CONTINUING EDUCATION MODULE

Kangaroo Mother Care 2: Potential Beneficial Impacts on Brain Development in Premature Infants

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ABSTRACT

Kangaroo mother care (KMC) involves infant skin-to-skin contact with the mother from as soon as possible after birth, exclusive breastfeeding, early discharge from the health facility, and supportive follow-up at home. Much evidence supports use of KMC clinically as an aid to mitigating some detrimental features of prematurity. This article—the second of two—explores impairments in brain development because of uncongenial inputs from the postnatal therapeutic environment of premature infants, not encountered in utero, and some of their negative neurobehavioral, psychosocial, sociocultural, and economic implications. It is concluded that evidence favoring the use of KMC in stable preterm infants is very strong and that, as noted by others, barriers to implementation of KMC, apart from infant infirmity, are mainly because of hesitancy from parents, health-care professional, and/or institutions, which may be unfounded.

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INTRODUCTION

Key elements of the impaired physiology of preterm infants and some beneficial effects of kangaroo mother care (KMC) on their physiology were considered in the preceding article (Bear and Mellor, 2017). This article seeks to extend this understanding by briefly reviewing relevant neurobehavioral, psychosocial, sociocultural, and economic perspectives.

Premature infants are known to be neurobehaviorally immature, with their untimely birth representing a significant trauma during a sensitive period where the environment has a major role in the neurodevelopmental trajectory of the baby (Altimier & Phillips, 2013). Genetic, epigenetic, or

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environmental influences may disproportionately predispose the developing brain toward immediate and long-term pathological outcomes, thereby emphasizing the challenge of ensuring that brain development is supported as optimally as possible during this critical phase. The first proximal environment of the premature infant in relatively affluent countries is generally an incubator within a neonatal intensive care unit (NICU). From an evolutionary perspective, the resulting maternal–infant separation is environmentally suboptimal and is a barrier to normal parent–infant interaction (Charpak et al., 2005; Cho et al., 2016; Nelson & Bedford, 2016).

The natural and expected environment for the baby as it transitions from the intrauterine environment is skin-to-skin contact with the mother and maternal proximity (Bergman, 2015; Feldman, 2007). Within this dyad, physiological processes stabilize, neurological maturation continues largely uninterrupted and the first human relationship begins to unfold as a template for emotional regulation and social interrelatedness. Maternal–infant contact, ideally continuous in the early neonatal period, provides support for development within four important domains (Feldman, 2007):

1. Regulation of infant arousal, attention, and emotion
2. Acceleration of neuromaturation
3. Improvement of the mother's mood
4. Promotion of the parent–infant relationship and the coregulation of social interactions.

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NEUROBIOLOGICAL STATES AND KANGAROO MOTHER CARE

The neurobiological system as a whole consists of five subsystems, and the maturation, regulation, integration of which precede modulation of infant behavior (Ferber & Makhoul, 2004). The integration of these subsystems in a physiologically appropriate manner results in a more effective use of internal resources whereby purposeless movements and fussy and crying states are reduced, thereby enhancing self-regulation (Ferber & Makhoul, 2004). Assessments of preterm infants are particularly challenging because of their neurobehavioral immaturity. Thus, application of assessment approaches used with full-term babies may result in erroneous data because the preterm neonate may be unable to exhibit full crying or protest behavior and may have a markedly different neurobehavioral baseline from their full-term peers (Ferber & Makhoul, 2008). The five neurobiological subsystems that influence or control behavior are the following:

1. Autonomic nervous system (ANS)
2. Motor control system
3. State integration system
4. Attention/interaction system
5. Self-regulation and dyad coregulation system

Autonomic maturity manifests as an improving balance between the tone of the parasympathetic and sympathetic pathways resulting in more effective physiological reactions to stress; undesirably, sympathetic tone dominates in premature babies who exhibit larger physiological reactions to stressful events such as heel stick (Feldman & Eidelman, 2003). The maturity of ANS function assessed by resting vagal tone is less in premature babies at term age than in their full-term peers and is predictive of the characteristics of infant development to 6 years of age (Feldman & Eidelman, 2003).

The neuromotor subsystem forms the functional basis of posture, muscle tone, and reflexive and voluntary movement and also affects quality of movement by moderating overreaction in gross body movements. Mild to severe neuromotor functional disability, including cerebral palsy, was found in one study to affect 22% of premature babies born at or before 26 weeks gestation when tested at school age, with 41% of all extremely premature children found to have substantial general cognitive deficits

at that time (Marlow, Wolke, Bracewell, & Samara, 2005). Impaired motor development is a risk factor for later developmental pathology in cognition, learning ability, and behavior, which are all common sequelae of an early birth (de Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009).

A neurodevelopmentally mature neonate is recognized as exhibiting organized, smoothly functioning, and integrated neurophysiological and behavioral systems resulting in the maintenance of homeostatic equilibrium. This is reflected in an ability to regulate their internal state, to mobilize sufficient energy in response to external and internal stimuli, and to clearly display and transition between different states ranging from quiet sleep to full arousal (Feldman & Eidelman, 2003; Nieder-Heitmann, 2010). Although cyclic patterns are observable in healthy preterm infants, the ability to achieve, maintain, and withdraw from each behavioral state is immature. For example, an overstimulated preterm infant may spend 60%–70% of the time in active sleep, a state of high energy demand when compared with the more desirable state of quiet sleep (Nieder-Heitmann, 2010).

The attention/interaction subsystem forms the neurological basis of behaviors such as emotion regulation, modulation of arousal, coordination of attention directed toward mother and object, and sustained exploration of the environment (Feldman, Eidelman, Sirota, & Weller, 2002). This subsystem forms the basis of the ability to interact socially, emotionally, and cognitively with the environment (Nieder-Heitmann, 2010), and an increased risk of this system being disrupted is widely recognized as a consequence of preterm birth and maternal separation (Feldman et al., 2002). Organizing attention, regulating negative affect, maintaining optimal reactivity, moderating social interactions, and sustaining environmental exploration are often impaired as a result of altered development of cortical and other central nervous system (CNS) structures in the premature baby (Feldman et al., 2002).

From a neurobiological perspective, self-regulation is defined as the capacity of an infant to adapt to internal and external stimuli that have caused a shift in physiological stability away from baseline (Ferber & Makhoul, 2004). In mammalian young, self-regulation is inextricably linked to maternal physiological state where "individuals dynamically alter their actions with respect to the ongoing and anticipated actions of their partners," a process defined by Fogel as "coregulation" (Neu, Laudenslager, & Robinson, 2009, p. 226).

The capacities of preterm infants to self-regulate are commonly impaired, and this is predictive of cognitive impairment later in life (Feldman et al., 2002). This likely reflects the sequential nature of neurodevelopment whereby disorganized or dysregulated lower innervating systems detrimentally affect later developing limbic and higher cortical structures (Perry, 2009).

Current supportive management of healthy premature infants is aimed at providing appropriately nurturing environments and interventions which optimize sleep–wake cyclicity, promote behavioral inhibition, and reduce potential stressors and subsequent physiological activation of immature and/or injured nervous systems, most notably the ANS (White-Traut, 2004).

Authors commonly summarize KMC as one such intervention which supports autonomic organization and sleep–wake rhythmicity, recognized by the maintenance of autonomic stability in the face of environmental change (Nieder-Heitmann, 2010). For example, infants experienced improved autonomic stability in KMC compared with incubator care (Cong et al., 2012), and improved attention/interaction indices were also noted with KMC intervention (Feldman et al., 2002).

Goals for support of the sensory motor subsystem include improved motor regulation, muscle tone, postural support, vestibular adaptation, and energy conservation by minimizing overreaction to the environment, decreasing unnecessary movements, and maintaining the flexed and midline orientation. KMC may contribute to achieving these goals by mimicking physical containment within the uterus. This reduces random movements, helps to maintain a flexed position and movements appropriate for vestibular adaptation, and promotes energy conservation by decreasing agitation and jerky movements associated with noncontainment (Nieder-Heitmann, 2010).

PSYCHOSOCIAL, SOCIOCULTURAL, AND ECONOMIC FACTORS AFFECTING FAMILIES OF PREMATURE BABIES

A family-centered health-care paradigm occurs when parents and caregivers are supported in becoming fully responsible for developing the skills they need to meet the physical, emotional, and intellectual needs of their child or children (Altimier &

Phillips, 2013). The physiology of normal childbirth and lactation usually triggers neuropsychobiological pathways which increase maternal behavior and responsiveness to infant need (Feldman, 2007), setting the potential trajectory for childhood and beyond. When this process is disrupted, as it is with premature birth, conventional medical care protocols often result in incubator-based treatments which impose maternal separation as a norm (Bergman, 2015).

It is understood that optimal caregiver interaction with babies is the foundation for the development of emotional security, stability and self-confidence, readiness to learn, social competence, and good infant mental health (Browne & Talmi, 2005). When babies are born early into the NICU environment, psychological effects are apparent with the entire family, including the extended family, and the local community. These may put the baby at risk of poor long-term outcomes for reasons apart from the disruption of mother–infant interaction (Browne & Talmi, 2005). A high incidence of neglect, abuse, and failure to thrive in babies hospitalized during the neonatal period is known to be linked to parental stress, and studies show that parenting the preterm infant is highly stressful for almost all mothers (Browne & Talmi, 2005). Studies also confirm that short-term hospital-based interventions which increase the mothers' knowledge of infant behavior in conjunction with guided interaction with their infant are most effective when combined with home-based interventions in infancy and early childhood (Browne & Talmi, 2005).

Key Psychosocial Aspects of the Parent–Premature Baby Relationship

Infants with "normal" competency are active participants in promoting interactions with caregivers who provide the conditions for their growth and development (Goldberg, 1979). Prompt and effective interactions as signalled by infant cues for caregiving are thought to avert the development of maladaptive behaviors such as learned helplessness which predispose to later poor psychological and mental health, as seen in the example of retarded development of institutionalized infants (Goldberg, 1979). Equally important is the early experience of parenting from the adult's perspective because early interactions can either enhance or depress feelings of competency in the parental role. Maternal affectionate touch and caretaking decrease in the immediate postnatal period following premature birth partly because of disruptions in the psychobiological process of maternal bonding (Feldman & Eidelman, 2003).

The predominant first experiences of a preterm neonate with caregivers in the NICU are likely to be negative and may include tube feedings, blood sampling, heel stick, and temperature taking. The predominant NICU-related events experienced by parents and immediate family may be birth trauma and recovery, infant separation, and adjustment to a very different parental role to the one expected. The three major components of the mother–infant coregulatory dyad are all affected by premature birth, namely, touch, gaze, and affective vocalization. This is in part because of a lack of maternal proximity and lowered capacities of the infant to self-regulate and maintain attention/interaction, which may lead to disrupted attachment (Feldman & Eidelman, 2003). Twenty-five percent of prematurely born children are reported to have multiple or severe psychological dysfunction, with a further 25% having mild to moderate psychological issues, generally categorized in the literature under four major headings (Wolke, 1998):

1. Cognitive development, particularly intelligence, memory, and language
2. Behavioral and emotional status
3. Social functioning including the ability to form and maintain social relationships, self-conceptualization, and quality of life
4. School adaptation

It is the combination of the nature, pattern, and timing of environmental events which determines how the brain senses, processes, stores, and responds to those events (Perry & Pollard, 1998). Modern theory of developmental neurobiology states that (Liu et al., 2007; Perry, 2009; Perry & Pollard, 1998)

1. Development is both hierarchical and sequential, organization occurring from the "bottom up" in sequence from brainstem, diencephalon, limbic, and through to cortical areas. Each of these regions has periods of greater developmental activity during childhood, commonly known as *sensitive periods*, whereby trauma, neglect, and experiences which poorly match the neurodevelopmental needs at those times produce more profound disruption of neural pathways. Thus, put most simply: "Organization of higher parts of the brain depends upon input from the lower

parts of the brain" (Perry, 2009, p. 242) and "timing, intensity and nature of exogenous stimulation are all important to normal neurosensory development" (Liu et al., 2007, p. S51).

2. The brain develops in a use-dependent fashion and is dependent, in part, on the total sensory experience of the child. Thus, chaotic and disordered noxious stimulation, such as that experienced by a hospitalized infant, may create use-dependent changes in brain structure that may persist for a lifetime. The nature of the changes in important neural networks will be a result of the nature, timing, and intensity of the stimulus, in combination with the stage of neurodevelopment and alterations in pertinent neurotrophic factors at that time (Perry, 2007).

It may be inferred from these observations that "prevention is better than cure" and that optimal situations will arise when neurodevelopment is supported by environments which offer well-timed, repetitive, and patterned positive stimulation for babies that will gear their neural apparatus toward psychological health: "Effective therapy seeks to change the brain" (Perry, 2009, p. 244).

KMC is an intervention known to produce significant benefits in many areas including psychological outcomes for both mother and baby. Applied to physiologically stable infants at a time of ongoing extensive trauma, it is an intervention with no known deleterious "side effects" (Boundy et al., 2016). Thus, it reduces maternal separation, enhances attachment neurobiology, and improves ongoing family relatedness, thereby helping to engender infant–parent relationships characterized by higher sensitivity and reciprocity, lower intrusiveness, and reduced infant negative emotionality (Feldman & Eidelman, 2003). Because mothers have been found to be the most significant environmental modifiers of risk for preterm infants (Browne & Talmi, 2005), widespread education based on larger controlled studies of the positive psychological and social-emotional benefits of KMC for premature infants, their parents, and their families may be well advised.

Cultural and Societal Influences

Attitudes, beliefs, and practices of the societies in which we live create powerful paradigms which may be difficult to change even when strong evidence-based scientific knowledge supports recommendations for a beneficial change in paradigm.

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An example of this is the contrast between the standard treatment protocols of premature baby and family care in low income settings compared to those in affluent settings. Thus, based on increasing evidence of the benefits of KMC for both infants and families in all intensive care settings, continuous KMC (c-KMC) has been widely implemented in less affluent settings, whereas in affluent settings where high-tech NICU facilities are more affordable, KMC implementation is commonly intermittent with sessions often restricted to only 1–2 hours per day (Nyqvist et al., 2010a).

The benefits of KMC for premature babies in the high-tech environment reported in the research literature include improved infant physiological responses, enhanced thermoregulation, lower infant cortisol, decreased pain responses during invasive procedures, improved sleep patterns, improved neurobehavioral and psychomotor development, and better psychosocial outcomes such as improved parent–infant interaction and less maternal postpartum depression (Nyqvist et al., 2010a). In addition, higher breastfeeding rates of longer duration and higher proportions of exclusive breastfeeding are repeatedly found and reduced hospital stays were also noted (Nyqvist et al., 2010a).

World Health Organization (WHO, 2003) recommendations for the implementation of c-KMC, based on increasing and compelling evidence supporting the use of this intervention as a standard care model, were released in the form of a "practical guide." This advice was reinforced in 2015 by the statement that "kangaroo mother care is recommended for the routine care of newborns weighing 2000 g or less at birth, and should be initiated in health-care facilities as soon as the newborns are clinically stable" (WHO, 2015, p. 3). Despite this, absence of clear and explicit protocols, uncertainty about the importance of KMC, perceived increased workload for nursing staff, and the view that KMC places more strain on mothers and families have all been cited as obstacles to its implementation as a standard protocol (Chan, Labar, Wall, & Atun, 2016; Feldman & Eidelman, 2003; Nyqvist et al., 2010a).

Key Economic Factors

Modeling of the immediate and long-term economic costs of premature birth is in its infancy, but trends already documented provide valuable "big picture" information. Six categories of the economic cost of prematurity are generally considered (Mangham, Petrou, Doyle, Draper, & Marlow, 2009): health-sector costs of *prevention*, health-sector costs of *treatment in the neonatal period*, health-sector costs *after initial hospital discharge*, special education and social service costs *during childhood*, *family economic burden*, and *societal economic burden*. One review has shown that the cost of neonatal hospitalization of a very low birth weight (VLBW) premature infant was *47 times* that of a full-term baby, and the first-year medical costs *24 times* those of a healthy full-term child, even if the baby was deemed to be free of disability (Petrou, Sach, & Davidson, 2001). Also, health-care costs during the postdischarge period were 5- to 16-fold greater in children at 8–9 years of age who were prematurely born compared with controls (Petrou et al., 2001).

Thorough understanding of mechanisms that underlie nature/nurture facets of premature baby development will aid in informing decisions regarding intervention and planning of services for infants, children, and families affected by early birth and its consequences. Current early childhood intervention programs involving special education and home environment enrichment have not provided many benefits for VLBW children possibly because of those interventions not addressing the appropriate sequential and use-dependent processes of neurobiological development at the appropriate time (Perry, 2009). However, there is already significant evidence that a wider scale implementation of KMC is a cost-effective intervention in high-tech and affluent settings, so that further evaluation of its use as a primary preventative and treatment strategy may result in more resources being directed to this end (Petrou et al., 2001).

SUMMARY AND CONCLUSIONS REGARDING KANGAROO MOTHER CARE

KMC is widely known and variably applied to the intervention and care of premature babies and their families. A worldwide move toward clinical implementation of the KMC model irrespective of the health-care environment is being seen, with the emergence of two different applications, one in low income settings and the other in affluent high-tech settings (Nyqvist et al., 2010b). WHO issued practical guidelines in 2003, updated in 2015 for KMC in both low-income and affluent settings, which communicated urgency of application based on increasing and compelling evidence that KMC decreased mortality, enhanced breastfeeding and psychosocial indicators, and decreased some morbidities associated with premature birth (WHO, 2003, 2015). There is ample literature to support the use of KMC as a mode of care for nonseparation of infants and their mothers based on the premise that premature infants are exterogestational fetuses and the expected evolutionary environment for the infant outside the uterus is within the skin-to-skin milieu. KMC offers warmth, comfort, physiological and psychosocial benefits, enhanced growth and development, improved lactation, and breastfeeding initiation and duration as well as contributing toward the emotional needs of the family (Nyqvist et al., 2010b).

Current evidence-based research allows the following conclusions to be drawn in the areas of physiological, behavioral, neurobehavioral, and psychosocial factors for preterm infants:

1. Mortality is reduced in very low birthweight, physiologically stable infants who receive KMC.
2. Physiological stability is enhanced in healthy preterm infants by KMC, including, but not restricted to, thermoregulation, cardiorespiratory function including less bradycardic and apneic episodes, and improved oxygen saturation with less desaturations.
3. To date, there are no significant reports of adverse physiological outcomes for physiological indices in healthy, stable preterm babies.
4. Neurobehavioral indices of state integration show marked reduction of arousal from sleep and improved integrity and organization of sleep.
5. Up to 60% reduction of circulating cortisol indicating reduced infant stress levels
6. Decreased nosocomial (hospital-acquired) infection
7. Positive emotional and behavioral indices including increased infant sleep, relaxation and calmness, and decreased agitation; increased maternal satisfaction; and decreased postpartum depression scores with less maternal anxiety within the hospital and home settings

8. Less infant crying in general and reduced crying with painful procedures such as blood sampling
9. Enhanced autonomic development and neurobehavioral/mental development scores at 1 year corrected for gestational age with reduced likelihood of developmental delay
10. Improved parental affect, confidence and competence, better attachment, and more positive interactions with their infants

Some evidence also exists for the benefits of KMC in physiologically unstable and sick preterm infants; however, there are far fewer studies comparing efficacy and safety of unstable with stable infants. Gaps in knowledge where research results are either lacking or remain inconclusive persist in the following areas of KMC intervention:

1. Sick and physiologically unstable infants
2. Febrile infants, where there is little known about the thermoregulatory capacity of the baby
3. Effects on weight gain and growth
4. Short-term analgesic effects and longer term modulation of pain hypersensitivity
5. Blood glucose/insulin metabolism
6. Effects and mechanisms of KMC on brain maturation

CONCLUDING COMMENTS

Overall, the evidence to support the practice of KMC for physiologically stable preterm infants in all settings is extremely strong, and it is noted by many in this field that the barriers to its implementation other than infant infirmity are issues of parental, health-care professional, and institutional hesitancy.

There are currently no practice management tools within the quality assurance infrastructure of hospitals and neonatal units to measure the awareness, teaching practices, or implementation of KMC to preterm infants and their caregivers. Statistics for timing, application, and duration of KMC for any preterm individual throughout his or her hospital stay are not easy to access at this time, which may be required information for enabling the improvement of maternal and infant outcomes in this situation.

Collecting relevant maternity outcome data for KMC is a suggested first step in the process of health-care providers being competent in reviewing, reflecting on, and adjusting practice according to the standards of the neonatology profession, thereby enhancing the service provided by caregivers, health-care providers, and physicians and improving outcomes for the families affected by premature birth.

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