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Evolutionary Paediatrics
A Case Study in Applying Darwinian Medicine

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Introduction

One of the principal goals of evolutionary medicine is to identify and examine consequences to the health of modern humans that are derived from incompatibilities between the lifestyles and environments in which humans currently live, and the conditions under which human biology previously evolved.[1,2] A related approach specific to infant and child health, known as ethno-paediatrics (the comparative study of parents and infants across cultures) explores the way different caregiving styles affect the health, well-being, and survival of infants and children.[3] The confluence of evolutionary medicine and ethno-paediatrics has provided fertile ground for the emergence of what we have termed evolutionary paediatrics—an approach to infant and child health that draws upon cross-species, cross-cultural, historical, and palaeoanthropological evidence to inform critical examination of Western postindustrial and biomedical models of infant care. Over the course of the last decade biological anthropologists and paediatric clinicians with an interest in evolution have been instrumental in the development of this area of study, which (as I will later demonstrate) is now finding a foothold within aspects of mainstream infant and child health care. One of the key features of the growing success of evolutionary paediatrics has been the effort of its proponents to use the evidence generated by their studies to ameliorate the iatrogenic effects of mismatches between evolved mother-infant biology and Western postindustrial/biomedical infant care practices.[4–6] Successes have been achieved by challenging both parents and practitioners to reexamine key assumptions about infant care and development in light of evolutionary perspectives on maternal-infant behaviour and physiology. Where necessary, this has necessitated the proponents of evolutionary medicine directly involving themselves in clinical trials that test the validity of interventions informed by an evolutionary perspective.[7]

Encouraging Infant Independence and the Separation of Mothers and Babies

The consequence of what physical anthropologist Sherwood Washburn christened the "human evolutionary obstetric dilemma"[4,8–10]—how to accommodate the passage of the head of an increasingly large-brained infant through a bipedally adapted pelvis—was for human infants to be born sooner than would be expected for a primate of our brain size.[11] Martin[11] estimates that human gestation should be at least twice its current duration were it not for the constraint imposed by the maternal pelvis on infant brain size at birth. This truncation of human gestation means our infants are neurologically underdeveloped at birth in comparison with other hominoids (being born with 25% of their adult brain size, compared with >50% in other apes) and require a prolonged period of caregiver dependency while brain growth is prioritised.[3,11,12] Given their state at birth, human infants are said to be secondarily altricial, and their vulnerability, if abandoned during this period, suggests there would have been powerful selective pressure in our evolutionary past to ensure mothers and infants did not become separated.[3,12] Truly altricial infants (i.e., those born hairless and helpless with closed eyes and ears) are cached in nests while their mothers forage, but are rarely left alone, remaining in physical contact with nest mates who provide warmth and physiological regulation. Among such species infants are adapted to remain silent, and to inhibit defecation in their mother's absence, thereby avoiding advertisement of their location to predators. At the other end of the mammalian spectrum, precocial infants, born singly, with well-developed hearing and vision and the ability to walk soon after birth, are able to flee from danger and maintain close proximity with their mothers.[3] Even the infants of great apes, although unable to walk and climb in the immediate neonatal period, are able to cling to their mother's fur, and thereby avoid the dangers of separation, within a few weeks of birth.[12] Human infants, however, show none of these characteristics. As precocial infants with secondarily altricial traits, human neonates are unable to hide, flee, or cling to their mothers in the face of danger, and are dependent upon their caregiver to ensure they are kept in close proximity. The distinctive human infant cry (unique among primates) is hypothesised to have evolved as a separation distress call to elicit the attention of adults,[13] but this instinctive response to separation and fear also increases vulnerability to predation. In our hominin past, those infants who were separated from their mothers would simply not have survived,[14] and mother-infant separation is unlikely to have been a parenting strategy pursued by our ancestors.

Although the risks of death or injury in the face of predators are greatly diminished (but not entirely lost; see BBC News[15]) in the Western postindustrial environment, separation of an infant from its mother still carries harmful consequences. Due to their neurological immaturity, newborn humans are poorly equipped to regulate their own temperature or breathing patterns for the first few months of life, and experience greater physiological stability and energy conservation when in physical contact with a caregiver than when alone.[16–18] It is unsurprising, therefore, that separation is physiologically stressful for infants—as it also is for many mothers.[19] Culturally, however, infant independence has been valued as a parental goal in many Euro-American countries,[20–24] and separating infants from their mothers for sleep, transport, and periods of quiet wakefulness is a normal, widespread, and seemingly desirable custom. Both infant development and parental competence are often measured by the yardstick of infant independence. But a cross-cultural perspective reveals that postindustrial humans are unusual in encouraging the early independence of their offspring, and in nonindustrial societies infants remain in contact with their mother's body, day and night, for the initial months,[23,25–27] and in contact with the bodies of allocarers (such as fathers and siblings) for several months more.

This view of infants as separate and independent entities from their mothers is historically novel and culturally circumscribed, becoming prevalent only in the twentieth century in North America and parts of Europe where the production of a self-soothing solitary sleeping infant epitomised the socially desirable outcome of successful parenting for at least half a century (early 1930s to early 1980s).[28,29] Prior to this time it is clear from both commentaries on normal family life[30] and the emerging genre of physicianauthored advice books to mothers appearing in the 1800s that the mother's body was the primary source of comfort and the normal sleeping place for the dependent infant.[28]

The change in perspectives regarding the nature of infancy throughout the twentieth century in the United States and western Europe has been described and documented in detail by several historians of child rearing.[28,29,31] The transformation of the "role" of infancy culminated in the increasing popularity of so-called scientific infant care, advocated by the infant care experts of the interwar era. These men (e.g., John B. Watson, Frederick Truby King, and Arnold Gessell) espoused the virtues of instilling self-control and self-reliance from an early age by means of scheduled feeding, minimal picking up and cuddling, and an avoidance of "spoiling" (e.g., refusal to respond to an infant's cries).[28,29] A "good" baby was predominantly comatose and undemanding, and early independence from the mother was a developmental goal to be achieved rapidly by infants, particularly at night. Mothers and physicians alike were advised that infants should be sleeping through the night by the age of 3 months, and lack of attainment of such developmental goals signified a wilful, noncompliant infant—or worse still—an inconsistent and overindulgent mother.[28,29] The goal of Western parenting was the training of an infant who learned from an early age to expect and to require minimal parental attention. The emergence and subsequent reinforcement of this parenting strategy did not occur randomly, but was a product of a particular historical era and cultural environment that valued independence, regulation, and control as desirable characteristics. It had little to do with the needs of infants and much to do with the needs of parents and the aspirations of the societies in which they lived.[20]

The Role of Hospital Birth in Separating Mothers and Babies

Popular acceptance of the desirability of infant independence is unlikely to have been accomplished were it not accompanied by a significant development in the experience of childbirth, which had serious repercussions for early infant care and mother-infant relationships. Throughout history and prehistory childbirth was a hazardous and liminal activity.[32] For Victorian women (many of whom experienced particular childbearing difficulties due to pelvic deformities consequential to rickets) the fear of pain and death in childbirth loomed large.[32,33] It was against this backdrop that, in the late nineteenth and early twentieth centuries, the practice of administering chloroform to women in labour was initiated—initially for humane reasons, but subsequently at women's request. Such anaesthesia could only be delivered in a hospital setting, and in the years that followed mothers increasingly chose to deliver their babies in hospitals in order to absent themselves from the fear and pain of childbirth. Chloroformed women were unable to care for their babies for several days while recovering from the effects of the gas, but women saw the use of anaesthetic to be a boon and eagerly requested it.

Nurseries were introduced into hospitals as a consequence of mothers' incapacitation and babies had to be cared for by nursing staff.[33]

In the late thirties, the anaesthetic-amnesiac known as twilight sleep was introduced to women in labour; a combination of scopolamine and morphine, it provided a painless conscious birth, but removed the mother both mentally and emotionally from the birth experience, most being subsequently unable to remember the event itself. Twilight sleep societies established in the United States and the National Birthday Trust—headed by prime minister's wife Mrs. Stanley Baldwin—in the UK campaigned for women's rights to a pain-free birth, and its use became widespread.[23,34,35] This heavy dose of narcotics and amnesiacs completely incapacitated labouring women, causing them to lose control and resulting in many being literally strapped to their beds to prevent injury. With the introduction of intravenous barbiturates to this cocktail women were again rendered practically unconscious during labour. Recovery was a long process because of the drugs, and infant care was impossible. Twilight sleep and barbiturates also caused difficulties for the babies, who were born sleepy and unable to respond or suck, and many were force-fed in the first days after birth. Even respiratory movements were suppressed and babies in the nurseries had to be watched carefully to ensure that they did not stop breathing.[36,37]

In the initial decades of the twentieth century hospital deliveries increased geometrically due to the appeal of unconscious childbirth (figure 7.1), despite the fact that hospitals were not safe places for women to deliver. In many medical facilities infections were transmitted from woman to woman by physicians who did not wash their hands between patients,[32] and although the pain of childbirth was ameliorated, the prospect of death increased as maternal mortality from puerperal fever reached epic proportions (7/1,000 births in the United States between 1900 and 1930). In 1880 Pasteur demonstrated that the streptococcal microbes he had identified 20 years previously were the cause of puerperal fever; however, it was not until almost 1940, when aseptic practices and sulphur antibiotics were introduced into clinical practice, that hospital birth mortality rates dropped below those of

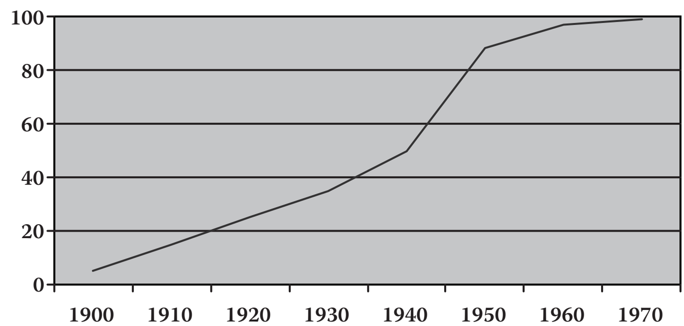

Figure 7.1 Proportion of U.S. infants delivered in hospital from 1900 to 1970.

home deliveries. Now the proportion of hospital births increased exponentially to a zenith in 1973, when 99% of all U.S. births took place in a hospital, and under the control of a physician.[37]

In the hospital environment of the mid-twentieth century the separation of mothers and infants following birth had become routine. Campaigns to reduce medicated childbirth, such as those spearheaded by Grantley Dick-Reed and Fernand Lamaze, reduced narcotic use in labour throughout the fifties and sixties.[33,36,37] The rationale for the continued transfer of newborn infants to the hospital nursery was now justified with reference to infection control. Although mothers were no longer completely incapacitated, newborn babies were removed to a safe place for observation, and mothers were encouraged to rest following delivery—viewing their infants through glass partitions and meeting them only at scheduled feeding times.[19] Throughout this period physicians advocated feeding infants via formula milk so that their food intake could be scientifically managed.

The Consequences of Mother-Infant Separation

This untested and unprecedented intervention in human reproductive biology and behaviour—the separation of mothers and infants following birth—subjected Euro-American mothers and infants to experiences that contrast markedly with the close and prolonged postnatal contact of mothers and infants across the anthropoid primates, and across human societies worldwide.[3,25] The lens of hindsight has shown this large-scale disruption of normal mother-infant interaction to be associated with subsequent negative outcomes such as sudden infant death syndrome,[38,39] colic and excessive infant crying,[40] maternal postnatal depression,[41] shaken baby syndrome, and other forms of infant abuse,[42] with consequences potentially as far-reaching as antisocial behaviour and delinquency in adolescence.[43]

A comparative evolutionary perspective reveals that the development of an early physical relationship between mothers and infants, where infants remain in direct contact with their mother's body night and day for periods of weeks or months following birth, is vital for both infant survival and normal development. The results of Harlow's innovative but traumatic research with infant monkeys demonstrated dramatically the importance for infants of the physical comfort provided by contact with their mother's bodies—even when the mother was an inanimate cloth-covered surrogate.[44,45] Subsequent clinical studies regarding the effects on infants of separation from their mothers confirm the importance of close physical contact, not just in terms of psychological development but in terms of basic physiological functioning and the expression of innate survival reflexes.[46–49]

The negative outcomes of early mother-infant separation are not, however, confined to its effects on infants. Arguably, the most harmful outcome of the near-universal uptake of hospital births, medicated deliveries, and mother-newborn separation was the fall in the proportion of mothers initiating breast feeding. In the United States and western Europe breast feeding rates (which had once been almost universal) fell dramatically, reaching a nadir of 20–22% initiation rate in the United States between 1956 and 1972.[50] The massive popular acceptance of artificially formulated milk for infants in this part of the world in the mid-twentieth century signified an unprecedented cultural shift in infant care, the repercussions of which circumnavigated the globe. When, in the 1980s, research began to demonstrate the detrimental health consequences of feeding babies with artificial formula,[51–53] mechanisms were sought to reverse the breast feeding decline, and it soon became apparent that mother-infant separation in the post-birth period undermined both the initiation and establishment of breast feeding.[48]

The Importance of Skin-to-Skin Contact

In the immediate postnatal period, human infants who have been born following an unmedicated labour and who are placed directly onto their mother's abdomen exhibit innate nipple-seeking behaviour,[46] during which they crawl and squirm up their mother's bodies, locate the nipple by head bobbing, and spontaneously latch and suckle without assistance[54] over the course of their first hour of life. They are guided to the nipple by smell.[47,55] Infants who are delivered following a medicated labour involving the opioid analgesics in common use today (e.g., diamorphine or pethidine) make little or no attempt to crawl, and those that try are disorganised, uncoordinated, and unsuccessful in gaining the nipple.[46,56] Unmedicated infants perform an instinctive pattern of hand movements during nipple seeking that is associated with an increase in maternal oxytocin levels, and is similar to those observed in other mammals where massage of the mammary tissue facilitates milk letdown.[57] Mothers and babies who experience unhurried skin-to-skin contact immediately following delivery have a far greater chance of both establishing successful breast feeding and prolonging breast feeding duration.[58,59] The benefits of skin-to-skin contact in the immediate postnatal period are now increasingly recognised and incorporated into perinatal care. Although one recent randomised trial reported no significant difference in breast feeding percentages for mothers and infants who did and did not receive recent systematic review of early skin-to-skin contact and concluded there was clinical benefit in avoiding early mother-infant separation,[48] clinical research has examined limited types of reinforcement of postdelivery mother-baby contact, reflecting the restricted opportunities for contact in the hospital environment.

By the end of the twentieth century, recognition of the importance of breast feeding to infant health, and the role of separation in preventing the effective establishment of breast feeding, led to moves to close newborn nurseries in the hospitals of many European countries (e.g., Sweden, UK), although the United States still lags behind.[60] With the closure of nurseries came a shift to mothers and babies rooming-in, with the baby located at the mother's bedside during the day (but removed to a communal nursery at night) or (more recently) all day and night, with mothers performing all aspects of their infant's care. Research that has examined the effects of rooming-in in comparison to nursery care has concentrated primarily on sleep and breast feeding initiation, with studies demonstrating that separation of infants to neonatal nurseries resulted in less frequent breast feeding[61] and greater likelihood of breast feeding failure,[39] but no increase in maternal sleep or alertness.[62,63] These findings contradicted the traditional argument that recently delivered mothers sleep better if their infants are cared for by others. Infants who spent their nights in nurseries were also found to sleep significantly less and to cry more than those at their mother's bedside.[64] Following a review of these studies, the UNICEF UK Baby Friendly Initiative concluded: "Mothers and babies should stay together at all times unless medically indicated or the mother makes a fully informed choice."[65] Round-the-clock rooming-in is now standard practice in all Baby Friendly accredited hospitals, and in progressive nations such as Sweden,[66] but still suffers resistance from hospital staff and mothers in some circumstances, as discussed by researchers in several countries (see references 67–69). The evidence concerning the impact of mother-baby separation on breast feeding drives the current emphasis on practices such as skin-to-skin contact following delivery, and rooming-in on the postnatal ward.[70–73]

The view from evolutionary paediatrics suggests that although the situation regarding mother-infant separation following delivery has improved following hospital deliveries with the advent of skin-to-skin contact and rooming-in, current hospital procedures still do not go far enough in facilitating the expression of the mother-infant behavioural interactions that stimulate normal lactational physiology. The process of lactogenesis (the initiation of lactation) involves two phases: Lactogenesis I—differentiation of alveolar epithelial cells for milk production—occurs during pregnancy and precedes copious milk production. Lactogenesis II—copious production of all milk components, i.e., when the milk comes in—normally occurs 3 days after parturition.[74] Very high levels of prolactin and glucocorticoid are required for milk production to begin in earnest. Following delivery of the placenta, maternal progesterone levels fall, and prolactin levels (which are suppressed throughout pregnancy by progesterone) begin to rise.[74] In the early postnatal period, each time the infant stimulates the nipple via suckling or touch, the mother experiences a rapid increase in prolactin secretion.[58,59] In these early days of breast feeding the amount of prolactin released is directly related to the intensity of nipple stimulation,[75] and breast feeding at night is associated with greater prolactin release than daytime feeding[76,77] due to the circadian nature of prolactin production. Researchers have found that the time of first breast feeding and the frequency of breast feeding on the second postpartum day are positively correlated with milk volume on day 5, suggesting that frequent stimulation of prolactin secretion in the period between birth and lactogenesis II increases the efficiency of subsequent milk production.[74,76]

These findings lead to the conclusion that frequent nipple stimulation, frequent suckling, and particularly frequent attempted and successful feeds at night, in the period immediately preceding lactogenesis II, will lead to an earlier onset of lactation and more prolific milk supply.

In addition to being critical for breast feeding initiation, high initial prolactin levels are also important for successful long-term lactation. According to the prolactin receptor theory, the maintenance of lactation after lactogenesis II (galactopoeisis) is dependent upon the successful development of prolactin receptors, which occurs in the early postpartum period and also depends upon frequent feeding.[74,78] These prolactin receptors are crucial in maintaining lactation following the switch from endocrine to autocrine control. This suggests that frequent early feeding attempts will not only lead to effective establishment of milk production but enhance its continued maintenance.

Although it is currently assumed that rooming-in provides mothers and babies with the chance to feed frequently on the postnatal wards of modern Western hospitals (and rooming-in is clearly more favourable than nursery care), an evolutionary perspective provoked us to question whether a plastic bassinette at the mother's bedside provided sufficient opportunity for the close physical contact needed to reinforce the benefits afforded by delivery room skin-to-skin contact. From both physiological and evolutionary viewpoints, the clinical model of rooming-in as a mechanism for keeping mothers and babies together, and thereby facilitating frequent feeding attempts, would appear less than ideal. Neither nonhuman primate nor (by extrapolation) hominin mothers would place their infants to sleep in separate containers located an arm's reach or more from their own sleep location. Why, then, should we expect this to be an optimum environment for the development of appropriate mother-infant interaction for modern humans? Evolutionary paediatrics suggests that reinforcement of postdelivery skin-to-skin contact implies closer physical contact than rooming-in can provide. Cross-species and cross-cultural evidence indicates that newborns are in constant physical contact with their mother's body[79]—in fact, cross cultural evidence indicates that it is not simply immediate skin-to-skin contact and early suckling that facilitates development of the mother-infant interaction in most societies, but prolonged postnatal close contact in the days and nights following birth.[80] It is likely, therefore, that despite recent alterations in maternity care practices, a proportion of breast feeding failure remains an iatrogenic consequence of the physical separation of mothers and infants imposed by a rooming-in scenario on the postnatal ward.

Based upon evolutionary assumptions, plus physiological and cross-cultural evidence, I hypothesised that (1) providing mothers and infants with the facilities for unhindered contact on the postnatal ward will facilitate breast feeding initiation more successfully than rooming-in, and (2) the benefit of unhindered contact on the development of the behavioural and physiological relationship between mother and baby will give rise to improved long-term breast feeding outcomes. To test these hypotheses, my collaborators and

I designed and conducted a randomised trial using overnight video monitoring to examine two forms of unhindered mother-infant contact (also known as bedding-in) on the postnatal ward, in comparison with 24-hour rooming-in. As we were aware that safety issues would need to be addressed in the context of bedding-in before such a practice could be considered clinically acceptable, we designed the trial to examine both breast feeding and infant safety outcomes. As secondary measures, we examined the impact of the three sleep conditions on maternal and infant sleep in the hospital, and explored whether they also affected sleeping arrangements at home over the infants' first 6 months of life.

Case Study: The Trial

This study was conducted on the postnatal ward of the Royal Victoria Infirmary, Newcastle-upon-Tyne, UK, a tertiary-level teaching hospital delivering five thousand babies annually in the northeast of England. Prior to commencement of the trial, approval was obtained from the clinical governance and research ethics committees of the Newcastle and North Tyneside Acute Hospitals Trust. Based on previously obtained pilot data, a target sample of sixty participants (twenty in each arm of the trial) was calculated as being necessary to provide 80% power to detect a difference of at least 5% in breast feeding behaviour between groups. Complete details of the trial protocol following CONSORT guidelines can be found in our clinical report of this trial.[81]

Methods

Pregnant women with a prenatal intention to breast feed (but little* or no previous breast feeding experience) were recruited at 32+ weeks' gestation at introductory breast feeding workshops. Prenatal inclusion criteria specified that we could include in the trial only healthy, non-moking women, pregnant with a single infant, anticipating a normal vaginal delivery at the participating hospital. Volunteers who returned completed consent and enrolment forms and who met the above inclusion criteria were anonymously randomised (following standard RCT procedures) to one of three postnatal sleep conditions: baby in the mother's bed with a cot-side attached (bed condition), baby in side-car crib attached to mother's bed (crib condition), and baby in stand-alone cot adjacent to mother's bed (cot condition). Postnatal ward staff were alerted to a woman's participation in the study by a sticker placed on her medical notes. Following delivery and transfer to the postnatal ward, staff contacted the research team who ascertained the mother's continued willingness and eligibility to participate in the trial. Postnatal exclusion criteria specified that an ill baby or mother, or a woman experiencing caesarean

AU: Please introduce RCT.

* "Little" breast feeding experience referred to women who had attempted breast feeding with a previous infant but did not breast feed after leaving the hospital.

delivery, or receipt of intravenous or intramuscular opiate analgesics in the preceding 24 hours, was not allowed to take part.

Eligible participants were provided with a single room and the appropriate equipment for their randomly allocated sleep condition, and signed a further consent form to indicate their willingness to be filmed on their first two postpartum nights. A small camcorder was mounted on the top of a 2 m monopod clamped to the frame at the foot of the mother's hospital bed and adjusted to capture an image of the upper half of the bed and the whole of the infant's cot (where appropriate). The camera's nighttime recording facility was activated to film in the dark; it was connected to a long-play video recorder (VCR) and time-code generator housed in a custom-built case located under the foot of the mother's bed. The VCR was operated by the mother using a remote control, and she was requested to start recording whenever she was ready to settle down for sleep. Filming then continued for 8 hours or until the mother stopped the tape. Mothers were requested to keep their infants in the designated location when they were asleep, but we did not specify how or where mothers should feed their infants. After two nights of filming were completed, research staff dismantled the camera equipment and offered mothers the opportunity to review their own tapes prior to giving final consent for their use in the study. Mothers participated in a semistructured debriefing interview regarding their postnatal experience, and medical records were accessed for labour and delivery details. After they were discharged from the postnatal ward, mothers participated in follow-up telephone interviews at 2, 4, 8, and 16 weeks regarding infant feeding and sleeping practices at home. As a gratuity for their participation in the study, mothers each received a gift voucher for £10 of baby supplies, and a tape of clips from their videos.

Videotapes were coded ethologically at Durham University's Parent-Infant Sleep Lab using Noldus® Observer 5 software and employing a behavioural taxonomy developed during a pilot study. The tapes were coded by three trained observers, each of which coded equal proportions of tapes from each condition to minimise any effects of observer bias. Observers undertook regular intra- and interobserver reliability testing, maintaining kappa scores reflecting at least 90% reliability. Statistical analyses were conducted using SPSS, and all analyses employed pair-wise comparisons between conditions. Medians and nonparametric tests are used for nonnormally distributed data.

Results

Sample and Analyses

Between March 2003 and December 2004, 144 eligible pregnant women were enrolled to participate in the trial and randomly allocated to a postnatal condition (bed = 48, crib = 50, cot = 46). Following delivery, fifty-five mothers were excluded due to postnatal ineligibility and twenty-five were lost due to unavailability of a single room or camera equipment, or communication failure between postnatal and research staff. Sixty-four mother-infant pairs were filmed; two of the participants, however, became ineligible during the intervention period (one mother unwell, one infant admitted to SCBU), and one set of tapes was unusable. Therefore, final video analyses were conducted using 61 participants (bed = 18, crib = 23, cot = 20). All mothers who participated in filming were interviewed on the ward and subsequently via telephone at 2, 4, 8, and 16 weeks. The characteristics of the mothers and infants in each of the three groups are shown in table 7.1.

We defined compliance with the allocated condition as the infant spending greater than 50% of the observed time in the assigned sleep location. Although we could not ethically require mothers to comply with their assigned condition, we requested that they try it for at least an hour. Of the sixty-one participants who were filmed, five did not meet the criteria for compliance with their allocated condition on either night, and a further fourteen did not com-

Table 7.1 Characteristics of the Three Randomised Groups

	Mother's Bed (n = 18)	Side-Car Crib (n = 23)	Stand-Alone Cot (n = 20)
Mean age mother ± SD (years)	32.8 (± 2.7)	31.4 (± 5.3)	30.9 (± 3.7)
Mean infant age ± SD (hours)	15.4 (± 9.8)	16.6 (± 6.9)	17.6 (± 6.3)
Mean gestation ± SD (days)	283.9 (± 9.6)	283.2 (± 6.9)	280.6 (± 7.9)
Mean birth weight ± SD (kg)	3.3 (± 0.4)	3.4 (± 0.4)	3.5 (± 0.3)
Ethnicity n (%)			
White European	16 (88.9%)	22 (95.7%)	20 (95.0%)
Asian	2 (11.1%)	1 (4.4%)	1 (5.0%)
Labour n (%)			
Spontaneous	16 (88.9%)	17 (77.3%)	16 (80.0%)
Induced	2 (11.1%)	5 (21.7%)	4 (20.0%)
Mean 5 min APGAR ± SD	9.3 (± 0.6)	9.3 (± 0.4)	9.2 (± 0.4)
Mean time since prebirth maternal sleep ± SD (hours)	39.9 (± 10.2)	35.0 (± 18.7)	36.4 (± 17.6)
Mean duration of maternal sleep postdelivery ± SD (hours)	1.4 (± 2.2)	1.8 (± 2.2)	1.7 (± 1.6)
Mean duration of initial contact ± SD (min)	25.9 (± 18.4)	21.1 (± 20.2)	21.8 (± 13.1)

Table 7.2 Analysis Methods for Randomised Control Trials

For clinical evaluation purposes, analysis of a randomised controlled trial (RCT) is preferably conducted as intention to treat (ITT), whereby all participants are analysed in the groups to which they were assigned, regardless of crossover or degree of compliance. ITT analysis allows determination of the potential efficacy of the intervention in a real-world scenario (i.e., where a portion of patients will not follow treatment instructions). In this study it provides the opportunity to assess the effect of implementing an evolutionarily informed strategy for postnatal care in the real world.
A per-protocol (PP) analysis of an RCT considers only those participants who complied with their random allocation (i.e., those who completed the study as per the protocol). This gives an assessment of the effect of the intervention under a best-case scenario—in this study it tells us about the maximum potential effect on breast feeding of following an evolutionarily informed model of postnatal care.

ply on one night. We used these data to conduct both intention to treat (ITT) and per protocol (PP) analyses (see table 7.2). The results of the ITT analyses for this study are available in our clinical report,[81] and we present PP analyses here to directly test the hypotheses that prolonged nighttime contact between mother and infant in the postnatal period will enhance breast feeding initiation and subsequent duration. The number of nights of data included in this per protocol analysis (i.e., where mothers and infants fully complied with their allocated sleep condition) are shown in table 7.3. Where only one night of data were available for a mother-infant pair, the missing night was entered into the analyses as missing data. Significance was set at $p < 0.05$.

Proximity

The proportion of observation periods that mothers and babies in the three groups spent in each of four proximity categories (physical contact, baby's arm's reach, mother's arm's reach, beyond touch) can be seen in figure 7.2. Together with table 7.4, displaying the results of two-tailed pair-wise t tests between all groups for all proximity categories, this confirms that bed babies spent a significantly greater duration in contact with their mothers, crib babies spent significantly longer within their mother's reach, and cot babies spent a significantly greater proportion of the night unable to touch or be touched by their mothers. This verifies that the allocated conditions provide mothers and infants with different opportunities for physical contact.

Table 7.3 Compliance with Randomly Allocated Condition

Condition Allocated	Nights Filmed	Nights Complied
Bed	31	22 (71%)
Crib	38	19 (50%)
Cot	36	25 (69%)

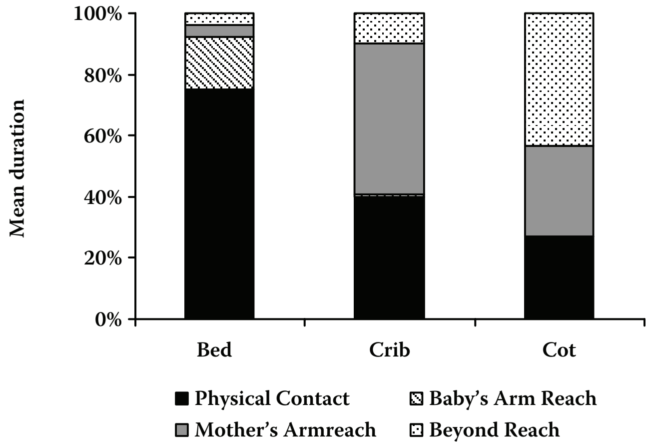

Figure 7.2 Mean percentage duration per night of observed proximity by allocated condition.

Table 7.4 Results of Pair-Wise Comparisons for Proximity Categories (Two-Tailed T Tests)

	Bed vs. Crib	Bed vs. Cot	Crib vs. Cot
Physical contact	$p = 0.000$	$p = 0.000$	$p = 0.072$
Baby's reach	$p = 0.015$	$p = 0.003$	$p = 0.008$
Mother's reach	$p = 0.000$	$p = 0.000$	$p = 0.018$
Beyond touch	$p = 0.152$	$p = 0.000$	$p = 0.000$

Breast Feeding Initiation

Figure 7.3 summarises data on the frequency with which mothers attempted to initiate breast feeding (i.e., offered the nipple), successful breast feeding, and overall breast feeding effort exhibited by mothers and babies who complied with their allocated sleep condition. Breast feeding data were not normally distributed, so medians and nonparametric tests are used. Offering the nipple to the baby is self-explanatory. Successful breast feeding bouts were defined as those where the baby latched on to the nipple and clear sucking and swallowing was observed for at least 5 seconds. Breast feeding effort represents the total number of feeding attempts observed, whether or not they resulted in successful sucking and swallowing. A feeding attempt was scored each time the baby attempted to latch on to the nipple, with or without assistance from the mother. Nipple presentations to which the infant did not respond were not included in the calculation of breast feeding effort; however, attempts by the baby to obtain the nipple of his or her own accord (e.g., when the mother was asleep) were included.

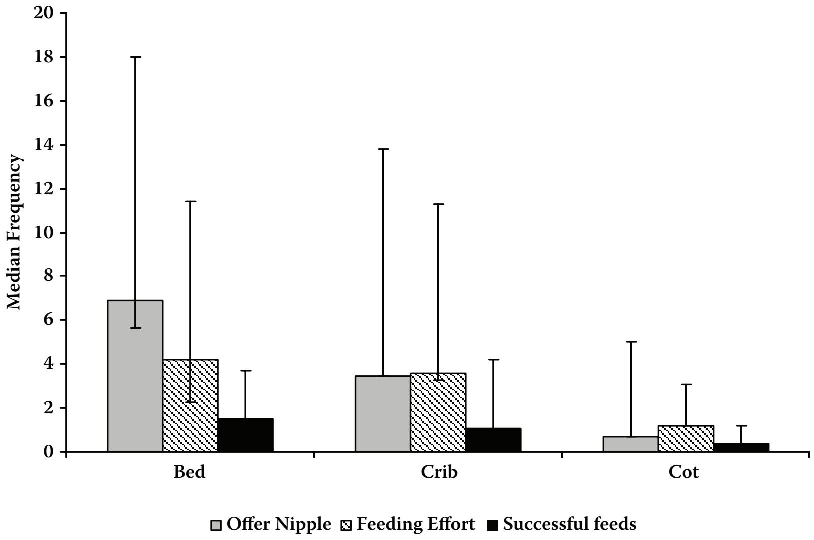

Figure 7.3 Median frequency per hour (and interquartile range) of breast feeding variables for mothers and infants who complied with allocated sleep condition.

There was much interindividual variation in feeding frequency, with some mother-infant dyads practicing repeatedly throughout the night, and others never feeding during the observation period. All infants in the bed condition accomplished some feeding, and figure 7.3 reflects a general pattern of more attempts by the mother to initiate feeds, more effort by the baby to engage in feeding, and consequently more successful feeds for the two groups in closest proximity to one another during the night. Table 7.5 summarises the results of pair-wise comparisons between each of the conditions using two-tailed Mann-Whitney U tests. No significant differences were found in any feeding frequency measures between the bed and the side-car crib condition. The frequency of all feeding measures was significantly greater for those mothers and babies who remained in the bed condition than for those who remained in the cot condition. The differences between crib and cot teetered on the edge of significance for feeding effort and successful feed frequency.

The median proportional duration of time spent engaged in successful feeds and all feeding attempts was calculated for each condition. Figure 7.4 shows that mothers and infants in the bed condition spent approximately five times as long engaged in feeding activities as mothers and babies in the cot condition, with the crib condition being intermediate between the two. Only the differences between bed and cot were significant (successful breast feeding, bed versus cot, $p = 0.048$; all breast feeding effort, bed versus cot, $p = 0.016$, two-tailed Mann-Whitney U tests).

Table 7.5 Significance Levels for Comparisons between Conditions (Two-Tailed Tests)

	Bed vs. Crib	Bed vs. Cot	Crib vs. Cot
Offer nipple	$p = 0.38$	$p = 0.004$	$p = 0.10$
Feeding effort	$p = 0.37$	$p = 0.000$	$p = 0.04$
Successful feeds	$p = 0.33$	$p = 0.001$	$p = 0.05$

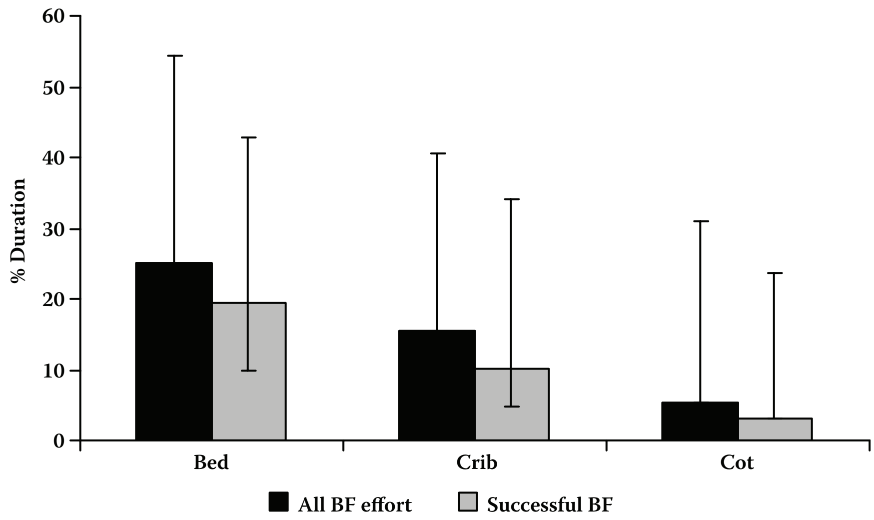

Figure 7.4 Median proportional duration per night (and interquartile range) of breast feeding activity.

Breast Feeding Continuation

The continuation of breast feeding following discharge from the postnatal ward was ascertained via telephone interviews conducted at 2, 4, 8, and 16 postnatal weeks. The proportion of mothers and infants complying with their allocated sleep condition on at least one night of the trial and who were still engaged in exclusive or any breast feeding at each of the contact points is shown in figure 7.5.

Although all mothers initiated breast feeding prior to discharge from hospital, it is clear that the proportion of infants being exclusively breast fed fell rapidly in the standard-care (cot) group, while those in the intervention groups (bed and crib) showed a slower (and very similar) decline in exclusive breast feeding. Likewise for any breast feeding: the proportion of those allocated to the cot condition who were still engaged in any breast feeding at 16 weeks was almost half that of the two intervention groups (cot = 43%, crib = 73%, bed = 79%). In testing the prediction that close sleep-

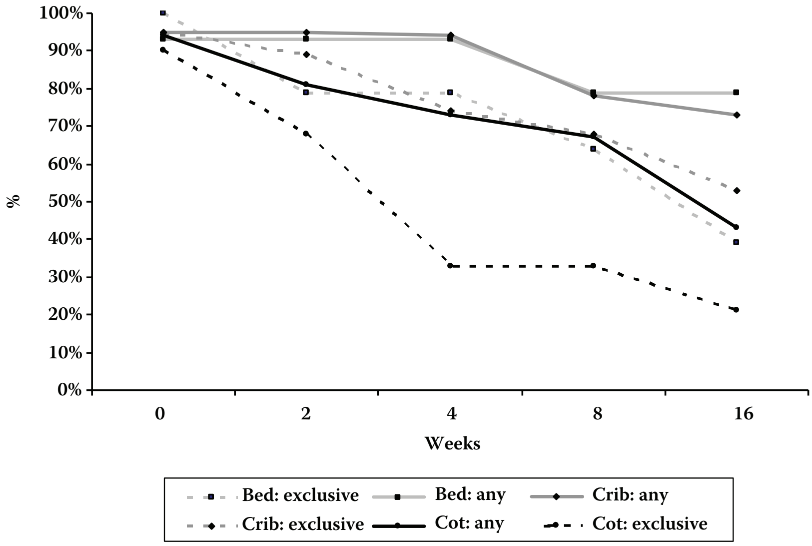

Figure 7.5 Breast.feeding continuation to 16 weeks by condition on postnatal ward.

ing proximity in the immediate postnatal period would be associated with greater breast feeding duration, we found significant differences between the bed and cot conditions for the duration (to at least 16 weeks) of any breast feeding (bed versus cot, $p = 0.031$, one-tailed t test) and exclusive breast feeding (bed versus cot, $p = 0.022$, one-tailed test), and between the crib and cot conditions for exclusive breast feeding (crib versus cot, $p = 0.015$, one-tailed t test). It is also important to note that no significant differences were found between the bed and crib conditions; figure 7.5 demonstrates that the decline in any and exclusive breast feeding up to 16 weeks in these two groups tracked one another closely. It should be noted that these breast feeding duration data are truncated at 16 weeks, and so the mean figures do not reflect absolute breast feeding duration for those who continued after this time.

Maternal and Infant Sleep

Maternal and infant sleep states were visually determined as "active awake," "passive awake," "appears asleep," and "indeterminate." Duration of "appears asleep" was calculated for all mothers and infants and expressed as a proportion of the time each was visible during the observation period. Mothers and infants achieved very similar proportions of sleep in each of the three conditions (figure 7.6), and pair-wise two-tailed t tests revealed no significant difference for any intercondition comparison.

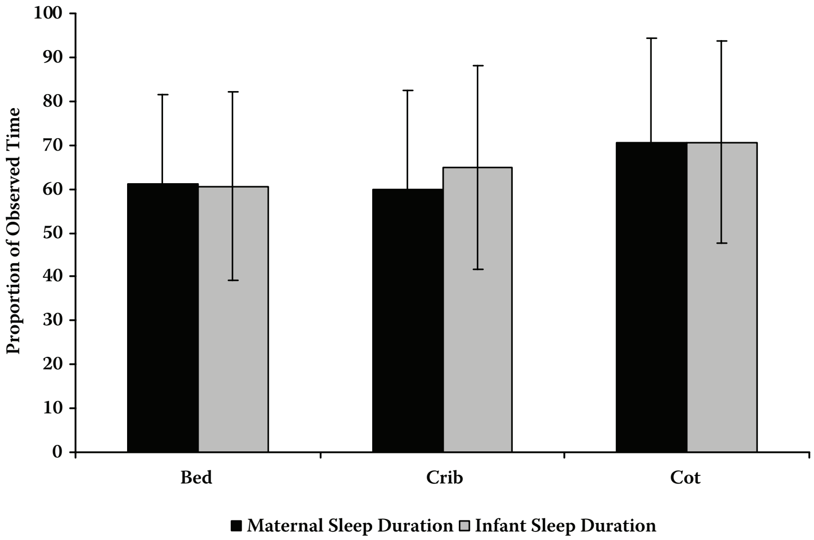

Figure 7.6 Maternal and infant mean (and SD) sleep duration.

Sleep Proximity in the Home Environment

In order to assess whether intervening in the postnatal sleep location of infants affected their sleep location once they were at home, we asked mothers about their infant's sleep locations during each of the follow-up telephone interviews at 2, 4, 8, and 16 weeks. Up to the 16-week cutoff point the mean number of weeks during which infants bed shared at home at least once per week was: bed, 11.5 weeks; crib, 11.3 weeks; cot, 10.1 weeks. Pairwise tests revealed no significant differences between the three groups in terms of bed-sharing behaviour at home.

Discussion

The results of this trial support hypotheses derived from an evolutionary view of mother-infant behaviour in the days immediately following birth and an understanding of lactation physiology. We predicted that enhanced nighttime proximity would be beneficial to breast feeding initiation. The three sleep conditions to which mothers and infants were randomly allocated in this trial are consistent with different amounts of physical contact (figure 7.2); therefore, this trial provides a valid test of the effects of nighttime proximity in the immediate postpartum period. Mothers and infants with unhindered access to one another attempted to feed, fed successfully, and fed more frequently than those separated by a physical barrier in the form of the cot wall. This study, then, provides evidence that prolonged close nighttime contact between mothers and infants in the postpartum period is an effective mechanism for the successful establishment of breast feeding. The 20% discrepancy between the proportion of cot versus bed and crib mothers performing any breast feeding 2 weeks after the birth of their infant attests to the impact of this intervention. In the UK Infant Feeding Survey for the year 2000,[82] 23% of mothers who initiated breast feeding in hospital were no longer breast feeding 2 weeks later. It has long been recognised that feeding frequency in the early postnatal period is a key factor in establishing milk production and in learning how to suckle,[83–86] with the frequency of nighttime feeds being of particular significance.[76] The benefits of unhindered nighttime contact on the establishment of breast feeding by increasing feeding effort, raising prolactin levels, and encouraging mothers and infants to practice feeding technique appear to be effective in ameliorating breast feeding failure at an early stage.

We further predicted, based on current knowledge of lactation physiology, that prolonged close contact in the early postnatal period would increase breast feeding duration. The relationship between frequent feeding attempts (both successful and unsuccessful) and increased levels of prolactin is crucial to both the establishment of milk production and the maintenance of lactation. The significantly earlier termination of both exclusive and all breast feeding by cot mothers compared to crib and bed mothers by the 16 week cutoff point supports our prediction and reinforces the long-term consequences of unhindered contact in early infancy. The proportion of cot mothers engaged in any breast feeding at 16 weeks (50%) was consistent with the finding of the UK Infant Feeding Survey 2000[82] that 50% of mothers who initiated breast feeding were still doing so 4 months later. In contrast, approximately 80% of the mothers in the bed and crib conditions in this trial were still breast feeding at 16 weeks.

The evidence presented here, that prolonged close contact between mother and infant on the initial postnatal nights results in increased breast feeding frequency and enhanced long-term duration, enables us to link behavioural practices with both short-term physiological mechanisms and long-term survival consequences that have evolutionary implications. These findings challenge the current medical model of appropriate postnatal care, and provide support for the importance of mother-infant sleep contact. Data on infant safety in the three sleep locations are presented in our clinical report of this trial and yield no surprising findings.[81]

In view of the fact that both side-car crib and bed conditions were equally effective at promoting increased feeding frequency, and the side-car crib presented no difference from the stand-alone cot in terms of safety, while the bed condition showed a slightly increased potential risk, the side-car crib appears to be the most effective and safest means of maintaining extended mother-infant contact for the duration of the postpartum hospital stay.[81] Although the lack of individualised breast feeding support documented by Dykes[87,88] undoubtedly plays an important role in undermining mothers' efforts to initiate breast feeding on the postnatal ward, the current maternity "production line" is not the only aspect of postnatal care that could be improved in order to facilitate breast feeding initiation and establishment. As documented here, one non-labour-intensive change would be to provide facilities for mothers and infants to experience unhindered access to one another's bodies 24 hours a day.

Incorporating Evolutionary Perspectives into Policy and Practice

For most of human evolutionary history, successful mother-infant interaction in the immediate postnatal period was a critical component in our species' survival. Natural selection has produced human neonates equipped with a suite of innate characteristics that serve to stimulate and elicit maternal care, and thereby enhance their own survival chances. Human mothers, primed by a powerful mixture of neurochemicals and hormones, are programmed to respond both behaviourally and physiologically to their infant's cues and signals. Under the appropriate environmental conditions, the evolved system of interaction, feedback, and exchange between a newborn infant and its mother unfolds spontaneously according to a predictable sequence. Under inappropriate environmental conditions, the process can be so severely disrupted that maternal and infant health, and even infant survival, is compromised. Only in the last 100 years has the development of medical technologies made it possible for large numbers of neonates to survive the immediate postnatal period without a mother. This is a significant achievement of medical science, but one that came with a price. So successful was medical technology in promoting infant survival when mothers died or were unavoidably absent, that half a century or so ago, in the maternity wards of industrialised societies, maternal presence in the earliest period of an infant's life began to be considered superfluous, with mothers' increasingly passive role in the birth process ending with the removal of their infants to the care of experts. Half a century later we now observe the consequences of what we have lost.

Our research demonstrates the importance of maintaining physical contact between mothers and newborn infants, and the iatrogenic consequences of the disruption caused to the evolved maternal-infant relationship by their separation on the hospital postnatal ward, as tested by an experiment in evolutionary paediatrics. Throughout the course of this project, and our previous research, we have challenged clinicians, midwifery ward staff, community health care professionals, managers, health care policy makers, and parents to consider our evolved propensities as humans, primates, and mammals when contemplating care strategies for infants and proposing care interventions, and to work toward patterns of care that are congruent with the evolved characteristics of our species' behaviour and physiology.[89–93] This challenge has been accepted by many and found resonance with many more, and over the course of the past decade we have been invited to contribute, or have found our research being used to support, a variety of policy documents, position statements, and guidance papers for health professionals on issues surrounding mother-infant sleep contact.[94–102] Those working in the fields of childbirth, infant care, and breast feeding support have direct knowledge and experience of the capabilities and limitations of the maternal and infant bodies and behaviour, and recognise many innate and instinctive features in mother-infant biology. For this reason, perhaps, in discussions and correspondence we have found that these health professionals are particularly receptive to an evolutionary approach (and many report experiencing a light-bulb moment during talks where the evolutionary explanation for the helplessness of human neonates is explained). The perspectives of evolutionary medicine on infant care have been embraced particularly strongly by those working to effect change within maternity provision and infant health in the UK—especially by those taking a position of advocacy for the rights of mothers and infants for physical access to one another's bodies, such as the UNICEF UK Baby Friendly Hospital Initiative, La Leche League, National Childbirth Trust, and breast feeding support organisations such as Baby Café, Sure Start, and Breastfeeding Network. However, the perspectives of evolutionary paediatrics have made minimal headway in convincing those organisations who hold steadfast to beliefs that maternal bodies are hazardous for infants. In the UK, the major cot death charities and the coroners represent this position most strongly, basing their arguments on the outcomes of epidemiological case control trials that have demonstrated detrimental outcomes of mother-infant sleep contact. In order for an evolutionary perspective to carry equivalent weight in an era when "evidence" is judged via meta-analyses and systematic reviews, we have found that it is necessary to subject the hypotheses of evolutionary medicine to rigorous testing via randomised trials, to report those trials in clinical journals, and to publicise the results widely. It is our experience that health professionals working in postnatal care are willing and able to implement lessons learned from an evolutionary perspective—and are even willing to directly challenge the establishment view if we, as researchers and proponents of the value of an evolutionary approach to health, are willing to invest the time and effort to make these perspectives relevant and accessible to their work, and to provide them with both encouragement and ammunition to initiate change in their health care domain.

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