.0			
	RS	104.0 ± 14.1	87.9 ± 6.2	0.036*	0.455	0.193
No. REM episodes	RB	4.2 ± 0.2	4.1 ± 0.2			
	RS	3.6 ± 0.3	3.4 ± 0.3	0.040*	0.349	0.753

Both groups show corresponding increases in time spent in lighter, Stages 1–2 sleep, while bed-sharing, possibly permitting more awareness of the needs of their infants (from Mosko et al. (1997) *Sleep* 20(2):142–150 with permission, © 1997 Associated Professional Sleep Societies LLC).
BN, bedsharing night; SN, solitary-sleeping night; WASO, waking after sleep onset; REM, rapid eye movement; RB, routinely bed-sharing; RS, routinely solitary; SEM, standard error of the mean; ANOVA, analysis of variance.
* Significant findings.
[a] Table entries reflect group means (±SEM) and ANOVA results for 20 RB and 15 RS mothers. *P* values are given in the three columns on the right for group, night, and interaction effects.

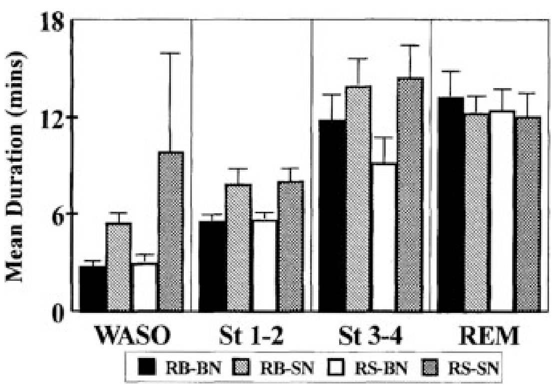

Fig. 4. Mean sleep-wake stage duration of maternal sleep graphed by group (RB vs. RS) and by night (BN vs. SN). Lines above the bars indicate standard errors of the means. Notice declines on BN in deep sleep (Stage 3–4) with corresponding increases in light sleep (Stage 1–2), in both RB and RS mothers (from Mosko et al. (1997) *Sleep* 20(2):142–150 with permission, © 1997 Associated Professional Sleep Societies LLC).

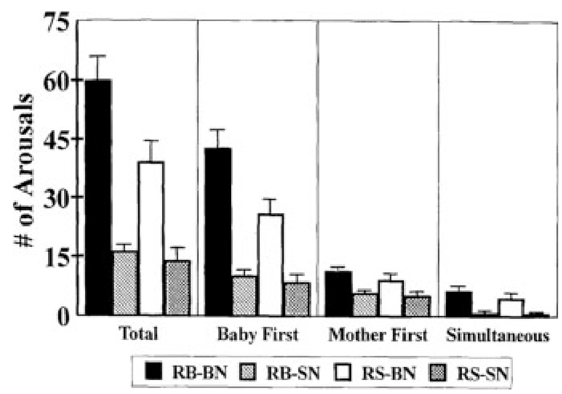

Fig. 5. Mean number of *maternal* arousals overlapping infant arousals is graphed by group and by night. Lines above the bars indicate standard errors of the means. All within-group comparisons of the bed-sharing night (BN) and the solitary-sleeping night (SN) were highly significant ($P < 0.002$); this was also true for all between-group comparisons of routinely bed-sharing (RB) on bed-sharing nights (BN) versus solitary (RS) on solitary-sleeping nights (SN) ($P < 0.001$) (from Mosko et al. (1997) *Sleep* 20(2):142–150 with permission, © 1997 Associated Professional Sleep Societies LLC).

ethological coding of the simultaneous video recordings made of the sleeping mothers and infants; videotapes were scored by adherence to a strict behavioral criterion defining what exactly constitutes the beginning and end of a breastfeeding episode (see McKenna et al., 1997). For routinely bed-sharing infants both the frequency and total duration of breastfeeding episodes were significantly greater on the bed-sharing night than on the solitary night. Routinely bed-sharing infants spent more than twice as long breastfeeding on the bed-sharing night than on the solitary night, however as the mean duration of breastfeeding episodes was not significantly greater on the bed-sharing night this difference was attributed to greater breastfeeding frequency. All three breastfeeding variables were greater in the routinely

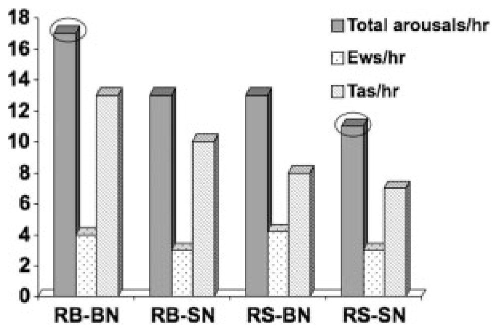

Fig. 6. Total number of infant arousals further delineated into EW's and TA's per group (RB vs. RS) and night (BN vs. SN). Routinely bed-sharing infants on their bed-sharing (normal) night arouse ~25% more frequently (without necessarily fully awakening the mother) compared with the routinely solitary sleeping infants when sleeping in their routine condition alone. Circles highlight the major differences in arousal averages for RB and RS mother–baby pairs in nightly arousals in the two groups of infants. All "bed-sharing night" effects are significant for both groups ($P < 0.001$). Data from Mosko et al. (1997c).

separate sleeping group on the bed-sharing night than on the solitary night, but none of the differences reached significance. The greatest differences found in breastfeeding were consistently between the two groups in their routine conditions. Comparison of the routine bed-sharing group on the bed-sharing night to the routine separate group on the solitary night revealed a twofold (and significant) increase in mean breastfeeding frequency. Average interfeed interval was calculated for both groups on both nights and showed that routine bed-sharing infants in the bed-sharing condition breastfed on average every 97 min compared with 187 min between feeds for the routine separate group, in their routine solitary condition (McKenna et al., 1997).

Sleep position and orientation during bed-sharing. Details of infant sleep position and orientation were also recorded via the ethological coding of video data, as mothers spontaneously positioned their infants for sleep without instruction. Routinely bed-sharing mothers almost always placed their infants to sleep in the supine position (which facilitates easy breastfeeding access). Presence or absence of the mother in the infant's immediate sleep environment (bed-sharing and solitary night) was hugely influential on infant orientation; when infants were sleeping alone their faces were oriented upwards and to each side for equal proportions of the night; however, when bed-sharing, all infants exhibited a preference for facing the mother (Richard et al., 1996). All but one mother spent the majority of sleep time in a lateral position facing their infant while infants faced their mothers for an average of 83% (range 14–100%) of the night. All but two infants of a sample of 12 studied in detail (see Richard et al., 1996) faced the mother for (on average) 69% of the night. Of the nine infants who slept supine for part or all of the night, infants turned their heads to face their mothers for an average of 80% (range 0–100%) of supine time.

Maternal–infant sleep proximity in relation to maternal–infant CO_2 exposure. Richard et al.'s (1996) analysis of maternal–infant sleep position, orientation and proximity during bed-sharing led to an examination of the possible impact of a mother's proximity on her infant's environmental CO_2. Whether or not, or to what degree, maternal respiration can affect the CO_2 environment of her infant is important from the standpoint that increased exposure to CO_2 can be potentially beneficial or deleterious depending on the degree of exposure. For example, CO_2 concentrations as low as 0.5% are known to significantly increase minute ventilation in infants based on previous studies by Kalapesi et al. (1981) and Katz-Salamon et al. (1991), who showed that infant exposure to increased CO_2 converted periodic breathing—thought to be indicative of respiratory instability (with especially longer apneas)—to normal breathing patterns in the newborn. On the other hand, at high doses (~>15%) CO_2 concentrations can be lethal [such as occurs during rebreathing when babies sleep face down prone and breathe into a soft mattress or pillow (Chiodini and Thach, 1993; Kemp et al., 1994)]. McKenna and Mosko's team hypothesized that increased CO_2 in the normal cosleeping microenvironment created by the mother would act naturally as a respiratory stimulant that may help to prevent SIDS should an infant's own internal breathing control system somehow falter (McKenna, 1986; Mosko et al., 1997c).

This study confirmed that exhaled maternal respiration increased the CO_2 concentration in the vicinity of a bed-sharing infant's face. Within the range established by the Richard's et al. (1996) analysis at which routinely bed-sharing infants were observed to sleep, and in both sitting and reclining positions, concentrations of CO_2 were measured using six healthy, wakeful female participants. Furthermore, because of the postulated relationship between CO_2 rebreathing into bedding and fatal outcomes (e.g., Chiodini and Thach, 1993; Kemp et al., 1994), Mosko et al. (1997a) measured air CO_2 concentrations produced by women when breathing into an air pocket formed by a blanket, as sometimes occurs around an infant's head while sharing a blanket with the mother. All measurements were made in the absence of infants so that the CO_2 levels would not be contaminated by infant respiration (Mosko et al., 1997a).

CO_2 concentrations were measured at distances of 3–21 cm from the nares of seated participants and the relationship of distance to CO_2 concentration was assessed (see Fig. 7). For the reclining measurements the sampling tube was attached to the nose of a doll (see Fig. 8) which approximated the body size of a 3-month-old infant. The woman and doll were placed on their sides in a face to face orientation with the doll's face in line with the participant's expired air. CO_2 concentrations were assessed both uncovered and after covering with a cotton blanket for a 2-min period (see Fig. 8).

Mean peak expiratory CO_2 concentrations and 95% confidence limits are graphed in Figure 7. The highest single peak for all measures, including when covered with a blanket, was below 4% for all subjects. Peak CO_2 was well above air concentration (0.04%) at all distances for all subjects. At 3 cm from the nares the mean peak was 2.36%, and at 21 cm the peak CO_2 averaged 0.34% (approximately eight times the value for room air). The application of a blanket to form a partial air pocket gradually (over 30 s) caused a rise in both the baseline and peak CO_2 concentration at distances of 9, 15, or 21 cm from the nares of the woman (see Fig. 9). It is important to note that while the effect of the blanket was highly significant, none of the CO_2 concentrations recorded

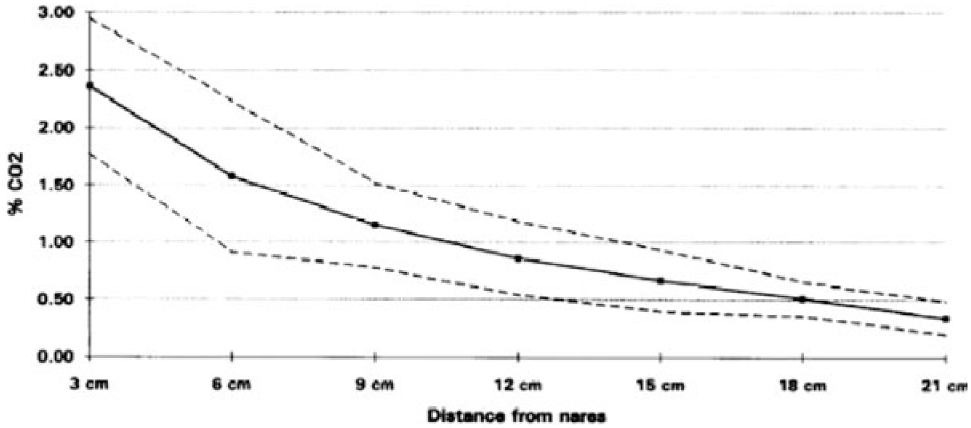

Fig. 7. Mean peak expiratory CO_2 concentrations with 95% confidence limits, at distances of 3 cm to 21 cm from the nares of women in the sitting position (n = 6). (Mosko et al., 1997a).

Fig. 8. Drawing showing co-sleeping simulation performed with doll to measure the effect of partial air pocket formed around an infant's head on CO_2 levels produced by the mother's respiration. The dotted line represents the blanket. (Mosko et al., 1997a).

approached a point that could be injurious to infants. Whether or not the increased accumulations of CO_2 created by mothers' breath can induce more stable breathing in the infant [as hypothesized by McKenna (1986) and Mosko et al. (1997)] remains to be determined. Baddock et al. (2006) examined CO_2 concentrations in the bed-sharing environment amongst both crib-sleeping and bed-sharing babies and mothers in their home environments. Their data show a similar range of CO_2 accumulation amongst bedsharing mother–infant pairs (between 2 and 5%) similar to what was ascertained by Mosko et al. (1997a). But also it is important to note that the nature of CO_2 exposure in the infant social sleep environment and the mechanisms by which it may stimulate infant respiration, can only be fully understood by acknowledging the many other simultaneous sensory experiences that function synergistically. At this point it is reassuring to have demonstrated that CO_2 concentrations do not reach levels that are dangerous to the infant.

Significance of the UC Irvine studies: infant and maternal sleep architecture, infant and maternal arousal patterns, breastfeeding and SIDS prevention

Many researchers believe that arousal deficiency—the inability of an infant to arouse and breathe following an otherwise "normal" breathing pause or apnea—may play an important role in the etiology of SIDS (see Byard and Krous, 2001 for reviews). If this is true, then manipulation of the conditions that facilitate arousability might be protective against SIDS. This might be especially true during quiet sleep (Stages 1–4) given the relatively low rate of spontaneous arousals generally associated with this sleep stage and especially the relatively high arousal threshold required to arouse from deep Stages 3–4 sleep (Mosko et al., 1996).

The UC Irvine studies demonstrated that a curtailment of deep (Stages 3–4) sleep and an augmentation both for the mother and infant of light sleep (Stages 1–2) occurred while bed sharing. It would be reasonable to argue that these features of a shared sleep experience and the facilitation of arousals that was documented during bed sharing could serve to minimize the occurrence of long periods of consolidated sleep from which infants with deficient arousal mechanisms may have difficulties in terminating prolonged apneas (Mosko et al., 1996, 1997). Therefore documentation of the effects of bed sharing on what has been assumed to be "normal" sleep architecture is one of the most important findings derived from the UCI laboratory studies. Furthermore, Mosko et al. (1996) have suggested that during the critical period when infants are most vulnerable to SIDS mother–infant sleep contact may assist in consolidating the integration of the neural mechanisms that underlie the arousal response. While further research is required in this area, the finding that transient arousal frequency was higher among routinely bed-sharing infants than among infants who routinely slept alone supports the notion that practice has a sustained impact on arousability.

McKenna and Mosko (2001) further hypothesized that there are other means by which mother–infant sleep

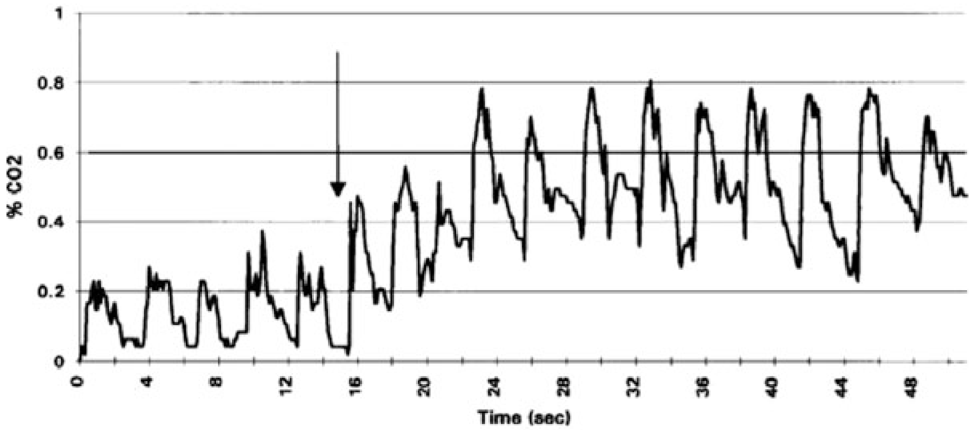

Fig. 9. Example of continuous CO_2 recording, measured at the doll's nose, 21 cm from one reclining woman's nares. The blanket was applied at the arrow, and the graph depicts the sudden precipitous climb of accumulating CO_2 gas (Mosko et al., 1997a).

contact, when practiced safely and in the absence of known adverse conditions that put infants at increased risk (e.g., maternal smoking, prone infant sleep, overwrapping), might be protective against SIDS. The proximity of the bed-sharing infant allows the mother to effectively monitor changes in her infant's status. Mosko et al. (1997) demonstrated that mothers aroused 30% more often when they bed shared than when they slept alone and that mothers did not habituate but experienced heightened sensitivity to infant arousals through routine bed-sharing behavior. Furthermore, these studies demonstrated an approximate doubling on the bed-sharing night in the temporal overlap of infant and maternal arousals. Given that the largest increase in overlapping arousals reflected instances where the infant aroused first, these findings imply a high level of responsiveness on the mother's part. That is, mothers do not habituate to the presence of their babies during routine bed-sharing. This means that they do not get so used to the baby being present that they fail to notice or respond to them, which would be dangerous. A high degree of maternal attentiveness is also strongly suggested by the close proximity, and face-to-face orientation generally maintained by the mothers during bed-sharing, as was found by Ball (see below).

Another way that bed-sharing might be protective against SIDS is through facilitation of breastfeeding. The UCI studies showed that bed sharing significantly increased the frequency and total duration of nighttime breastfeeding by participants; indeed, all the subjects studied by other research teams, have shown the same results: the closer that the mother and infant are for sleep, the more they breastfeed. Several studies of sudden infant death have shown that breastfeeding reduces the risk of SIDS (Hoffman et al., 1988; Mitchell et al., 1992; Ford et al., 1993; Fredrickson et al., 1993; Jura et al., 1994). Furthermore, the prone infant sleeping position—which is widely documented as a significant SIDS risk factor—is rarely practiced by breastfeeding mothers sleeping next to their infants, as the supine position provides the infant with the ability to suckle spontaneously.

The principal findings, then, of the bed-sharing studies conducted at UCI can be summarized in terms of the impact of the mother's presence (or lack of it) on infant sleep parameters; the effect of sleeping with her infant on the mother; and the interactive nature of dyadic sleep contact. The crucial findings for infants were less deep sleep, shorter bouts of deep sleep, more frequent arousals, significantly increased breastfeeding sessions, but also more total sleep when in their mother's presence than when sleeping alone. The modest increase in exposure to maternal CO_2 by the bed-sharing infant may function alongside other sensory stimuli to improve the infant's chances of either avoiding or responding more effectively to breathing control errors.

For mothers, sleep contact with their infant was also associated with less deep sleep, more light sleep, a greater frequency of REM sleep episodes and more frequent sleep stage changes than when sleeping alone. Taken together these results indicate that sleep contact affects the sleep architecture of both mothers and infants in fundamental ways. Evidence of simultaneous arousals and sleep stage shifts between mothers and infants demonstrates the existence of physiological and behavioral synchrony that McKenna argues is an adaptive feature of mother–infant sleep (McKenna et al., 1994). The impact of sleep contact and separation on breastfeeding frequency implicates breastfeeding in the regulation of maternal sleep cycles during offspring infancy, by interrupting and synchronizing maternal sleep cycles with those of her infant. The observation that the majority of simultaneous arousals were infant-initiated indicates that the principal role of mothers during shared sleep is to be responsive to their infants, supported by the finding that routinely bed-sharing mothers are more responsive to their infants during shared sleep than are routinely solitary sleeping mothers. The data on sleep position and orientation reinforce this picture, with infants being placed more consistently in the supine position on bed-sharing than solitary nights, and preferentially orienting towards their mothers on shared sleep nights.

Finally, while there remains some bitter disagreement over what *form* mother–infant sleep contact should take, under what circumstances sleep contact may be protective, and what protective mechanisms might be involved (McKenna and Gartner, 2000; Scheers et al., 2003; see Gessner et al., 2006) the hypothesis that sleeping in close enough proximity to enable sensory exchange reduces SIDS risk has been partially confirmed by at least three epidemiological studies. In these reports mother–infant shared sleep in the form of cosleeping (also known as room-sharing, where the infant sleeps close to, but on a different surface than, its mother) has been shown to be associated with a reduction in SIDS risk by as much as one-half (Mitchell and Thompson, 1995; Blair et al., 1999; Carpenter et al., 2004). As reviewed in detail by McKenna and McDade (2005) sleeping with baby in a shared-bed environment gives rise to both advantages and disadvantages. Under some conditions the physical and social characteristics of the bed-sharing environment (especially if the mother smoked during pregnancy, places her baby prone in her bed, does not breastfeed) can prove dangerous (Blair et al., 1999; Kemp et al., 2000). It is because bed-sharing with infants can lead to a range of beneficial or deleterious outcomes depending on how it is practiced that bed-sharing (as one form of mother–infant sleep contact) remains controversial within the SIDS research community. As shall be seen below, many of these themes have been picked up and pursued in subsequent studies conducted in homes, sleep labs and hospitals in various parts of the world.

PROLIFERATION OF INFANT COSLEEPING STUDIES OUTSIDE THE UNITED STATES

Bed-sharing studies at Sebastian Diamond Sleep Lab, St Michael's Hospital, Bristol, UK

In collaboration with the Mosko-McKenna research team, the sleep laboratory of Peter Fleming at St. Michael's Hospital in Bristol, England, began the first bed-sharing physiological study outside the United States. This cross-over study design compared bed-sharing and cot-sleeping among mother–baby pairs. Young (1999) conducted a longitudinal (five month) behavioral and physiological study in which 10 breastfeeding infant–mother pairs were monitored over a two night period. Mothers and infants checked in once a month for physiological monitoring and video recording. Each mother and infant alternated between bed-sharing on the first night and sleeping separately on the second night, with the infant sleeping in a cradle next to the bed. Sleep stages were assessed not through continuous simultaneous mother–infant polysomnography but through the use of behavioral sleep-stage criteria, and the findings were consistent with those found by McKenna's team. During bed-sharing maternal–infant sleep-wake states demonstrated stronger temporal concordance (SAT) than during cot-sleeping; significantly more mother–infant interactions (touching, physical management activities, infant directed speech) occurred when mothers and infants shared a bed as opposed to when the infant slept in the cot, and bed-sharing mothers exhibited quicker responses and aroused more quickly in relationship to the infant's activities. Moreover bed-sharing mother–infant pairs exhibited more face-to-face body orientations, touched more frequently, and breastfed more frequently than when mothers and infants slept on different surfaces.

Physiological monitoring of infant temperatures by the Bristol group revealed that during bed-sharing all the infants were able to self-regulate their core temperatures by dissipating heat. Moreover the infants awoke or removed themselves from any potential rebreathing CO_2 situation, such as moving their heads out of the armpit area of their mothers (Sawcenko and Fleming, 1996). Ball et al. (2000) and Baddock et al. (2004, 2006) (see below) later replicated this finding. Both research teams confirmed that while bed-sharing babies are generally warmer than cot-sleeping babies, they are nonetheless able to maintain a stable core temperature and are not in any way overly heated (Baddock et al., 2004). Ball (personal communication) argues that since infants spend a greater proportion of sleep time in REM when bed-sharing than when sleeping alone and core temperature is higher in REM than quiet sleep (Stages 1–4) the temperature differences of bed-sharing and solitary sleeping infants when averaged across a night simply reflects the greater proportion of time spent in REM. By analyzing core rectal temperature for REM and quiet sleep in the same infants sleeping alone and in the parental bed Ball showed that no significant difference actually exists within the two locations when analyzed by sleep state (Ball, 2000).

The Bristol research group concluded that bed-sharing by low SIDS risk mothers does not as some were claiming increase the chances of any infant dying from SIDS (Young, 1999).

Infant sleep and bed-sharing studies at Durham University Parent–Infant Sleep Laboratory

In the mid-1990s biological anthropologist Helen Ball from Durham University (UK) began a new research trajectory devoted to examining human parent–infant sleeping arrangements and breastfeeding issues in the homes of UK parents. She and her colleagues have explored what constitutes "safe infant sleep" and potential ways to a) help prevent SIDS by safely bed-sharing and b) promote infant health by enhanced initiation and duration of breastfeeding.

In fact, Ball opened the second (the first being at the University of Notre Dame) laboratory in the world dedicated to studying maternal–infant sleep, the Parent–Infant Sleep Laboratory at Durham, and subsequently conducted a variety of studies using infrared photography and physiological monitoring of families sleeping not just in her sleep laboratory but in their homes. She conducted the first studies on the father's role in the bed-sharing environment (Ball et al., 2000, 2006a) and mothers sleeping alongside and/or in the bed with their babies while on the hospital maternity ward (Ball et al., 2006; Ball 2006b, in press; Ball and Klingaman, 2007) She also conducted the first integrated in-home and laboratory study of cobedded twins (Ball, 2006c, 2006d) as discussed below.

Interview studies in North-East UK. Ball's initial study, undertaken with PhD student Elaine Hooker, involved 60 mothers who were contacted for prenatal interviews at North Tees Hospital (Great Britain) regarding their intentions for infant care practices. Forty of these mothers were then reinterviewed regarding their actual practices two to four months following the birth of their infants (Ball et al., 1999). At two to four months 70% of new parents were found to bed-share at least occasionally despite the fact that 0% expressed an intention to bed-share at the time of their prenatal interviews. Furthermore, 35% of experienced parents anticipated bed-sharing whereas 59% were actually doing so at the time of follow up. The important contribution of this study for our understanding of bed-sharing was in showing that parents do not always perceive that they "bed-share" when in fact they do. If, for example, a family owns a crib, or if babies begin the night in the crib, but are later relocated to the parent's bed (a common phenomenon) parents do not respond consistently when asked whether or not they bed-share. Had Ball and Hooker not reasked the questions about bed-sharing in different ways they may have missed as many as 47% of their sample who did in fact sleep with their infants in their bed, even after saying they did not. As Ball et al. (1999) indicate, this has important implications for how such questions are asked in case–control studies involving bed-sharing.

After establishing that parent–infant sleep contact was not an unknown phenomenon to UK families, Ball and colleagues conducted a larger interview and sleep diary study examining the normal nighttime infant care practices of 253 families with newborn infants in Teesside. The results of this study in demonstrating the role that bed-sharing plays in promoting a greater number of months of breastfeeding is especially important (Ball, 2002, 2003; Blair and Ball, 2004) and has been confirmed by subsequent studies in demonstrating that bed-sharing and breastfeeding are mutually reinforcing (McCoy et al., 2004; Rigda et al., 2000; Quillin and Glenn, 2004). Sleep contact promotes a greater number of breastfeeds per night—a finding consistent in all bed-sharing studies conducted thus far when compared with infants sleeping away from the mother or alone (McKenna et al., 1997; Young, 1999; Baddock et al., 2006; Ball et al., 2006).

The interview portion of this study (conducted when infants were 1 and 4 months old) also explored parents' explanations of why they shared a bed with their infants. Although the most common explanations given for bringing their infant to sleep in their bed revolved around the ease and convenience of nighttime breastfeeding, other common reasons involved the enjoyment of spending time in close contact with the baby (especially if apart during the day); concern about the baby's health or safety expressed as a desire to keep the baby close for monitoring; recognition that fractious infants would calm and settle in physical contact with one or both parents in their bed; and affinity to a family-bed ideology (Ball, 2002).

The results of Ball's 2-year interview study were combined with data from the UK CESDI study (Confidential Enquiry into Stillbirth and Deaths in Infancy) for an analysis of the prevalence of bed sharing in the UK. The resulting publication by Blair and Ball (2004) revealed that ~50% of UK parents engage in bed-sharing in their infant's first month of life, falling to 25% in their third month. Blair and Ball were able to ascertain that on any given night in the UK, 20% of 1-month-old infants will sleep in their parental bed. These figures for bed-sharing prevalence are far higher than had previously been acknowledged and are substantiated by a range of recently published studies documenting similar proportions of families sleeping with their infants in other western countries (Tuohy et al., 1998; Gibson et al., 2000; Rigda et al., 2000; Brenner et al. 2003; Van Sleuwen et al., 2003; Willinger et al., 2003; McCoy et al., 2004; Lahr et al., 2005).

How breastfeeding changes the bed-sharing environment. Many western medical authorities continue to insist that bed-sharing carries a singular risk factor for asphyxiation and/or suffocation by an adult caregiver, whether breastfeeding or not, even in the absence of all known adverse risk factors (Scheers et al., 2003; e.g., American Academy of Pediatrics 2005 SIDS Guidelines), and despite significant critiques of these characterizations of bed sharing (McKenna and Gartner, 2000; Fleming et al., 2006; Gessner et al., 2006). This prompted Ball and her team to examine whether the bed-sharing behavior exhibited by breastfeeding mother–infant dyads differed from that of dyads that did not breastfeed.

Just as the laboratory studies show that routinely bed-sharing mothers and infants exhibit more sensitivity to each other both physiologically and behaviorally, Ball (2006a) demonstrated that when compared to formula feeding, breastfeeding creates a very different functional connection between the mother and infant in the bed, with profound implications for the increased safety of breastfeeding bed-sharing infants compared with formula feeding bed-sharing infants. Ball observed the in-home, nighttime behaviors of 20 regular bed-sharing families, including 10 currently breastfeeding bed-sharing mothers–infant pairs and 10 mother–infant pairs that had never breastfed. Her findings show that the bed-sharing relationship is markedly different for both the infant and the mother based on the method of feeding. One difference between the two groups related to the positioning of the mother relative to the infant's sleep position. For instance, mothers of formula fed infants faced their infants only 59% of the time, whereas breastfeeding mothers did so 73% of the time. Likewise, formula fed infants had their faces at the level of their mother's face or chin during 71% of the night and at their mother's chest height 29% of the time. Breastfeeding infants were never observed positioned on or between pillows and remained with their faces at maternal chest level 100% of the night in order to facilitate feeding as needed. This finding is important given the emphasis in the literature on sudden infant deaths of the dangers to infants of suffocation by pillows (Unger et al., 2003).

Finally, in terms of infant sleep position, formula fed infants spent the night sleeping supine 83% of the time compared to 6% laterally. Breastfed infants slept supine 40% of the time and laterally 54%. This last figure, again is likely explained by the fact that frequent access and/or proximity, to the breast probably determines why breastfeeding infants are so different than bottle feeding infants as regards position and orientation once in bed with their mothers. The function of lateral or side sleeping in the breastfeeding, bed-sharing environment, according to Ball, should not be conceptualized in the same way as a solitary lateral sleeping infant might. The breastfeeding, lateral sleeping infant is unlikely to role into the prone position (a risk factor for SIDS) due to the fact the breastfeeding mother has positioned her body in a way, knees tucked up and facing the infant, that prevents the infant from rolling completely prone (see Fig. 10). None of the breastfeeding-lateral sleeping infants in Ball's study rolled prone nor did it appear that physically they could (although see below).

Altogether, these data reaffirm the idea argued elsewhere that feeding method changes the functional relationship between the bed-sharing mother and her infant in the direction of increased safety. This occurs by way of changes in the likely function or consequences of factors that, had the infant been sleeping alone, or as reported, with a formula feeding mother, they might otherwise have to be considered risky. But observations show that a breastfeeding mother plays an active role in mediating what otherwise might have to be considered a

Fig. 10. Typical bed-sharing position of breastfeeding mother–infant dyad. The infant remains generally at the level of mother's chest (away from pillows) with mother and infant facing each other, mother on her side with knees tucked up under the infant. These positions are thought safer than the position that the bottle feeding, bed-sharing mother–baby pair assume once in bed.

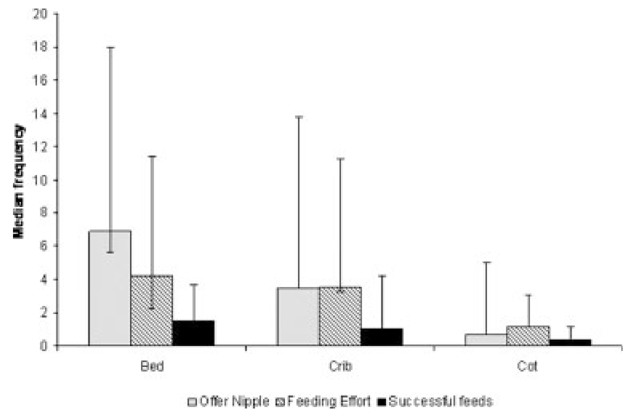

Fig. 11. Median frequency per hour (and Inter-Quartile range) of breastfeeding variables for mothers and infants who used the bed, side-car crib, and stand-alone cot conditions on the postnatal ward. Feeding effort is the frequency of attempted plus successful feeds.

"risk." The studies conducted by Ball and colleagues on the nighttime relationships of mothers and their newborn infants on hospital postnatal wards (see below) have convinced her that the bed-sharing behavior of breastfeeding mothers in curling up around their infants and creating a space with their bodies within which the infant sleeps is an innate response as she has found it to be universally exhibited by first-time mothers on the first night following delivery without previous instruction or discussion (Ball and Klingaman, 2007).

The importance of early sleep contact on breastfeeding initiation and duration in the hospital environment. Ball and colleagues' most recent work has taken place on the postnatal ward of the Royal Victoria Hospital in Newcastle upon Tyne, UK. Working in collaboration with Consultant Pediatrician Martin Ward-Platt, Ball and her research team have embarked upon a series of studies to examine the influence of sleeping arrangements on the postnatal ward on the establishment and continuation of breastfeeding. These studies are underpinned by an understanding of the evolutionary biology of human lactation and the role of mother–infant contact in promoting frequent and unregulated suckling in stimulating lactogenesis (milk production) and galactopoesis (maintenance of milk supply). Using the clinical "gold standard" research technique of the randomized control trial (RCT), Ball and Ward-Platt undertook to evaluate the effects on breastfeeding initiation of three infant sleep locations on the postnatal ward for the first two nights following birth (Ball, 2006b). Mothers and their newborns were randomized to one of three sleep conditions: infant in the bed, in a three-sided crib attached to the bed (side-car) and infant adjacent to the bed in a standalone bassinette. Using all-night infrared video monitoring Ball and Ward-Platt examined mother–infant interactions, feed frequency and infant safety in the three conditions.

They found that the two sleep conditions in which mothers and infants experienced unhindered access (baby in bed and baby in side-car crib) were associated with significantly more frequent attempted and successful suckling bouts than did the separate (stand-alone bassinette) condition (Ball et al., 2006) (see Fig. 11). Mothers were more responsive to their infants' feeding cues in the bed and side-car conditions, and infants were able to rouse their mothers from sleep more quickly than when placed in a stand-alone bassinette. Particularly active newborns were even able to locate and latch on to the nipple without their mothers' assistance when lying side by side. The physiological consequences of this frequent nipple stimulation by infants on maternal physiology has been well researched (e.g., Johnston and Amico, 1986; Uvnas-Moberg et al., 1990; Neville et al., 2001) and is known to stimulate prolactin production. Frequent prolactin surges in turn give rise to greater milk secretion. Neville (2001) found that the frequency of suckling on Day 2 postpartum was positively correlated with milk production on Day 5. Ball and Ward-Platt recommend that in order to promote the establishment of breastfeeding, hospital postnatal infant sleeping arrangements should facilitate unhindered access between mother and infant 24 hours per day (Ball et al., 2006). Although the above study was conducted with mothers and infants who experienced normal vaginal deliveries only, it raises important implications for the postnatal care of mothers and infants at increased risk of breastfeeding failure such as those who are born preterm and those who experience operative deliveries. To explore the effectiveness of unhindered mother–infant access on improving successful breastfeeding in such groups, graduate student Kristin Klingaman is now working with Ball and Ward-Platt to conduct a randomized trial of side-car crib use for post-c-section mothers and infants (Klingaman and Ball, 2007).

Ball and Ward-Platt are continuing their collaboration by examining how the early postnatal environment

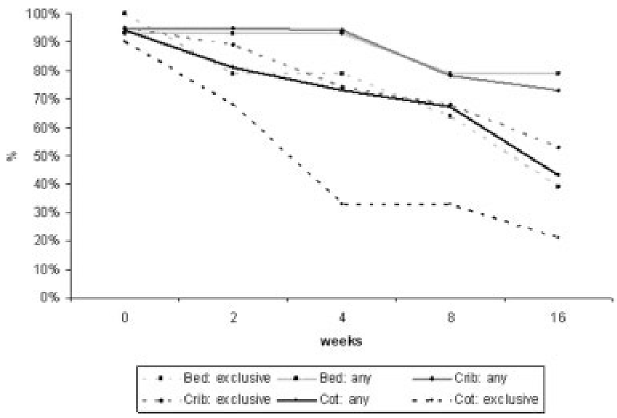

Fig. 12. Proportion of infants receiving any and exclusive breastfeeding between 0 and 16 postnatal weeks following allocation to bed, side-car crib and standalone bassinette conditions on the postnatal ward.

might affect long-term breastfeeding outcomes. In their initial study they followed-up the mothers who participated in the randomized infant sleep location trial to ascertain breastfeeding behavior at 2, 4, 8, and 16 postnatal weeks and found that twice as many mothers and infants who had been allocated to the "unhindered access" conditions were both breastfeeding and exclusively breastfeeding than were mothers and infants who had been randomized to the "normal" postnatal ward condition of a bassinette by the mother's bed (Ball and Klingaman, 2007; Ball, in press) (see Fig. 12). This led them to seek funding for a large-scale RCT to prospectively examine breastfeeding outcomes at six months following random allocation to side-car or standard postnatal ward care. Having successfully achieved this funding the project, in which 1,100 mothers will participate, will commence in Fall, 2007. If the results obtained confirm those suggested in the previous and much smaller trial, then this study will provide compelling evidence that the night-time separation of mothers and their newborns has serious long-term consequences in undermining the establishment of breastfeeding and denying both mothers and infants all of the life-time health advantages that breastfeeding confers.

Cobedding twins: a different kind of cosleeping. Ball (2006c,d) also conducted the most extensive study to date of the sleep behavior of twins and their parents, especially what is called "cobedding," a situation in which twin infants sleep in the same crib or bassinette or some other structure—a different kind of cosleeping. From a scientific point of view, the cosleeping of twins (placed in the same sleep structure on the same surface) is relatively unexplored. The "cobedding" of twins is very different from adult–infant (especially mother–infant) cosleeping in a number of ways. For example, cobedding takes the form of two bodies of equal size and weight in the same crib or sleep surface. How cobedding functions and its role in infant development and safety is very different from other forms of cosleeping. Since twins and multiples are associated with a higher risk for SIDS (Sanghavi, 1995; Daltveit et al., 1997; Mitchell et al., 1997), questions regarding what kind of sleep environment might best protect them or put them at increased risk is especially critical. Questions pertaining to cobedding emerge against the larger background of trying to understand how and why prematurity in general is associated with SIDS, as many twins are born premature.

Since the challenge of all newborns in making their way from the womb to the worldly environment is to reestablish some kind of "biorhythmic balance" by stabilizing the functions of sleep-wake cycles, eating patterns, blood chemistry levels, respiratory and heart rates, several researchers (Nyquist and Lutes, 1998; Lutes and Altimer, 2001) have argued that the mutual sensory exchanges that are facilitated by cobedding may enhance the ability of any one twin to accomplish this task especially by improving breathing, using energy more efficiently and reducing stress levels. It is known for example that the stress response which leads to increased cortisol production can negatively impact growth and development and generally alter thermal regulation, sleep duration, breathing and heart rate in potentially negative ways. These researchers found that, similar to what is observed to occur in the womb, cobedded twins move close together, touch and suck on each other, hold each other, and hug one another.

Ball's (2006c) research supports anecdotal reports by parents of twins that their infants prefer to be together and that their babies settle better together and sleep more soundly when cobedded. Despite the concerns of some parents they neither wake one another nor overheat (Ball, 2006d). Given the challenges of caring for two babies, as Ball points out in her reports, it is not surprising that parents will come to practice any behavioral care pattern that tends to maximize their own sleep and ease the burden of caring for and feeding two babies simultaneously (Ball, 2006c).

While reports that recommendations against cobedding are being made by NICU nursing personnel remain anecdotal, where they do occur it may illustrate cultural biases against cosleeping in general where medical authorities assume (without any data) that if some instances of bed-sharing between an adult and a baby are dangerous then two infants of equal body size to each other must likewise pose a mutual threat. When and where there is a gap in our knowledge, or little information is available, recommendations are sometimes prone to fall back on generalizations, stereotypes, and anecdotal information. In this case, studies of bed-sharing involving adults and infants are being applied to the question of whether or not it is safe or beneficial for twins to share a crib. What Ball's research actually showed was that parental variations in cobedding configurations (i.e., the ways in which infants and bedding were arranged) were more likely to introduce risk than the fact of the babies being in the same crib (Ball 2006c, 2006d)—see Figure 13.

Bed-sharing studies at the University of Otago, New Zealand

In contrast to the aforementioned laboratory studies comparing bed-sharing and infant cot-sleep, Sally Baddock of the University of Otago (New Zealand) recorded overnight, in-home physiologic and video data for 40 bed sharing and 40 cot-sleeping infants (Baddock et al., 2006, 2007). To establish normative data for bed-sharing mother–infant dyads Baddock et al. examined differences between bed-sharers and cot-sleepers in regard to sleep time, sleep position, movements, feeding, parental blanket height, and parental checks in order to explore possible mechanisms underlying risks and benefits iden-

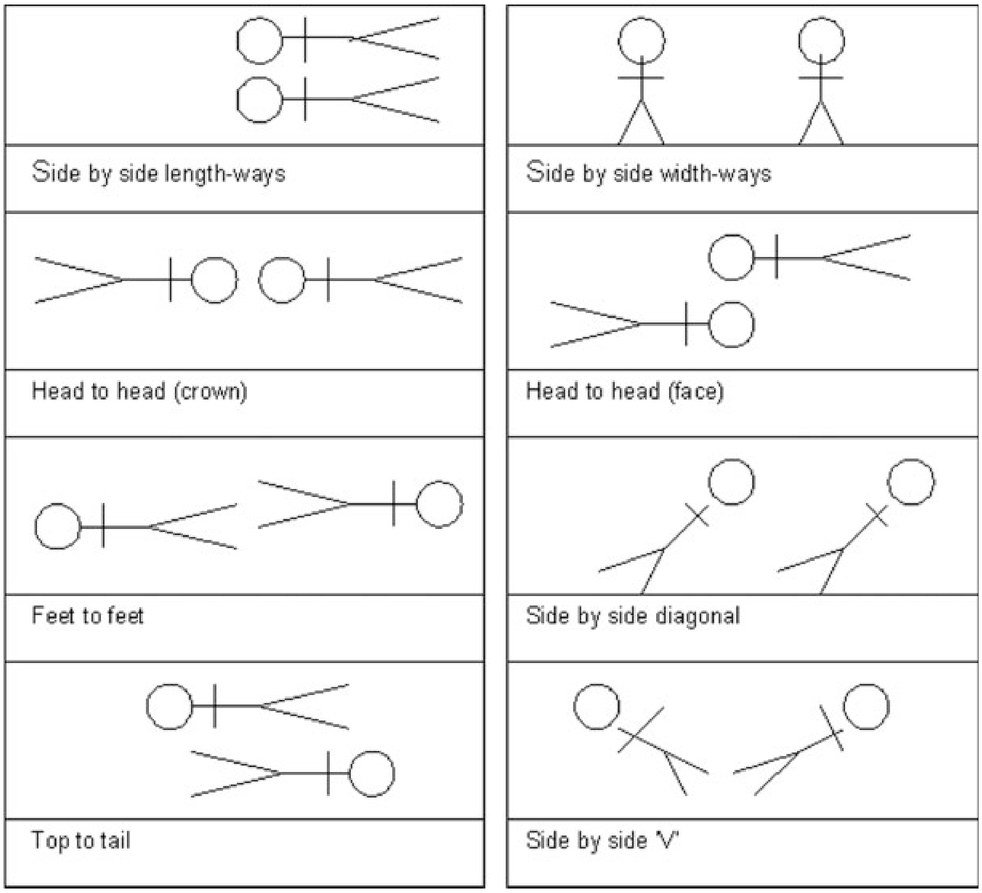

Fig. 13. Twin co-bedding configurations as depicted by parental illustrations. When infants were positioned width ways and diagonally across the cot, parents introduced hazards in two ways: a) separating babies with pillows or rolled up blankets, and b) loosely draping covers over babies that were not big enough to be properly tucked in—both increasing risk of head covering and thereby suffocation and overheating. [Figure first published in Ball H. (2006). Caring for twin infants: sleeping arrangements and their implications. *Evidence Based Midwifery* 4(1):10–16. Reprinted with permission.]

tified from epidemiological data. Bed-sharing infants were defined as sleeping a minimum of 5 hours per night in the parental bed, whereas cot-sleeping infants regularly slept in a cot/bassinette in the parental bedroom for a minimum of five hours per night. All infants were aged 0–6 months and had no prenatal or postnatal complications; all of the bed-sharing infants and 35/40 cot-sleeping infants were breastfed. Infants were monitored over two consecutive nights in their homes in their normal sleep situation and following the set up and commencement of recordings by the researchers families were left unattended for the duration of the night. Total infant sleep time and sleep efficiency were found to be similar in the two conditions (median sleep time: bed-sharing = 8.6 h; cot-sleeping = 8.2 h; median sleep efficiency: bed-sharing = 90.7%; cot-sleeping = 87.1%).

Regarding sleep position Baddock et al. found that bed-sharing infants slept the majority of the night in the side position (median: 5.7 h, 66% sleep time) whereas cot-sleeping infants slept supine (median: 7.5 h, 100% sleep time). The time spent prone was not significantly different between groups and of minimal duration overall with only 5 bed-sharing infants spending any time prone (range = 1.6–3.5 h, respectively) and 2 cot-sleeping infants spending the entire night prone (8.9 and 10.2 h, respectively). All cases of prone sleep amongst bed-sharers began with the infant sleeping on the mother's chest, sometimes after feeding. In one case the mother then placed the infant to sleep prone in the bed while in another instance the infant rolled into the prone position from his side when the mother moved.

Blanket position over the two infant groups differed as cot-sleeping infants (median: 8.1 h, 100% of sleep time) spent more time with blankets below the chin level than bed-sharing infants (median: 7.1 h, 82% of sleep time), and bed-sharing infants spent significantly more time with blankets partially over the face, up to the eyes. Head-covering incidents took place in 22 bed-sharing infants and one cot-sleeping infant, and upon final awakening five of the bed-sharing infants remained with their heads covered. Despite this difference, there were no oxygen desaturation events ($SatO_2 < 90\%$) and no increase in rectal temperature beyond the reference range during head-covering incidents for either group of infants. Baddock et al. note that the frequency of head covering in bed-sharing infants, relative to the cot-sleeping infants, may be attributed to the movement of bedding on and off the infants throughout the night due to the participants' natural course of sleep. Consequently, only one quarter of infants who experienced head-covering incidents awoke with the head covered at the end of the night.

In terms of parental checks, which usually consisted of touching rather than merely looking, the study found no significant difference in the amount of time bed-sharing mothers spent checking their infants relative to mothers of cot-sleeping infants; however, the frequency of checking was much greater among the bed-sharing group (median frequency per night = 11) than the cot-sleeping group (median frequency per night = 4). These more frequent checks did not always result in full arousals and small patting movements were seen despite the appearance of sleep. In addition to the potential benefits afforded to infants by way of increased parental checks, including temperature regulation and perhaps decreased SIDS risk (cf. Carpenter et al., 2004), mothers reported an emotional benefit from bed-sharing because they could easily check their infant (Baddock et al., 2006).

In a subsequent paper Baddock et al. (2007) conducted detailed analysis of sleep arrangements and behavior among the bed-sharing families in their sample. In examining who slept in the bed, they found that sleep arrangements varied when the father and/or siblings shared the bed; however, most frequently the mother's body acted as a barrier between the infant and the father/siblings. Two infants slept the entire night in this arrangement thus precluding contact with anyone but the mother. In 19 cases families spent the majority of the night in this configuration. It was therefore common for infants to be in some form of contact with their mothers throughout the night either in terms of either touching or cradling. There was little contact between fathers and infants even when the infant slept between the parents. The majority of the night the infants were oriented with their head at the level of the mother's breast (median: 6.1 h; IQR: 2.4–8.4). Consistent with other studies, feeding was found to be 3.7 times more frequent amongst bed-sharers than cot-sleepers, reinforcing the robust association between bed-sharing and increased breastfeeding (McKenna et al., 1997; Young, 1999; Ball, 2002, 2003; Blair and Ball, 2004; Ball et al., 2006; Ball, 2006a; Ball and Klingaman, 2007; Ball, 2007).

What ethnographic studies contribute to our understanding of "normal" infant sleep development

A logical question arising from the short-term sleep studies described above is whether the repeated nightly physiological changes that differentiate the solitary sleeping infant from the routinely bed-sharing infant has a cumulative effect on the trajectory of infant sleep development in the first year of life. The answer is that it appears from studies conducted outside the laboratory that the sleep environment experienced by an infant contributes to a very different pattern of sleep development. Elias et al. (1986) compared the development of sleep in infants of mothers following Spock's recommendations to minimize contact and feeding during the night with the sleep of infants whose mothers practiced prolonged breastfeeding, physical contact, and close sleeping as encouraged by the breastfeeding support organization La Leche League. Among infants receiving minimal nighttime contact and care, the maximum sleep bout length increased from an average of 6.5 h at 2 months of age to 8 h at 4 months and to greater than 8 h during the second year. Infants of La Leche League mothers at 2 months of age slept an average of 5 h during their longest sleep bout. Not until they were 20 months old did these infants sleep significantly longer than 5 h during their longest sleep bout. In contrast to the consolidated sleep of the Spock-care infants, their sleep was characterized by shorter bouts and frequent awakenings at night. In addition to bout length, total sleep time developed differently for contact sleepers. La Leche League infants slept a total of 15 h at 2 months, 12.5 h at 4 months, and just over 11 h by 2 years. Spock-care infants continued to sleep 13–14 h per day throughout the 2-year monitoring period (Elias et al., 1986). As such, Elias et al. concluded that feeding type (breast milk or formula) and sleep contact have major effects on the development of sleep patterns. Indeed, in their sample these two factors explained 67% of the variance in sleep bout length (see also Spock, 1946; Mintern and Lambert, 1964).

These data are consistent with those from babies born to mothers from a very different society but whose patterns of nighttime sleep and feeding were approximately the same as infants whose mothers practiced La Leche League-style baby care. For the first year of life, Super and Harkness (1987) documented significant differences in nighttime sleep behavior of Kipsigis infants in rural Kenya (who breastfeed and cosleep) and infants living in Los Angeles. Ten Kipsigis infants were observed over a 24-h cycle on a series of days during the first eight months of life with records kept on their sleep-wake state and feeding patterns, while comparison data for the Los Angeles sample was provided by work conducted by Parmalee et al. (1964). Kipsigis babies breastfed throughout the night and slept in close contact with their mothers in one room dwellings while American babies slept either in their own rooms or own beds. Whereas the American babies averaged 8 h of (apparently continuous) nighttime sleep by 16 weeks of age, the Kipsigis babies continued to wake at intervals of 3–4 h up to 8 months of age, the oldest age for which data were kept. They also found that over the 24-h cycle by the third and fourth month of age American babies were sleeping about 2 h longer (Super and Harkness, 1987).

What is difficult to disentangle here are the relative contributions of sleep contact and breastfeeding on infant sleep development, but these ethnographic studies demonstrate that the 'expected' developmental trajectory for infant sleep consolidation in western settings is an aberration rather than the norm. Of course, from an evolutionary perspective, both breastfeeding and mother–infant sleep contact are elements of the same adaptive complex, and together combine to encourage synchrony and responsiveness of mothers and infants to one another's sleep states. What happens to the developmental sleep trajectory of infants who bed-share in the absence of breastfeeding remains largely unstudied; however, the preliminary findings from the Durham University Parent–Infant Sleep Lab of the sleep interactions between never-breastfed bed-sharing infants and their mothers suggests that they do not have the same degree of synchrony and mutual awareness during the night (Ball, 2006a).

DISCUSSION: WHAT ANTHROPOLOGICAL STUDIES CONTRIBUTE TO PEDIATRIC SIDS AND INFANT SLEEP RESEARCH

"A solitary, unprotected, and unequipped sleeper is an aberration: for humans, sleep is embedded in behaviorally, socially and culturally constituted environments enabling safe sleep." (Worthman and Melby, 2002, p. 71).

The preceding review of the wealth of data now accumulated on the effects of sleep contact on both human infants and their mothers vividly demonstrates both its importance for normal human infant development and explains why it is a highly valued infant care practice for the majority of parents worldwide. The most crucial findings generated by the past twenty years of bioanthropological infant sleep research involve:

a) The discovery of the intricate interrelationship of sleep contact and breastfeeding including: the role of breastfeeding in attenuating infant sleep patterns and duration; the relationship of sleep contact and breastfeeding to infant sleep position; and the importance of sleep contact in breastfeeding frequency and therefore in initiation and maintenance of lactation;
b) demonstration of the mutual regulation and physiological interconnectedness of mother–infant sleep states during bed-sharing including the progression and timing of sleep (and awake state) stage;
c) documentation of more frequent infant arousals especially during quiet sleep while bed-sharing than when sleeping alone, with important implications for susceptibility to SIDS;
d) demonstration of the disruption caused to both breastfeeding and sleep-state regulation by the separation of mothers and infants, even if that separation is no greater than the infant in a crib adjacent to the mother's bed;
e) understanding of the variability of bed-sharing behavior in terms of 1) reasons for bed-sharing, 2) frequency, and 3) duration of bed-sharing and how these variables relate to infant feeding practices;
f) indication that bed-sharing prevalence in western societies is greater than previously acknowledged (~50% of all infants bed-share, with 70–80% of all breastfeeding infants) or than reported in the control groups of case–control studies and that younger infants (0–2 months) bed-share much more frequently than older infants (3–6 months);
g) identification of differences in bed-sharing behavior between breastfeeding and never-breastfed dyads, including that routine bed-sharing with breastfeeding is associated with heightened responsiveness of mother and baby to the other's cues, signals or other sensory stimuli;
h) demonstration that both infants and mothers arouse more frequently, often in relationship to the others arousals while bed-sharing (compared with when each sleeps alone), yet each gets more sleep than if sleeping separately.

Given this substantial progress in understanding the detrimental implications for infants of encouraging solitary sleeping practices, it is alarming that the American Academy of Pediatrics (2005) in the United States recently initiated educational campaigns aimed at preventing any form of same-surface mother–infant cosleeping, regardless of circumstances and context. It is even more concerning that these recommendations have been uncritically accepted and duplicated around the world by other pediatric organizations and national health bodies (e.g., Alm et al., 2006; Huang and Cheng, 2006). In light of this it is instructive to consider how public health recommendations have been influenced by cultural preferences (and prejudices) and why only certain types of "scientific evidence" are privileged in such recommendations. It is also illuminating to examine the deficiencies that are inherent in this evidence.

The recent wave of recommendations advising parents against sleep contact with their babies stems in part from a growing sense among medical authorities that there has been a rising trend in infant deaths in parental beds in countries such as the US and UK. The proportion of SIDS deaths located in parental beds, for instance, has occupied an increasing percentage of all SIDS deaths over the last decade (Blair et al., 2006). Some authorities have interpreted these data as indicating that bed-sharing is a new risk factor for SIDS, however, Blair has pointed out that the increased proportion of SIDS found in the parental bed does not represent an increase in frequency of such deaths—merely a decrease in the number of SIDS-infants found in cribs, consequent to the back-to-sleep campaign of the 1990s. The studies described above indicate why this would be a predictable outcome—in that bed-sharing infants rarely sleep in the prone position—and so one would expect that the greatest SIDS reductions would be observed among solitary-sleeping infants following such campaigns.

Another impetus for "anti-bed-sharing" recommendations has been concern regarding unsafe bed-sharing and other hazardous infant sleep environments. This concern stems in part from a series of uncontrolled studies emanating from the Consumer Products Safety Commission database on faulty products examining reports of accidental infant deaths (e.g., Drago and Dannenberg, 1999; Nakamura et al., 1999; Scheers et al., 2003) and in part from anecdotal reports and investigations of dangerous bed-sharing practices.

Finally, data accumulated via epidemiological case–control studies examining SIDS has been invoked as evidence that bed-sharing is associated with an increased risk of SIDS. These studies are particularly powerful in swaying the opinion of public health officials but are also particularly problematic when one scratches beneath the surface in the context of the bed-sharing "debate." Examples of discrepancies in recent publications from case–control studies include: definitions of bed-sharing that are very restrictive for the control group (e.g., bed-sharing defined as sleeping all night in a parental bed) while the case group includes any infant who died in a parental bed, regardless of how long s/he had or would have slept there under normal circumstances (e.g., Carpenter et al., 2004); inclusion of infants returned to cribs in the calculation of "bed-sharing deaths" (e.g., Tappin et al., 2005); and conflation of bed-sharing and sofa-sharing as bed-sharing deaths (e.g., Carroll-Pankhurst and Mortimer, 2001). Furthermore, case–control studies often fail to explore the circumstances surrounding bed sharing and how these might relate to infant death outcomes, for example, drug and alcohol use (Tappin et al., 2005); method of infant feeding (Carpenter et al., 2004); sleep position at time of death (Scheer et al., 2003). There is insufficient space in this review to give a detailed critique of how the case–control methodology is inappropriate for examining a behavioral phenomenon such as bed-sharing (which can be conducted in both safe and unsafe ways according to the circumstances in which it is practiced). Fortunately, however this has recently been extensively reviewed by a team of Canadian researchers (Horsley et al., 2007) led by pediatrician Aurore Cote.

This group was particularly damning in their conclusion regarding the appropriateness of basing public health recommendations on the outcomes of case–control studies, which are designed to be hypothesis generating—not hypothesis testing.

That the process leading to pediatric recommendations against all forms of bed sharing has either ignored or dismissed other contrary lines of research evidence is also troubling. The principles for applying 'evidence based medicine' described by Sackett et al. (2000), which explicitly state that case–control studies should not be relied on exclusively as the sole basis for public health recommendations, have not been followed in the case of bed-sharing. No consideration was given to the important reasons why parents adopt bed-sharing as an infant care strategy in the first place, nor to the numerous ethnographic, behavioral, and physiological studies of bed-sharing. Among other things, studies that examine the actual behavior itself, that is, bed-sharing (rather than simple outcomes) reveal that whether beneficial or deleterious, outcomes associated with mother–infant bed-sharing are dependent on how it is practiced. No acknowledgment of bed-sharing diversity and complexity is made, nor that in the context of enhancing breastfeeding bed-sharing increases the chances of infant survival and maternal well being. Medical institutional responses to bed sharing enthusiastically dismiss the legitimate biological and psychological reasons why close nighttime contact and proximity between the mother and infant occurs and the ways that both maternal and infant needs are met in facilitating and sustaining breastfeeding (Ball, 2003, 2007a).

CONCLUSION: THE NEED FOR MORE EVOLUTIONARY PEDIATRIC RESEARCH AND ANTHROPOLOGICAL INVOLVEMENT IN STUDIES OF INFANTS AND PARENTS

Present recommendations regarding infant sleeping arrangements in western societies place infants and mothers at odds not only with their own bodies but with the societies within which their behavior and emotions find expression. Moreover, medical authorities continue to endorse an authoritative view that dismisses the insights and confidence parents gain as they learn about the unique needs of their own infants and how best to respond to them. In so doing some medical authorities seek to deny the validity of biologically influenced parental inclinations, such as the desire to sleep with one's baby, which we argue is an instinctive human trait, a fundamental component of breastfeeding behavior, and an important mechanism for modulating infant sleep development.

As previously argued (McKenna and McDade, 2005) there are few places where the social values, expectations and preferences of the Western industrial world are more strongly reflected than in the clinical models of what is purported to be "normal" sleep and "normal" sleeping arrangements in the first year of an infant's life. In the field of pediatric sleep medicine, it seems, cultural rather than biological understandings predominate, often without the scientist's realization. The recent unqualified recommendation by the American Academy of Pediatrics against any mother–infant bed-sharing is having a cascading negative effect on many hospital policies. Some US hospitals for example, no longer permit an infant be in the bed with the mother at all, even when the mother is awake, or to lie prone on the mother's chest also while mother is awake. Fewer hospitals seem comfortable encouraging any kind of sustained contact between a mother and her infant at all, even in light of the strong evidence that early and sustained contact enhances successful breastfeeding, attachment and general infant and maternal health, as Ball's UK studies described here clearly reveal. Moreover, the cobedding of twins, that is, placing twins in the same bassinet is now being discouraged as well, as it is assumed that if adult–infant bed-sharing is deemed "dangerous" then so must be infant–infant bed-sharing, even though there are no data supporting such a view.

Altogether, the heavy emphasis on denying a mother spontaneous sustained contact with her infant leads us to believe that if such guidelines are widely adopted breastfeeding will be negatively impacted, as will the natural joys mothers and fathers experience when in contact with their babies, especially at night. These kinds of messages and public health recommendations can be challenged using anthropological perspectives and empirically collected data. They should be challenged because not only do they fail to acknowledge a diverse body of scientific evidence that refutes their claims and assumptions but because social judgments are masquerading as science. In illustrating how anthropological perspectives and approaches can lead to new research insights that challenge traditional medical paradigms, one important purpose of this review is to provoke enough thought and interest that others might join us in this important area.

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