Kangaroo Mother Care 1: Alleviation of Physiological Problems in Premature Infants

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ABSTRACT

Kangaroo mother care (KMC) involves placing the newborn infant into prolonged and continuous skin-to-skin contact with the mother as soon as possible after birth, exclusive breastfeeding, early discharge from the health facility, and supportive follow-up at home. Claimed benefits of KMC as an aid to the clinical mitigation of some detrimental features of prematurity need to be evidence based. This article, the first of two, provides an overview of the impact of prematurity on those features of neonates to which KMC may be directed. Specifically, the mitigation of some cardiorespiratory, neurophysiological, sensory, gastrointestinal, musculoskeletal, renal, metabolic, and immunological impacts are outlined. Relevant neurobehavioral, psychosocial, sociocultural, and economic perspectives are briefly reviewed in the companion article. These two articles provide scientific support for a wider upscaling of KMC education and its cautious use in physiologically stable preterm infants.

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INTRODUCTION

Kangaroo mother care (KMC) consists of a four-part practice which includes holding a diaper-clad infant skin-to-skin and prone on the bare chest of their primary caregiver as soon as possible after birth, exclusive breastfeeding where possible, and early discharge from the health-care unit with close monitoring and support at home (World Health Organization, 2003). KMC was first used as a developmental care method in the late 1970s by Dr. Rey and Dr. Martinez in Bogota, Colombia, where the use of incubators for traditional care of the infants was either not available and/or unsafe (Boundy et al., 2016). KMC is used worldwide for term and preterm

infants, and there is an extensive literature supporting its safe use with stable infants whether premature or full-term (Boundy et al., 2016; Conde-Agudelo & Diaz-Rossello, 2014; Lawn, Mwansa-Kambafwile, Horta, Barros, & Cousens, 2010; Moore, Anderson, Bergman, & Dowswell, 2012). The primary purpose

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of KMC is to meet the infants' biological needs for warmth, nutrition, and love, and it has been repeatedly shown to decrease mortality, enhance breastfeeding, and decrease the risk of morbidities such as hypothermia, hypoglycemia, neonatal sepsis, and readmission to the hospital (Boundy et al., 2016). Regarding the healthy development of premature babies, multidisciplinary teams acknowledge the effects of care methods and the environment during the peri- and postnatal periods and, for that reason, the application of related best practice knowledge to the care of premature babies is essential. This article briefly reviews key elements of the impaired physiology of preterm infants and considers some beneficial effects of KMC on their physiology. The second article (Bear & Mellor, in press) extends this understanding by briefly reviewing relevant neurobehavioral, psychosocial, sociocultural, and economic perspectives. Together, these articles support the integration of KMC into premature baby care and its upscaling, where appropriate, to enhance the outcomes for this vulnerable group of infants in agreement with current evidence-based recommendations (Boundy et al., 2016; Chi Luong, Long Nguyen, Huynh Thi, Carrara, & Bergman, 2016; Conde-Agudelo & Diaz-Rossello, 2014; World Health Organization, 2015).

PHYSIOLOGY OF THE PREMATURE NEWBORN

Attainment of a physiologically autonomous state during the transition from intra- to extrauterine life reflects the ability of the infant to maintain widespread homeostatic control. Birth is inherently a time of high risk, and preterm infants in particular are at greater risk of mortality and morbidity because of impairment in almost every aspect of their physiology, including for example, their cardiorespiratory, neurophysiological, sensory, gastrointestinal, musculoskeletal, renal, metabolic endocrine, and immunological functionality.

Aspects of Cardiorespiratory Changes in the Premature Baby

Several circulatory, cardiac, and pulmonary adaptations are required at birth for the lungs to successfully replace the placenta as the site of respiratory gas exchange (Noori, Stavroudis, & Seri, 2009). Briefly, the principal cardiorespiratory changes are as follows:

- a. Transition from parallel (fetoplacental) to in-series (neonatal pulmonary) circulation (Noori et al., 2009)

- b. Removal of the placental circulation by stretch/severance of the umbilical vessels and the resulting functional closure of the ductus venosus (Walker, 1993)
- c. Functional closure of the foramen ovale in response to increased pulmonary blood flow and loss of the placental circulation (Walker, 1993)
- d. Functional closure of the ductus arteriosus within 3 days of birth (Hamrick & Hansmann, 2010)
- e. Rapid thinning of the pulmonary vascular smooth muscle in the first few days after birth resulting in vasodilation and lowered resistance in pulmonary vessels and increased inflation of alveoli (Rudolf, 1970; Walker, 1993)

Birth prior to 37 weeks challenges the immature cardiorespiratory apparatus, often resulting in a need for medical intervention and ongoing support. The most common pathologies are patent ductus arteriosus (PDA), anaemia of prematurity, and respiratory distress syndrome. Common sequelae of these cardiorespiratory pathologies are as follows:

- a. Loss of lung compliance and worsening cardio-pulmonary status (Hamrick & Hansmann, 2010; Stute, Greiner, & Linderkamp, 1995)
- b. Increased risk of bronchopulmonary dysplasia and chronic lung disease (Hamrick & Hansmann, 2010)
- c. Persistent pulmonary hypertension and increased susceptibility to infection (Schreiber et al., 2003)
- d. Increased risk of abnormal neurological development, secondary to cardiovascular insufficiency (Noori et al., 2009; Schreiber et al., 2003; World Health Organization, 2012)
- e. Increased risk of intraventricular hemorrhage (Hamrick & Hansmann, 2010)
- f. Hypoxic tissue damage and deleterious effects on various organ systems (Hamrick & Hansmann, 2010; Stute et al., 1995; Walker, 1993)
- g. Lethargy, pallor, poor feeding behavior, and failure to thrive (Stute et al., 1995)

Neurophysiological Aspects of Premature Baby Development

“Adult brain connectivity is shaped by the balance of sensory inputs in early life.”

—(Beggs, Currie, Salter, Fitzgerald, & Walker, 2012, p. 404)

The structural and functional development of the brain is disrupted by the event of premature birth, resulting in the possibility of marked, long-lasting anatomical, and physiological neuropathology. Cognitive deficits *without* major motor deficits are now the dominant neurodevelopmental sequelae in the survivors of early preterm birth (Volpe, 2009). Initial brain injury in the earliest of preterm infants occurs between the late second and early third trimesters, with up to 70% of these babies now surviving into childhood. A 50% morbidity rate including cognitive, behavioral, attentional, and socialization defects is recognized (Volpe, 2009) to result from the remarkably plastic nature of the fetal brain prior to the pruning and arborization that occurs at full term (World Health Organization, 2012). Thus, exposure to a traumatic, threatening, and chaotic extrauterine environment between 23 and 37 weeks' gestation may influence the trajectory of neurophysiological development in adverse ways, depending on the pattern, nature, and timing of these experiences (Perry & Pollard, 1998).

Optimally, the life cycle of the human baby includes spontaneous onset of a physiological birth and labor at the end of 37–42 weeks in the uterus, an environment characterized by darkness, stable temperature, vibratory and auditory rhythms, warmth, and cushioning by amniotic fluid (Buckley, 2015; Perry & Pollard, 1998). Thereafter, development would normally progress in the hours, days, and weeks after birth with the mother providing most sensory cues for the baby, characterized by skin-to-skin contact, rhythmic rocking, soothing vocalizations, near-constant embrace, and breastfeeding (Crenshaw, 2014; Perry & Pollard, 1998; Phillips, 2013). When new experience is chaotic, traumatic, or mismatched to the developmental stage, neurodevelopment is likely to be disrupted and result in a neurobiological stress response, exacerbated by separation from the mother and removal of her capacity to promote regulation of her babies' physiological and neurobiological status (Chi Luong et al., 2016).

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The healthy development and capacity of each brain region is dependent on the function of the lower brain regions established earlier as well as the timing of critical experiences during this development (Altimier & Phillips, 2013; Perry & Pollard, 1998). Because key neurobiological systems that mediate the stress response are located in the brainstem and midbrain, both intrauterine and early childhood experiences play major roles in determining the sensitivity and final organization of these brainstem-mediated stress–response systems (Perry & Pollard, 1998; Shonkoff et al., 2012). Disruptions to the necessary timing, frequency, pattern and nature of experience, and their aligned patterns of neural activation may hinder the expression of core capabilities, including physiological state regulation, primary and secondary sensory processing and integration, motor control, affect regulation, speech and language development, capacity for healthy relational interactions, and abstract thinking (Perry, 2001). By definition, the event of premature birth is likely to lead to such disruptions.

Finally, *encephalopathy of prematurity* is a term which describes a constellation of white and grey matter abnormalities and disturbances of development brought about by brain injury at the time of premature birth and is reported to affect at least 50% of (very low birth weight [VLBW]) birthweight infants, its pathology being characterized by an amalgam of primary destructive disease and secondary developmental disturbance (Volpe, 2009). Other neurobehavioral features are considered in the next article (Bear & Mellor, in press).

Aspects of the Sensory Physiology of the Premature Baby

“... The preterm infant is not simply a smaller version of the full-term newborn.”

—(Anderson, 1986, p. 19)

Sensory physiology of the premature baby has unique features which result in altered developmental and functional capabilities of the sensory apparatus, including the primary organs and other neural structures of most sensory modalities. Inadequate or noxious sensory inputs, such as those that may be experienced by premature babies in neonatal intensive care units (NICUs), may adversely affect the development of the immature central nervous system (CNS). Thus, premature babies are at greater risk for developing various sensory deficits, including sensory integrative disorders, than are their full-term counterparts (Nieder-Heitmann, 2010). Affected sensory systems include tactile, vestibular, olfactory, gustatory, auditory, and visual pathways.

The best adaptive response for premature babies in the NICU is likely to arise when appropriate environmental stimulation is provided to meet the developmental requirements of each sensory modality (Nieder-Heitmann, 2010). However, it is not yet clear what sensory interventions would be most appropriate for preterm neonates, given their fragile and immature nervous systems, requirement for potentially noxious medical and care interventions, and mismatched habitat compared to that within the uterus. An “appropriate environment” may be deemed to be one that incorporates the following features: containment and body flexion; exposure to appropriate chemosensory and olfactory stimulation; appropriate auditory stimulation with maternal voice and modulation of NICU noise pollution; appropriate visual stimulation from 37 weeks’ gestation; promotion of maternal milk production, nutritive sucking, and breastfeeding; amelioration of the effects of noxious and potentially disruptive exogenous stimulation; and sleep promotion (Liu et al., 2007).

Aspects of Gastrointestinal Physiology of the Premature Newborn

The usual progression from nutrition in utero via the placenta to the first ingestion of milk through breastfeeding soon after birth is generally disrupted by premature birth (World Health Organization, 2012). Colostrum and milk are required nutritionally as an energy source and even more so in the premature neonate because of low liver and skeletal muscle glycogen stores (Mellor & Cockburn, 1986). Also required are well-documented nonnutritional benefits attributed to antimicrobial, growth, cytokine and anti-inflammatory factors, digestive

enzymes, hormones, transporters, and other peptides in colostrum and milk (Prentice, 1996; Weaver, Arthur, Bunn, & Thomas, 1998).

Malnutrition during critical stages of fetal, neonatal, and infant development has been shown to carry an increased risk of adverse and long lasting effects on growth, neurodevelopment, cardiovascular health, and metabolism-related conditions, including hypertension, type 1 diabetes, and hypercholesterolemia (Dusick, Poindexter, Ehrenkranz, & Lemons, 2003; Kent, 2012; World Health Organization, 2012). However, the most significant challenges to health because of gastrointestinal compromise in the premature baby during the early postnatal period are necrotizing enterocolitis (NEC) and postnatal growth failure (Claud & Walker, 2001; Dusick et al., 2003). Thus, current hospital interventions aimed at supporting gastrointestinal function and growth of premature infants include the following (Claud & Walker, 2001; Dinerstein et al., 2006; Vohr, Wright, Poole, & McDonald, 2005; World Health Organization, 2012):

- a. Establishing healthy intestinal flora
- b. Full enteral feeding with breastmilk as soon as possible after birth, with or without total parenteral nutrition and milk fortifiers
- c. Avoiding early energy and protein deficits with an early and aggressive parenteral and enteral nutritional regimen
- d. Antenatal steroid use
- e. Supporting mothers to produce and express breastmilk for the ongoing nutritional requirements of her infant

Aspects of Musculoskeletal Physiology in Premature Babies

Given that approximately 80% of fetal calcium stores are accreted during the third trimester, premature birth may significantly affect skeletal development with likely compromised skeletal health in adulthood (Hovi et al., 2009). Common musculoskeletal sequelae in infancy and childhood in babies born prematurely are metabolic bone disease (MBD), limb and extremity malalignment, skull deformity, and gross motor delay. In addition, significant motor impairment and the effect this has on the child’s later exploration of the world, handwriting skills, and socialization are known areas of difficulty in preterm and VLBW infants and are important indicators for long-term problematic outcomes.

Aspects of Renal Physiology of Premature Babies

Developmental features of renal function which persist into adulthood begin to appear in the seventh week of gestation, with most nephrons present by 20 weeks postconception (Keijzer-Veen & van der Heijden, 2012). Renal development may be disrupted by premature birth increasing the risk of both short- and long-term renal disease, possibly in conjunction with related cardiovascular and metabolic health issues including proteinuria and hypertension (Keijzer-Veen & van der Heijden, 2012; Kent, 2012).

Abnormal histological changes in the kidneys of premature babies include the following (Keijzer-Veen & van der Heijden, 2012; Kent, 2012):

- a. Diminished nephron numbers (oligonephronia)
- b. Abnormal glomeruli in the outer renal cortex
- c. Enlargement of Bowman's space and shrinkage of the glomerular tuft
- d. Glomerulomegaly and gross renal abnormality
- e. Decreased renal length, volume, and size

Aspects of Metabolism, Homeostasis, and Endocrine Function in Premature Babies

Metabolic homeostasis and endocrine function are likely to be impaired in the preterm infant because of immaturity of these systems at a time that approximates to the third trimester of pregnancy (Hawdon, Ward Platt, & Aynsley-Green, 1992; Hovi et al., 2009). The third trimester is putatively one of the sensitive periods for the programming of glucose metabolism (Hovi et al., 2009) and disruption of metabolic processes resulting in hypo- or hyperglycemia and limited ketogenesis provides evidence of compromised metabolic fuel supply (Hawdon et al., 1992). Premature infants have a reduced capacity to tolerate low glucose concentrations at birth, leading to increased variation in blood glucose concentration and inadequate or inappropriate glucose delivery to the brain (Hawdon et al., 1992). Hypoglycemia in the early neonatal period is a cause of significant morbidity in preterm neonates with reported acute and long-term CNS effects (Hawdon et al., 1992) and is also a risk factor for type 2 diabetes mellitus and an increased risk of death from cardiovascular disease in later life (Hovi et al., 2009; Ng, 2000).

Prenatal and perinatal stressors provoke adaptive changes in metabolic and endocrine processes which

may permanently impact on adult health via adaptations of the hypothalamic-pituitary-adrenal (HPA) axis and subsequent altered stress reactivity (Hovi et al., 2009; Ng, 2000). In animal models of environmental stress such as postnatal separation from the mother and sensory deprivation, an increased physiological stress response was associated with increased vulnerability to stress-related illness in adults and increased negative behavior traits (White-Traut, 2004).

Some Immunological Features of Prematurity

The underdeveloped immunological system of the premature neonate may leave the baby vulnerable to infection, and reportedly, 20% of all premature babies who survive beyond Day 3 after birth will develop a bacteremia, as will up to 50% of those born at 25 weeks' gestation or less (Tissières et al., 2012). Such microbial loading may arise in part because infants born and cared for in the NICU before full term are subjected to various insults, including an average of 12 invasive procedures per day (Warnock et al., 2010). This neonatal peripheral tissue injury may also lead to pain-related behavior and sensitivity and may have a neuroimmunological basis which persists into adulthood (Beggs et al., 2012).

POTENTIAL IMPACTS OF KANGAROO MOTHER CARE ON PHYSIOLOGY

Certain aspects of the physiology of stable preterm babies have been shown to be enhanced by KMC, thereby positively influencing their short- and long-term health outcomes. A recent Cochrane meta-analysis of randomized controlled trials compared KMC and conventional neonatal care of preterm infants and showed a reduction in the risk of mortality, severe nosocomial (hospital-acquired) infection/sepsis, hypothermia, respiratory tract disease, and lengthy hospital stays, as well as improvements in some measures of infant growth and breastfeeding (Conde-Agudelo & Diaz-Rossello, 2014).

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Also, meta-analysis and randomized cross-over trials have suggested that KMC provides effective and safe analgesic benefits for pain management in the NICU for both single and repeated procedures (Cong et al., 2012; Gao et al., 2015; Johnston et al., 2014). There were reduced autonomic pain responses to heel stick as indicated by enhanced physiological stability, less stress reactivity, reduced pain response, and less long-term hypersensitivity to pain (Cong et al., 2012).

Strong evidence for positive effects of KMC on the physiology of stable preterm infants emerged from a literature review of meta-analyses comparing KMC and incubator care in the following areas (Ludington-Hoe, Morgan, & Abouelfettoh, 2008):

- a. *Heart rate*: either no significant change or more stable during heel stick, fewer bradycardic events (HR <100 bpm), remains within clinically acceptable range
- b. *Respiratory rate*: remains within clinically acceptable range
- c. *Oxygen saturation*: minimal change, remaining mostly within clinically acceptable range
- d. *Oxygen desaturations*: fewer episodes of oxygen desaturation per infant and lower numbers of affected infants
- e. *Apneic events*: either no change or decreased apnea
- f. *Body temperature*: rises reliably if hypothermic, remains within the infant's neutral thermal zone; KMC with fathers in tropical regions may result in overheating; KMC not to be used if the infant is febrile because of lack of supporting evidence
- g. *Cortisol as an indicator of physiological stress*: either no change or a significant decrease in serum and salivary cortisol found
- h. *Sepsis*: significantly fewer nosocomial infections occur

The strength of this evidence warranted the recommendation to apply KMC in stable preterm infants post 30 weeks' gestational age, with moderate evidence in support of the possibility for increased weight gain and more stable blood glucose levels (Ludington-Hoe et al., 2008).

CONCLUDING COMMENTS

It is noteworthy that two distinct patterns of KMC for premature babies have emerged: first, continuous

kangaroo mother care (c-KMC), which is most prevalent in low-income and poorly resourced settings, and second, intermittent kangaroo mother care (i-KMC), which is more common in affluent hi-tech settings. The World Health Organization issued practical guidelines in 2003 for KMC in both settings, suggesting urgency of application based on increasing and compelling evidence that KMC decreased mortality and morbidity associated with premature birth while enhancing breastfeeding and some psychosocial indices. Following this, meta-analyses have produced further support for the recommendation of KMC upscaling in all income settings, including middle- and high-income countries (Boundy et al., 2016; Conde-Agudelo & Diaz-Rossello, 2014; World Health Organization, 2015).

To summarize and conclude this article on physiological aspects of KMC for the stable preterm infant, the World Health Organization issued the following recommendations on interventions to improve outcomes for preterm infants:

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. (World Health Organization, 2015, p. 3)

At its best, KMC provides warmth, comfort, physiological, and psychosocial benefits. This article, and the following one (Bear & Mellor, in press), may contribute to a more widespread upscaling of KMC education and cautious implementation in all settings for physiologically stable preterm infants by raising awareness of its scientific justification and appropriateness.

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