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Kangaroo father care: A pilot feasibility study of physiologic, biologic, and psychosocial measures to capture the effects of father–infant and mother–infant skin-to-skin contact in the Neonatal Intensive Care Unit

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Abstract

Robust literature supports the positive effects of kangaroo mother care (KMC) on infant physiologic stability and parent–infant bonding in the Neonatal Intensive Care Unit (NICU). Comparatively little is known about kangaroo father care (KFC) in the NICU, and KFC implementation has been limited. Our pilot feasibility study objective was to examine KFC effects on premature infants and fathers as compared to KMC. Parents of preterm NICU infants independently completed a 90-min Kangaroo Care (KC) session on consecutive days. Infant heart rate variability (HRV) and apnea/periodicity measures were compared (pre-KC to KC; KFC to KMC). Additionally, we assessed the feasibility of administering three psychosocial questionnaires to fathers and mothers in the NICU and after discharge. Ten preterm infants completed 20 KC sessions ($33^{4/7}$–$37^{4/7}$ weeks post-menstrual age). Results demonstrated similar infant physiologic responses between KMC and KFC, including significant differences in measures of HRV ($p < .05$) between KC and non-KC periods. Eighty-eight percentage of questionnaires administered were completed, supporting the utilization of these instruments in future research of this population. If confirmed, these preliminary results identify an opportunity to objectively assess KFC effects, supporting the development of empirically based KFC programs benefitting NICU families.

KEYWORDS

fathers, heart rate variability, Kangaroo Care, Neonatal Intensive Care Unit, periodic breathing, prematurity, skin-to-skin contact

1 | INTRODUCTION

Globally, an estimated 15 million infants are born prematurely each year (<37 weeks gestation), and require care in the Neonatal Intensive Care Unit (NICU) (WHO, 2015). Preterm infants are extremely vulnerable in the perinatal period, with increased risks of adverse outcomes including infection, acute respiratory distress, chronic intermittent hypoxemia, impaired temperature and metabolic regulation, and long-term neurodevelopmental impairment (Escobar et al., 2006; Escobar, McCormick, et al., 2006; Kramer et al., 2000; Pulver et al., 2009; Santos et al., 2008; Tomashek et al., 2007; Wang et al., 2004). Such prematurity-related complications are the leading cause of neonatal morbidity and mortality, and preterm infants experience, on average, longer lengths of hospital stay, compared to full-term infants (Escobar, Clark, et al., 2006). Specifically, instances of apnea, bradycardia, and a lack of thermoregulation are often what keep preterm infants, who are otherwise ready to go home, in the hospital for greater periods of time (Chandrasekharan et al., 2018; Higgins Joyce et al., 2019). These extended hospital stays and the bulky nutritional and respiratory support devices that infants often require in the NICU compound the direct physiological effects of prematurity by creating physical barriers to parent–infant bonding. Interrupted parent–infant interaction in the perinatal period has been shown to not only inhibit infant stability and attachment formation, but also negatively affect parent well-being and confidence in parental roles (Ionio et al., 2016; Kommers et al., 2016).

Kangaroo Care (KC), or skin-to-skin contact between a newborn infant and parent, is a low-cost intervention proven to improve infant stability and parent–infant bonding in the NICU. During KC, a parent holds an infant against their bare chest, skin-to-skin. NICU implementation of KC typically involves the infant's mother, in a practice familiarly termed Kangaroo Mother Care (KMC) (Klaus et al., 1972). Substantial research supporting the implementation and positive effects of KMC has been published, outlining improvements in physiologic, biologic, and psychosocial outcomes (Campbell-Yeo et al., 2015). Some of the well-established benefits of KMC include improvement of infant physiologic stability, reduction in morbidity and mortality, accelerated neurobehavioral maturation, promotion of the mother–infant bond, and overall improvement of positive development trajectories (Campbell-Yeo et al., 2015; Feldman & Eidelman, 2003). Additionally, KMC greatly benefits mothers with improved initiation and duration of breastfeeding, reduced anxiety, and improved sense of confidence in parenting (Moore et al., 2012). The World Health Organization recommends that KC be utilized as continuously as possible during the neonatal period, starting in the NICU and continuing at home after discharge (WHO, 2015). However, KC, especially Kangaroo Father Care (KFC) remains thoroughly under-utilized in the NICU. (Campbell-Yeo et al., 2015; Pallas-Alonso et al., 2012).

KFC specific research demonstrating positive outcomes has increased of late, but still pales in comparison to that of KMC, with KFC implementation remaining relatively limited. Reports of paternal feelings of marginalization and disempowerment at the NICU bedside have encouraged examinations of gendered parental experiences in the NICU and inspired explorations of methodologies to increase paternal engagement in the care of premature infants (Deeney et al., 2012; Helth & Jarden, 2013; Mackley et al., 2010). Only a handful of studies have investigated KFC and found it to be similar to KMC in regard to a limited set of infant physiologic parameters (e.g. heart rate (HR), oxygen saturation (SpO_2), skin temperature, and energy expenditure) (Bauer et al., 1996; Johnston et al., 2011). With the unique sensitivities surrounding a NICU stay for mothers and fathers, finding equitable approaches in the involvement, education, and support of both parents in the care of their premature infant may positively impact current and future infant and family outcomes.

Shorey et al. found that fathers who provided skin-to-skin care to their infants experienced less anxiety and stress, and had better interactive experiences with their newborns (Shorey et al., 2016). Fathers interviewed regarding their experience performing KFC expressed pride, increased self-esteem, a reduction in anxiety, and an amplified confidence that they could care for their infant in the same way, and just as well, as the mother could (Olsson et al., 2017). Furthermore, KFC performance immediately after cesarean section, a time when the mother is often not able to perform skin-to-skin contact, resulted in a shorter duration of crying, decreased length of time to initiate breastfeeding, improved physiologic stability, and reduced levels of depression and anxiety in fathers compared to groups where no KFC was performed (Ayala et al., 2021; Huang et al., 2019). Findings from a 2014 study conducted in India, a country rooted in the tradition of mothers being the primary caregiver, found that fathers who participated in skin-to-skin care demonstrated increased sensitivity toward their infant (Varela et al., 2014). Similar research has concluded that initially, fathers tend to feel less important than mothers when it comes to the care of their infant, however, after performing KFC, fathers report developing a comfort and understanding of their role which is strengthened through skin-to-skin contact (Helth & Jarden, 2013). Fathers of very low birth weight (VLBW) infants expressed how a stay in the NICU disrupted their transition to fatherhood, and incorporation of father-focused education around the care of their child would be a welcomed form of support (Garten et al., 2013). Furthermore, the feeling of becoming a parent was reinforced by fathers who participated in KC and believed skin-to-skin contact was a way to keep their infant safe a secure (Blomqvist et al., 2012). Taken together, these reports suggest the potential of KFC utilization to reduce current barriers to increased KC use and to improve infant, father, and family outcomes.

The present feasibility study aimed to pilot tools to evaluate the impact of KC on infants and parents in the NICU in order to determine whether KFC produces the same physiologic benefits that have been widely validated in KMC. In addition, existing research has collected limited physiologic parameters, therefore, we sought to combine a broader number of biological, physiological, and psychosocial parameters collected from infants, mothers, and fathers. Finally, and specific to participating fathers, we aimed to assess our ability to capture parental feelings on key psychosocial measures including relationship quality, parent–infant bonding, and parenting self-efficacy, as well as to evaluate the willingness of participants to provide their saliva for future analysis of stress and parenting hormones levels. We hypothesized that infants would exhibit similar physiologic responses to both KFC and KMC, measured by heart rate variability (HRV) changes and amount of time spent in apnea or periodic breathing. Additionally, we hypothesized that participating parents would be receptive to and allow collection of physiologic measurements from their infants, complete the psychosocial questionnaires administered, as well as provide saliva for themselves and allow the collection of saliva from their infants.

2 | METHODS

2.1 | Design

This was a single center, prospective, pilot study of KC in a level III NICU at Northwestern Medicine Prentice Women's Hospital (PWH; Chicago, Illinois). PWH is the 5th largest birthing hospital in the United States with over 12,000 annual deliveries. Family study participation occurred during their NICU admission, and parents completed a set of questionnaires while in the NICU, and at two points after discharge. In person study activity was conducted in the infant's bed-space on two consecutive days. Each day consisted of collecting vital sign data from infants using the bedside monitors and additional research wireless biosensors, collecting saliva from infants, and having parents self-collect their saliva, before, during, and after a 90-min KC session, with the total study time being 3 hr per day.

2.2 | Participants

Eligible participants were preterm infants born between $30^{0/7}$ and $36^{6/7}$ weeks gestation enrolled within their first 20 days of life. Infants were excluded if they were intubated, receiving vasopressors or analgesics, had a congenital anomaly or surgical intervention that could impact the performance of KC, or were deemed too unstable to participate by the clinical care team. Eligible parents had to be over 18 years of age, raising the child together in the same household regardless of marital status, and English speaking. Families would be excluded if either parent was taking corticosteroid or testosterone supplements, showing any sign of illness, or were non-English speaking because the study questionnaires were only available in English.

Eligible participants were screened for all inclusion and exclusion criteria using the electronic medical record. Families that met all of the study requirements and were approved by the clinical care team were approached for participation. Informed written consent was obtained from each parent, and for each infant.

2.3 | Kangaroo care sessions

Once enrolled in the study, 90-min KC sessions were scheduled for both mother and father on consecutive days that fit with the parents' visitation plan. As has been done in prior KC studies (Srinath et al., 2016) we randomized which parent session was conducted first, KMC or KFC, in accordance with parental availability. To minimize disturbance to the infant's daily schedule, the sessions began around the infants' every 3-hr hands-on-care schedule. Clinical hands-on-care consists of a diaper change, temperature measurement, and a feeding. Attempts were made to begin each KC sessions for each parent at the same time of day.

Each study day was divided into three periods: pre-KC, KC, and post-KC. The pre-KC period began 60 min before the initiation of KC. During the latter 30 min of the pre-KC period the research biosensors were placed on the infant and the infant's nurse performed regular clinical hands-on-care. The 90-min KC period began when the infant was settled on their parent's chest and ended when the infant was removed from their parent's chest approximately 90 min later. The post-KC period lasted 45 min, beginning when the infant was swaddled and back in her/his bed and ended with the removal of the biosensors. Throughout the post-KC period, the infant would remain undisturbed unless they needed to be soothed or for other medical purposes. Continuous physiologic bedside monitoring of the infants, including electrocardiography (ECG), respiration rate (RR), HR, and SpO_2, continued throughout the duration of the study.

For the KC session, the infant wore only a diaper and was placed centered and vertical on the parent's bare chest. A blanket was draped over the infant's back, the parent–infant dyad sat in a reclining chair, and they were left undisturbed for the 90-min session. If the infant ever experienced distress or needed care that necessitated disruption of the skin-to-skin session, all necessary measures were taken, and KC was reinitiated when appropriate.

2.4 | Vital sign monitoring

A Medicollector (MC) Bedside data collection system (Medicollector, Boston, MA) was connected to the infant's bedside monitor (IntelliVue MP70) to collect physiologic data for analysis throughout the study. In addition to the regular clinical monitoring systems, each infant wore two research wireless vital sign monitors for the duration of the study. These are soft, flexible, non-invasive devices capable of being worn safely on the skin for hours and can monitor and collect vital signs such as HR, SpO_2, respiration rate, temperature, and positional data using an accelerometer (Chung et al., 2020). One device was placed vertically in the center of its back and secured with hydrogel adhesive. The second device was wrapped around their foot and secured with a Velcro strap. For analyses presented in this study, data collected from the MC was used for HRV and respiratory metric analysis. The accelerometer data collected from the wireless wearable devices were used to analyze infant position.

2.5 | Heart rate variability measurements and analysis

HRV metrics were utilized to assess physiologic responses to KMC and KFC in participating infants following the methodology published by Kommers et al. (2017). Six HRV metrics were analyzed; the standard deviation of normal-to-normal intervals (SDNN), the root mean square of the standard deviation (RMSSD), the percentage of consecutive normal-to-normal intervals that differ by greater than 50 milliseconds (pNN50), high-frequency power (HF), low-frequency power, and the LF/HF ratio. SDNN, RMSSD, and pNN50 are metrics from the time domain, reflective of the beat-to-beat intervals of the heart. LF, HF, and LF/HF ratio are from the frequency domain, which reflects the influence the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) have on HRV. LF is reflective of SNS activity and HF is reflective of PNS activity.

The Physionet Cardiovascular Toolbox (Vest et al., 2018), implemented in MATLAB R2019b (The MathWorks, Inc., Natick, Massachusetts, United States) was used to perform QRS detection, detect signal quality, and analyze HRV metrics. Metrics were analyzed over 5-min intervals in 30- s sliding windows. Further details of the parameters chosen for the HRV analysis are presented in supplementary Table S1. For statistical analysis, 30-min epochs were compared from the pre-KC period and the KC-period—the first 30 min of the pre-KC period and minutes 15–45 of the KC period, as in Kommers et al. (2017).

2.6 | Assessment of apneas and periodic breathing

Respiratory waveforms acquired from the patient monitoring system were used to assess instances of apnea and periodic breathing during KC and were compared to their prevalence at other times. Since apnea and periodic breathing (PB) are rarer than HRV changes, we compared their prevalence during the 90 min of KC to all other time periods available (approximately 36 hr of data in total).

Apneas (Lee et al., 2012) and periodic breathing (Mohr et al., 2015) were detected in the respiratory waveform using automated algorithms via implementation in tools developed by the University of Virginia for the Pre-Vent multi-center NHLBI-funded study (Dennery et al., 2019). Apneas lasting longer than 10 s were included, and the total time in apnea was taken as a fraction of the total time of respiratory data available for the KC period versus other times available. Periods with a periodic breathing probability score > 0.6 were counted and again compared to the total time of respiratory data available for the KC period versus pre-KC, post-KC, and non-KC times.

2.7 | Wearable sensors for KC tracking

To evaluate a wearable sensor for detection of KC utilization, three-dimensional position data from the accelerometer of the wearable device were converted to rotational angles of phi and theta. Sections of the data when the infant was in KC or in their crib were then analyzed to determine if those spatial locations could be distinguished.

2.8 | Psychosocial measures

Three validated psychosocial questionnaires were administered to participating parents twice in the NICU and twice after going home. A description of the questionnaires and the times they were administered are provided in Table 1. Briefly, the three surveys measured parenting self-efficacy, relationship quality, and parent bonding. The *Revised Dyadic Adjustment Scale* (RDAS) has 14 items with total scores ranging from 0 to 69. A score of ≤48 indicates a distressed relationship (Crane et al., 2000). The *Postpartum Bonding Questionnaire* (PBQ) score can range from 0–125, assessed over 25 items. A score of ≥26 indicates some form of disordered bonding (Brockington et al., 2006). The last questionnaire, the *Parenting Sense of Competence Scale* (PSOC), has 17 items with a score that can range from 17 to 102, higher signaling greater parenting sense of competency (Johnston & Mash, 1989). In order to assess our ability to measure parent psychosocial responses, the completion rate was calculated for each questionnaire. Median and interquartile range (IQR) values were calculated for the questionnaire responses acquired from parents (Table 5).

2.9 | Saliva collection

Saliva was collected from all infants and parents during their study participation. The collection times were 30 min before the beginning

TABLE 1 Description of study questionnaires and times administered

Questionnaire	Administration timeline	Description
Revised dyadic adjustment scale	1[†] 2[‡] 3[§] 4[¶]	Assesses satisfaction, consensus, cohesion, and affectional expression in relationships. A higher score reflects greater levels of satisfaction, consensus, cohesion, and affection (Crane et al., 2000)
Postpartum bonding questionnaire	1 2 3 4	Evaluates the behavior and level of bonding parents experience with their infant. A lower score is reflective of higher levels of bonding between parent and infant (Brockington et al., 2001)
Parenting sense of competency	2 3 4	Assesses parental enjoyment and self-efficacy in parenting. A higher score signals greater parent self-efficacy (Johnston & Mash, 1989)

[†]Study consent,

[‡]Day before discharge,

[§]Two weeks post discharge,

[¶]Four weeks post discharge.

of the KC period, 15 min before the end of the KC period, and 45 min after the end of the KC period. This collection schedule resulted in parents providing three samples each, and infants providing six samples each, three per KC session. Parents provided their own saliva by a passive drool method using the Salimetrics SalivaBio Collection Aid (Salimetrics, LLC, Carlsbad, California, United States) at all of the collection points. Infant saliva was collected using Salimetrics SalivaBio Infant Swabs (Salimetrics, LLC, Carlsbad, California, United States). Two swabs were used consecutively at all collection times for three minutes each and placed in their own collection vials. All saliva samples were placed on ice immediately after collection, then transferred to a freezer at −20° Fahrenheit as soon as possible.

2.10 | Statistical analysis

Statistical analysis was performed using the MATLAB and Statistics toolbox Release 2019b (The MathWorks, Inc., Natick, Massachusetts, United States). Comparisons of HRV, apneas, and periodic breathing were made with Wilcoxon signed-rank tests. A non-parametric test was used as the data were not normally distributed. The first comparison was of all the data from the 20 KC sessions, comparing the pre-KC period to the KC period (minutes 0 to 30 of the pre-KC period, and minutes 15 to 45 of KC). The second comparison was of the data collected from KMC to the data collected from KFC. Confidence intervals of median differences were calculated by bootstrapping with 1,000 replications for each statistic, and effect sizes were estimated as correlations (Rosenthal, 1994).

2.11 | Research ethics approval

This study was approved by the Institutional Review Board at Ann & Robert H. Lurie Children's Hospital of Chicago in Chicago, Illinois (2019–2539). All parents gave their written informed consent to participate in the study, for themselves and for their child, before any study procedures took place.

2.12 | Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

3 | RESULTS

A total of 20 mother–father–infant triads were consented for this study. Of the 20 triads, three were discharged before study participation could take place, and two triad datasets were not included due to being incomplete. Of the remaining 15 triads, 10 had analyzable infant physiologic data and nine provided complete questionnaire scores. Characteristics of the 15 infant and 30 parent participants are provided in Table 2. Using parental availability to randomize the KMC and KFC sessions resulted in seven studies where KMC was conducted first. Both KMC and KFC were conducted at the same time of day for 11 of the 15 participating families. The other four studies could not begin at the same time due to the parent's schedule, and as a result, two began 3 hr earlier, one began 3 hr later, and one began 6 hr later, all on the second study day.

TABLE 2 Characteristics of study participants

INFANTS	
Gestational Age (mean) [range]	33 weeks 5 days [$31^{4/7}$–$36^{2/7}$]
Post Menstrual Age at Study (mean) [range]	35 weeks 5 days [$33^{3/7}$–$37^{3/7}$]
Length of Stay (mean)	22 days
Sex	
Male (*n*)	7
Female (*n*)	8
Delivery Type	
Cesarean section (*n*)	8
Vaginal (*n*)	7
Ethnicity	
Hispanic/Latino (*n*)	0
Not Hispanic/Latino (*n*)	13
Declined to provide (*n*)	2
Race	
Caucasian (*n*)	12
Black/African American (*n*)	1
Declined to provide (*n*)	2
At Birth (mean, standard deviation)	
Weight (grams)	2,228, 443
Length (cm)	45.17, 3.03
Head Circumference (cm)	31, 1.9
APGAR at 1 min	7, 2
APGAR at 5 min	8, 1
At Time of Study (mean, standard deviation)	
Weight (grams)	2,371, 342.2
Length (cm)	46.6, 2.5
Head Circumference (cm)	31.8, 1.5
At Discharge (mean, standard deviation)	
Weight (grams)	2,609, 373
Length (cm)	46.67, 4.25
Head Circumference (cm)	33.43, 4.25
PARENTS	
Mothers	
Age (mean)	33.7 years
Fathers	
Age (mean)	35.4 years

TABLE 3 Heart rate variability (HRV) metrics – all KC sessions

HRV Metric	Pre-Kangaroo Care; Median (IQR)	Kangaroo Care; Median (IQR)	*P* value	Effect size (*r*)
SDNN† (ms)	35.4 (27.9–40.2)	16.04 (13.4–18.5)	.00009	0.88
RMSSD‡ (ms)	15.2 (12.5–24.6)	6.95 (4.97–9.14)	.00009	0.88
pNN50§ (%)	0.016 (0.012–0.038)	0.002 (0.0002–0.006)	.00014	0.85
LF¶ (ms^2)	603 (375–859)	194 (121–224)	.00034	0.80
HF¶ (ms^2)	43.2 (22.9–79.8)	5.54 (2.27–10.51)	.00012	0.86
LF/HF¶ ratio	32.9 (21.1–57.9)	56.5 (47.2–82.4)	.01524	0.54

†Standard deviation of the normal-to-normal interval,
‡Root mean square of the standard deviation,
§Percentage of consecutive normal-to-normal intervals that differ by >50 ms,
¶Low-frequency power,
††High-frequency power,
‡‡Low-frequency to high-frequency ratio.

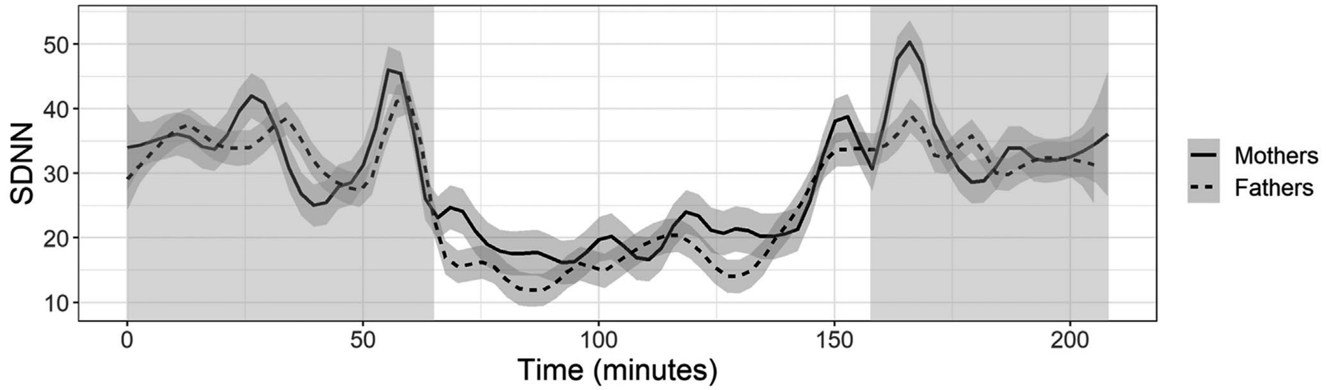

FIGURE 1 Variation in the standard deviation of the normal to normal interval (SDNN) over the duration of the kangaroo care (KC) recordings for mothers (mean; solid line) and fathers (mean; dashed line). ± *SEM* is shown as the shaded areas. SDNN was calculated over 5-min intervals, with a 30-s sliding window. The different sections of the figure represent the 60-min pre-KC period, the 90-min KC session, and the 45-min post-KC period

TABLE 4 Heart rate variability (HRV) Metrics – comparing change in HRV metrics between pre-KC and KC sections for KC sessions with mothers and fathers

HRV Metric	Fathers - Change pre-KC to KC; Median (IQR)	Mothers - Change pre-KC to KC; Median (IQR)	*P* value	Effect size (*r*)
SDNN† (ms)	−20.6 (−24.7 to −17.2)	−17.7 (−28.3 to −9.8)	.88	0.05
RMSSD‡ (ms)	−8.9 (−22.1 to −6)	−7.7 (−15.3 to −4.2)	.56	0.18
pNN50§ (%)	−0.011 (−0.07 to −0.004)	−0.016 (−0.03 to −0.006)	.65	0.15
LF¶ (ms^2)	−537.9 (−654.6 to −290.8)	−176.4 (−793.7 to −90.0)	.39	0.27
HF†† (ms^2)	−36.0 (−79.6 to −14.9)	−34.5 (−57.1 to −20.0)	.72	0.11
LF/HF‡‡ ratio	7.6 (−6.5 to 32.0)	27.0 (18.3 to 35.1)	.33	0.31

†Standard deviation of the normal-to-normal interval,
‡Root mean square of the standard deviation,
§Percentage of consecutive normal-to-normal intervals that differ by >50 ms,
¶Low-frequency power,
††High-frequency power,
‡‡Low-frequency to high-frequency ratio.

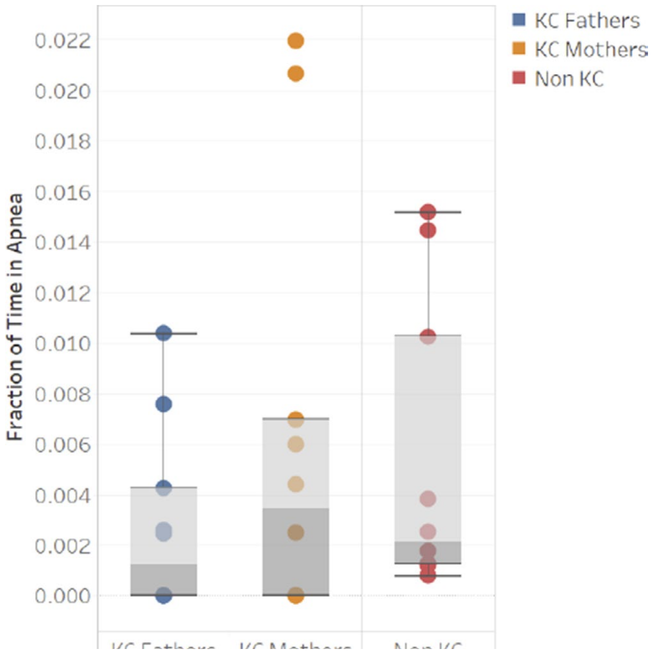

FIGURE 2 Fraction of the time infants spent in apnea during kangaroo father care (KC Fathers), kangaroo mother care (KC Mothers), and in non-kangaroo care (Non-KC) periods. The grey boxes represent the middle two quartiles of the data (25th to 75th percentile) and whiskers extend to 1.5 times the interquartile range. No significant differences ($p > .05$) were observed when comparing KC Fathers to KC Mothers, or in comparing time in KC to time, not in KC

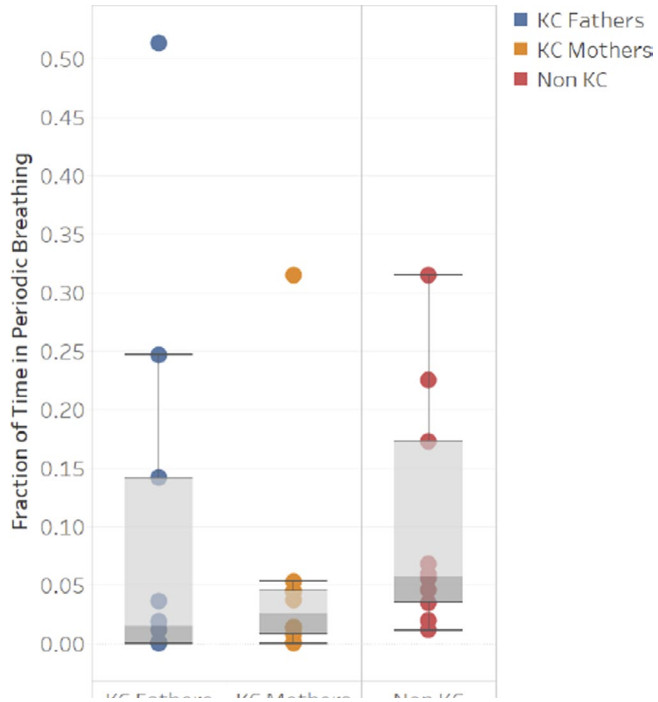

FIGURE 3 FIGUREFraction of the time infants spent in periodic breathing during kangaroo father care (KC Fathers), kangaroo mother care (KC Mothers), and in non-kangaroo care (Non-KC) periods. The grey boxes represent the middle two quartiles of the data (25th to 75th percentile) and whiskers extend to 1.5 times the interquartile range. Differences trended toward significance ($p = .08$) when comparing time in KC to time spent not in KC. No significant differences ($p > .05$) were observed when comparing KC Fathers to KC Mothers

3.1 | Infant physiologic responses to KC

Significant differences were identified between pre-KC and KC periods for all HRV metrics considered (RMSSD, pNN50, SDNN, HF power, LF power and LF/HF ratio; $p < .05$ for all measures; Table 3). Values between KFC and KMC did not significantly differ (Figure 1; Table 4; Supplementary Figure S5). Although with our small sample size a type II error is possible, HRV changes were very similar for mothers and fathers and effect sizes were small (Table 4), indicating that any difference between mothers and fathers is small. While there was no significant difference in the number of apneas or periodic breathing between either pre-KC and KC periods or between KMC and KFC (Figure 2), data showed a clear trend toward reduction in periodic breathing during KC ($p = .08$; Figure 3).

3.2 | Accelerometer analysis

Mean phi and theta angle data from all recording sessions were −0.532 ± 0.183 radians and −6.58 ± 0.072 radians, respectively, in KC, compared to −0.300 ± 0.243 radians and 0.732 ± 0.080 radians, respectively, in crib time. Positional data clearly distinguished KC time from non-KC time when the infants were supine in the crib ($p < .001$), with no overlap between body position data for the crib versus KC time periods in any of the studies. Depiction of the rotation versus time (Figure 4a) and theta versus phi (Figure 4b) plots from a representative recording session including KC and crib time are provided.

3.3 | Psychosocial measures and saliva collection

The survey completion rate from parents at study consent, the day before discharge, 2 weeks after discharge, and four weeks after discharge are 100%, 90%, 80%, and 88%, respectively. Though the focus was the questionnaire feasibility within the context of the larger study and data collection, the median and interquartile range values for mothers and fathers are detailed in Table 5. Response rates for mothers and fathers were 93% and 84%, respectively. For the RDAS, median values for mothers and fathers across all time-points indicated a non-distressed relationship (≥49). For the PBQ, median values for mothers and fathers across all time points indicated normal parent–infant bonding (<25). The median PSOC scores were similar between mothers and fathers and appeared to be stable over all time points. For saliva collection feasibility, 100% of the parents and infants in this study participated in, and provided saliva

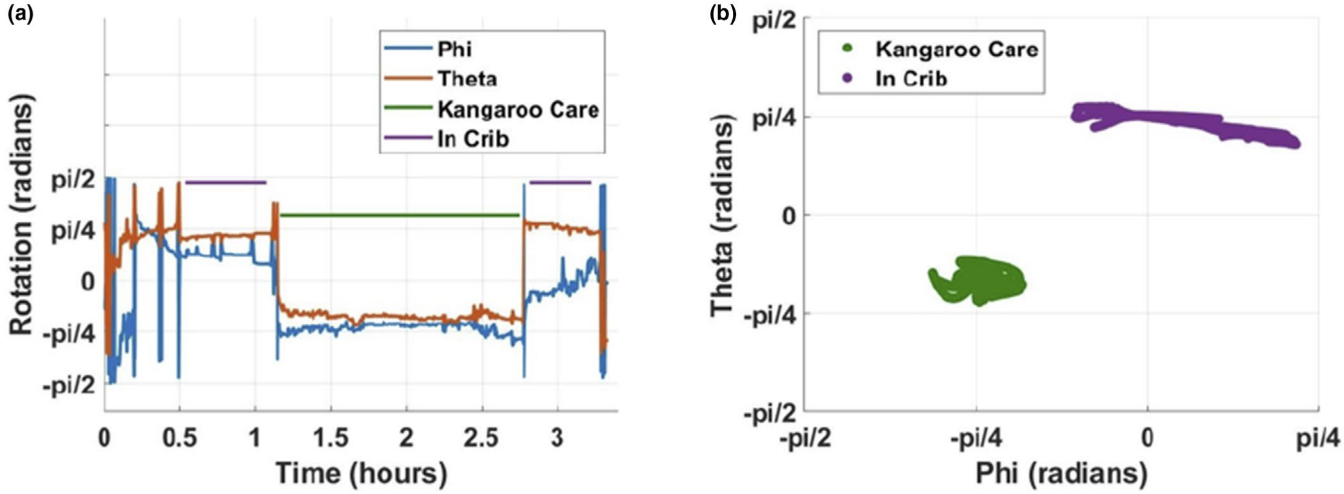

FIGURE 4 FIGURE(a) The rotation versus time graph for a representative kangaroo care (KC) session detailing the differences in position while the infant was supine in the crib and while being held semi-upright during the KC session. (b) The mean phi and theta angles of the same representative KC session demonstrate the distinction between the infant's body orientation while the infant was in the crib (supine), and while held semi-upright during the KC session

during, all the saliva collection time points (before, during and after their respective KC sessions).

4 | DISCUSSION

In our study, we piloted multiple tools to evaluate the effects of KFC on preterm infants and their fathers relative to the effects of KMC on the same infants and their mothers. We comparatively assessed the physiologic responses of infants participating in KMC and KFC via analysis of HRV, apnea and PB. Although a small pilot study, our findings demonstrated clear infant physiologic responses to KC which were similar in KMC and KFC. This finding provides support for the use of these tools and for the potential of KFC as a postnatal intervention with a comparable impact on infant physiology to KMC. We further assessed the feasibility to capture the impact of KC on psychosocial and behavioral outcomes in mothers and fathers by administering validated questionnaires at time points across their study involvement. Compliance of survey completion was limited, restricting our ability to adequately assess the impact of KC on these outcomes within this cohort. Additionally, we evaluated the feasibility to collect saliva from all participants before, during, and after each KC session, which was 100% successful. Finally, we assessed the ability of a wearable sensor with accelerometry to distinguish between periods of KC and non-KC. Our results support the potential of this technology for tracking KC utilization, which could be valuable for future research and programs aimed at improving KC implementation.

Our findings of similar infant physiologic responses to KMC and KFC as well as no adverse effects on infants during KC sessions are all in line with the limited previous KC research including mothers and fathers (Bauer et al., 1996; Johnston et al., 2011; Srinath et al., 2016) This study advances the literature by collecting a more comprehensive set of parameters then has been done in previous KC research, including expanded physiologic, biologic, and psychosocial data. We were able to successfully conduct 90-min KC sessions with mothers and fathers while simultaneously collecting infant physiologic data before, during, and after each session, also shown by Srinath et al., 2016. Our future investigations intend to expand on these methods, incorporating increased amounts of KC sessions, analysis of parent physiologic responses to the skin-to-skin sessions, infant and parent salivary biomarker analysis, and expansion of wireless vital monitor use to be able to further confirm KFC efficacy and potentially establish a dose response to KC.

4.1 | HRV and respiratory responses

Prior research has demonstrated positive benefits of KC on infant physiologic stability, but this research has focused primarily on KMC. The HRV results presented here are in keeping with the report by Kommers et al. who conducted one of the first studies specifically aimed at assessing HRV in premature infants before, during, and after KC (D. R. Kommers et al., 2017). This study identified statistically significant differences between KC and pre-KC periods in several HRV features. We have extended those results by demonstrating similar HRV changes between KC and non-KC periods in our cohort of infants and establishing that those changes are independent of whether KC is practiced by the mother or father.

Although we did not identify significant changes in apnea or periodic breathing during KC, the infants participating in our study experienced decreased amounts of PB while performing KC and none of the apneic events were of clinical significance. Research investigating acute physiologic responses such as apnea, bradycardia,

TABLE 5 Psychosocial questionnaires

Time Administered	Completion Rate		Revised Dyadic Adjustment Scale		Postpartum Bonding Questionnaire		Parenting Sense of Competence Scale	
	Mothers; Percent	Fathers; Percent	Mothers (n = 9); Median (IQR)	Fathers (n = 9); Median (IQR)	Mothers (n = 9); Median (IQR)	Fathers (n = 9); Median (IQR)	Mothers (n = 9); Median (IQR)	Fathers (n = 9); Median (IQR)
1†	100	100	54 (51–56)	53 (51–54)	6 (1–10)	6 (2–11)	NA	NA
2‡	90	88	53 (50–55)	54 (52–56)	4 (3–5)	6 (3–11)	81 (78–86)	82 (74–90)
3§	93	66	55 (49–57)	53 (52–58)	3 (3–5)	4 (2–9)	88 (81–90)	83 (75–92)
4¶	89	86	53 (52–56)	54 (53–57)	3 (3–5)	3 (2–6)	81 (76–89)	89 (79–93)

†Study consent,
‡Day before discharge,
§Two weeks post discharge,
¶Four weeks post discharge.

and desaturations have reported contrasting findings. Some have observed no apnea, bradycardia, or desaturation events during KC compared to controls, whereas others observed decreased amounts of desaturations and bradycardia in a KC group compared to controls (Ludington-Hoe et al., 2004; Mitchell et al., 2013). Most notable for our results, when comparing KMC to KFC no significant differences for either of the respiratory measures were seen, signaling a similar response was elicited regardless of which parent was performing the skin-to-skin session which is in line with previous research (Ludington-Hoe et al., 2004). Since we did not have a control group in this pilot study, we cannot confirm the changes in HRV and respiratory measures seen here are completely due to KC participation, or if another variable, like change in infant position, affected the physiologic responses. In light of this and previous reports investigating physiologic responses of infants in KC, more research exploring these acute responses in the same infants over multiple KMC and KFC sessions should be conducted.

4.2 | Wearable sensors

The World Health Organization recommends that KC be utilized as continuously as possible during the neonatal period, starting in the NICU and continuing at home after discharge (Organization, 2015). Currently, methods to track KC utilization are limited and typically rely on notation by the clinical team, which is often incomplete. This study utilized a wireless wearable technology to ascertain the infant's position during KC and non-KC periods. As seen in Figure 4a,b, such technology has the potential to clearly distinguish between periods in the crib and periods in KC. One previous study has used similar technology capable of tracking position and temperature during KC, which they deemed to be feasible (Rao et al., 2018). The technology used in the present study has more sophisticated capabilities such as collecting real-time vital sign data. By themselves, wireless vital monitors are a revolutionary idea in the NICU. Incorporating an accelerometer, with the ability to monitor infant position can only expand the devices' capabilities. This pilot study completed the initial step of testing the ability to distinguish infant position. Further validation of these devices will require the conjunction of accelerometer analysis and vital sign data gathered from infants performing KC and compare that to data collected from infants being held while clothed in the vertical orientation, to monitor the differences. If confirmed, such research could assist in the implementation of more sophisticated wireless vital sign monitors in the NICU that can track time spent in KC, monitor acute physiologic responses in infants during KC, and empower future research designed to assess the impact of KC on both short and long-term outcomes.

The potential of these wearable devices is profound. As a preliminary step, validation of the accelerometer capabilities to use this technology at its full potential in the NICU, and even once families are discharged home. Specifically, accelerometer data coupled with device communication could recognize parent–infant proximity providing insight into new areas such as how long each parent interacts with their infant, when, where and how parents are holding their infants, specifically in KC, and even parents' vital sign reactions to these encounters. Continual development of these wearable devices to allow infants and parents to wear similar monitors simultaneously can provide valuable, quantitative, information previously unattainable. In regard to transitioning to home from the NICU, a known stressor for parents, wearable devices such as these may further encourage KC at home and may additionally serve as a method for monitoring parental stress at a physiologic level.

4.3 | Psychosocial measures

One aim of this pilot study was to obtain data on the ability to assess parental relationships, parent–infant bonding, and mothers' and fathers' self-efficacy in their parental role. Administering multiple questionnaires across several timepoints, combined with our small sample size, proved difficult in acquiring substantial power to evaluate mothers' and fathers' psychosocial responses to KC, although we did have an overall 88% response rate. The highest response rate came with the questionnaires administered at study consent, which were handed to the parents in person, and retrieved before they completed their KC session. The response rates at the three other time points were similar (90%, 80%, and 88%, respectively) were similar. The day before discharge questionnaire was typically completed while still in the NICU, using REDCap. The other time points were completed from home, also using REDCap. The REDCap questionnaires were initiated with an automated email from the REDCap system reminding parents that a questionnaire was due. The similar response rates between those conducted in the NICU and those completed from home is interesting. The first weeks parents are at home with their infant can be very stressful and busy. Nonetheless, mothers and fathers are willing to complete these various questionnaires during that time, from home, which indicates the potential for more comprehensive and longitudinal analysis of psychosocial measures in this population using these methods. In comparing mothers and fathers' response rates, there was a trend toward improved participation in fathers that should be explored in future research. This could be caused by many factors, but in order to accurately analyze and observe potential similarities and differences in the parental psychosocial response to KC, fathers need to be more consistently included, and encouraged to participate, in the research conducted surrounding KC and fathers experience in the NICU and beyond.

Previous research has suggested that fathers may experience different feelings of bonding and confidence in parenting compared to mothers after the birth of their child, but throughout the NICU stay the psychosocial differences between mothers and fathers begin to fade (Blomqvist & Nyqvist, 2011; Chen et al., 2017). At birth, fathers may feel more disconnected from the NICU environment, and less bonded to their new child than mothers (Noergaard et al., 2018). Incorporating skin-to-skin time with fathers as early as possible has the potential to facilitate a positive bonding experience, which can extend beyond the father–infant relationship into the familial unit (Chen et al., 2017). It remains unknown whether the Initial psychosocial differences between mothers and fathers that grow more similar throughout the NICU stay is the natural progression fathers experience, or due to performing more skin-to-skin contact with their infant and pilot data collected here demonstrates the potential of future work to evaluate the basis of these differences.

4.4 | Saliva collection

Previous literature has detailed the valuable information measuring preterm infants, and NICU parents, salivary cortisol can provide, specifically, how interventions such as KC can result in lower infant salivary cortisol levels, whereas procedures such as a heel stick or eye exam produced and increase in infant salivary cortisol levels (Morelius et al., 2015, 2016). Furthermore, salivary cortisol levels have shown to be a noninvasive way to monitor preterm infant stress levels during the very vulnerable time they are in the NICU, and monitoring parent salivary cortisol, and oxytocin, can give insight to the progression of parent–infant bonding (Pena-Bautista et al., 2019; Vittner et al., 2018). In light of this, collecting premature infant saliva for analysis while they are in the NICU is often difficult (Morelius et al., 2016), and including the collection of saliva from the mother as well as the father has been studied relatively infrequently. Without such clear-cut guidance, we trialed a standard of care suction method before settling on the swab collection method which proved to be more successful. For the suction method, a six or eight french Argyle Single Suction Catheter (Medtronic, Minneapolis Minnesota, United States) and suction pressure at 60 mmHg or below was used. One study team member placed the catheter in the infant's mouth or cheek for up to 5 min, or as long as was tolerated. The catheter would initially be placed in one cheek (generally the side the infant was lying on) then moved to on top of and then below the tongue, before moving to the other cheek. The catheter was then removed, saliva was allowed to pool again, and the cycle was repeated. This was continued until time was up, the infant did not tolerate it, or enough saliva was assumed to be collected. Next, the catheter was cut into several pieces to fit in a collection tube and centrifuged for 15 min to remove the saliva. The pieces of the suction catheter were removed from the collection tube, which was centrifuged again for an additional ten minutes. Due to the difficulty of saliva transfer from the suction catheter to the collection tube, the SalivaBio swab (Salimetrics) method was developed and has been a better method in practice with larger infant saliva volumes obtained. Once analyzed, our rate of 100% participation for saliva collection from the infants, mothers, and fathers will allow for a quantitative measure of infant and parent stress response throughout a KC session, and, in conjunction with the psychosocial responses from the parent questionnaires, a more wholistic view of parent–infant, specifically father–infant, bonding while in the NICU and at home can be observed.

4.5 | Limitations

Our results must be interpreted in the context of several identified limitations. First, the sample size of our KC cohort was small and would benefit from expansion to a larger and more culturally diverse cohort along with testing over a wider range of gestational ages. Furthermore, this pilot study was limited to heterosexual parental dyads. Though we expect our findings to extend to all parents, regardless of family structure or parental gender, additional research is necessary to evaluate and encourage the implementation of KC in all familial units. Next, time constraints provided a limitation in that the pre-KC period, where HRV data were analyzed, incorporated co-occurrence of feeding and diaper changes. While our study followed the methodology of previous papers examining the effects of KC on HRV, it is possible that such activities had an impact on the HRV measures collected here.

4.6 | Future directions

KC is an important modality in the NICU that supports the premature infant's development and formation of the parent–infant bond. While the short and long-term benefits are clear, KC remains under-utilized in the NICU(Campbell-Yeo et al., 2015; Pallas-Alonso et al., 2012) and this is especially true of KFC, where limited data supporting positive benefits exists (Campbell-Yeo et al., 2015; Pallas-Alonso et al., 2012). Our findings support KFC as a NICU intervention that can benefit infants and incorporate fathers into the early care of their child with no reported detriment. Our study is one of very few to investigate KMC and KFC in a comparative way, incorporating the analysis of physiologic responses seen in infants during and after KC. We demonstrated that infant responses were similar in both KFC and KMC, including clear HRV responses to KC and a potential reduction in the amount of time infants spend in PB. Furthermore, mothers and fathers are supportive of diverse types of data collection including physiologic, biologic, and psychological measures across the NICU and home time periods. The next steps include the extension of these results to additional families to establish objective data that will further support the widespread implementation of KFC programs.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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