Inpatient Skin-to-skin Care Predicts 12-Month Neurodevelopmental Outcomes in Very Preterm Infants

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Objective To examine the relationship between inpatient skin-to-skin care rates and neurodevelopmental scores measured at 12 months in very preterm (VPT) infants.

Study design From a retrospective review of medical records of 181 VPT infants (<32 weeks gestational age [GA] at birth), we derived skin-to-skin care rate, ie, total minutes of skin-to-skin care each infant received over the number of days of hospital stay. We used scores on the Capute Scales from routine follow-up assessments at 12 months to measure neurodevelopmental outcomes.

Results Families averaged approximately 17 minutes/day of skin-to-skin care (2 days/week, 70 minutes/session), although there was substantial variability. Variation in skin-to-skin rate was positively associated with outcomes at 12 months corrected age ($r = 0.25$, $P < .001$). Skin-to-skin rate significantly predicted 6.2% unique variance in 12-month neurodevelopmental outcomes, after adjusting for GA, socioeconomic status (SES), health acuity, and visitation frequency. A 20-minute increase in skin-to-skin care per day was associated with a 10-point increase (0.67 SDs) in neurodevelopmental outcomes at 12 months. GA and infant health acuity did not moderate these relations.

Conclusion VPT infants who experienced more skin-to-skin care during hospitalization demonstrated higher scores on 12-month neurodevelopmental assessments. Results provide evidence that skin-to-skin care confers extended benefits to VPT infants through the first year of life. Skin-to-skin care offers promise as a family-centered intervention designed to promote positive developmental outcomes in at-risk infants. *(J Pediatr 2024;274:114190)*.

Caregiver-infant skin-to-skin care is a developmental care practice associated with numerous benefits to short-term health outcomes for infants born preterm.[1-4] Skin-to-skin care has been shown to positively impact infant health outcomes (eg, cardiorespiratory stability, growth, infection rates) and parenting practices (eg, attachment, breastfeeding). These positive experiences are, in turn, important predictors of neurodevelopment.[4-9] Skin-to-skin care has also been theorized to shape longer-term developmental trajectories because it may reduce stress, provide important nonnoxious sensorimotor input to the developing nervous system, and thereby promote healthy brain development.[10-14] However, direct evidence linking hospital-based experiences of skin-to-skin care to longer-term neurodevelopmental outcomes in children born preterm is currently lacking.[15] Moreover, it is unknown whether skin-to-skin care uniquely predicts outcomes over and above other clinical and socio-demographic factors, and notably, frequency of family visitation. Such data are needed to understand the specificity of the effects of skin-to-skin care on child development and the utility of skin-to-skin care for mitigating adverse neurodevelopmental sequele associated with preterm birth.

We investigated the relationship between the amount of family-administered skin-to-skin care that infants experienced in the Neonatal Intensive Care Unit (NICU) and neurodevelopmental outcomes at 12-months of age (adjusted for degree of prematurity) in infants born very preterm (VPT). We hypothesized that amounts of skin-to-skin care would significantly predict scores on a measure of child neurodevelopment. We further explored this relationship after accounting for other predictors of neurodevelopmental outcomes, such as gestational age (GA) at birth, socioeconomic status (SES) of the family, and the infant's medical risk for adverse outcomes. We adjusted for family visitation to assess the degree to which effects were specific to skin-to-skin care rather than reflective of general features of family involvement.[16] We additionally adjusted for prior neurodevelopmental scores at 6-months to assess the persistence of effects over time and to adjust for stable attributes of the child and family. Results shed light on the degree to which

VPT	Very preterm
EMR	Electronic medical record
SES	Socioeconomic status
GA	Gestational age
NICU	Neonatal Intensive Care Unit
CAT	Cognitive Adaptive Test
CLAMS	Clinical Linguistic and Auditory Milestone Scale
DQ	Developmental Quotient

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https://doi.org/10.1016/j.jpeds.2024.114190

skin-to-skin care may be neuroprotective and provide needed empirical justification for promoting institutional and social supports for skin-to-skin care for infants born VPT.

Methods

Study Design

All data were collected during routine clinical care and retrospectively derived from the Electronic Medical Record (EMR). All infants were cared for at a 72-bed level IV NICU with a predominately open bay design. Participants were not required to give consent because this study was considered a minimal-risk retrospective chart review. Stanford University Institutional Review Board approved the experimental protocol (IRB-44480).

Sample

Participants were infants born VPT (<32 weeks GA) who were cared for at a single site, Lucile Packard Children's Hosptial. Infants were included in the initial sample if they were born between 5/1/2018 and 6/15/2022, received the majority of their neonatal inpatient care in our center (inborn or transferred into our NICU before 7 days of life), discharged to home from our center (not transferred or deceased before discharge), and had no diagnosis of a genetic or congenital anomaly known to affect neurodevelopment. The initial sample thus reflected all VPT infants who had complete skin-to-skin care data observed throughout their NICU stay, were eligible for follow-up testing, and did not have known genetic factors associated with neurodevelopmental impairments. The start date for inclusion was chosen because a protocol standardizing the execution and charting of developmental care, including skin-to-skin care, was fully operational by 5/1/2018. Only infants born after this date were included to ensure reliable and standardized tracking for the duration of hospitalization. The end date for inclusion allowed sufficient time for the child to receive developmental testing at follow-up. From this initial sample, we derived our final sample (n = 181; 47% female), which included all infants who had follow-up data with our outcome of interest at 12 months of age. **Supplemental Figure 1**, online; available at www.jpeds.com provides a flow chart indicating how this final sample was derived from the initial sample and describes supplemental analyses used to confirm that the final sample was representative of VPT infants who met initial eligibility criteria.

Measures

Clinical and Demographic Measures. Demographic and clinical characteristics of infants were extracted from the EMR, including sex assigned at birth (male = 0, female = 1), GA (weeks), age at hospital admission (days), weight at birth (g), and length of hospital stay (days). We used insurance status (private = 0, public = 1) to index family SES. In California, qualification for public insurance is calculated based on a family's income-to-needs ratio and thus reflects family economic resources. Information regarding 4 major comorbidities of prematurity was also extracted. Bronchopulmonary dysplasia was defined as treatment with supplemental oxygen at 36 weeks postmenstrual age. Intraventricular Hemorrhage (IVH) was defined as the presence of a grade I or higher using the Papile classification system.[17] Sepsis was defined as a positive blood culture or >7 days of antibiotics. Necrotizing enterocolitis was defined as a diagnosis of medical or surgical necrotizing enterocolitis. A binary health acuity score was calculated to categorize infants into those with none (health acuity = 0) vs one or more of these conditions (health acuity = 1).

In-Hospital Skin-To-Skin Care and Family Visitation. As part of routine daily charting at our hospital, all bedside nurses document in the EMR instances of family engagement in developmental care activities as they occur. Charting of developmental care activities notes the type (Skin-to-skin Care, Swaddled Holding, Touch, Massage, Music, Talking, and Singing), the approximate duration in minutes, and who is involved (mother, father, other family member, nurse, other staff member, or any combination of these). Starting May 2018, a developmental care protocol, the iRainbow,[18] was implemented and created standardized clinical criteria for skin-to-skin care delivery from staff and family members. Major contraindications to skin-to-skin care per protocol in our unit included status on a high-frequency ventilator, poorly controlled hypotension, vecuronium infusion or diagnosis of a critical airway as per a consulting otolaryngologist. We specifically extracted all skin-to-skin care instances involving a family member. We computed skin-to-skin care rate as the number of minutes of skin-to-skin care that each infant received divided by the number of days of hospital stay (to account for individual variation in length of hospital stay). We computed 2 additional metrics to further understand the patterns of skin-to-skin care occurring in our unit. Skin-to-skin care frequency captured how often families engaged in skin-to-skin sessions, defined as the number of instances of skin-to-skin care divided by the number of days of hospital stay. Skin-to-skin duration captured the average length of skin-to-skin care sessions as the number of minutes of each skin-to-skin session divided by the number of instances of skin-to-skin care across hospital stay.

Bedside nurses also document any time there is a person at the bedside who is not clinical staff and note who is visiting (mother, father, other family member, or any combination of these). We defined family visitation as the total number of visitation instances by any family member divided by the number of days of hospital stay (to account for individual variation in length of hospital stay).

Neurodevelopmental Outcomes. Infants born <32 weeks GA are eligible for developmental follow-up assessments as a part of California's High-Risk Infant Follow-Up program. Our metric of neurodevelopment was The Capute Scales Composite score[19] assessed at 6 and 12 months of age

(adjusted for prematurity) and recorded in the EMR. The Capute Scales is a 100-item measure consisting of cognitive and language subscales: (1) the Cognitive Adaptive Test (CAT) uses clinician observation and parental report to assess visual-motor problem-solving ability in standardized tasks (eg, "pulls down a ring," "releases one cube in a cup") and (2) the Clinical Linguistic and Auditory Milestone Scale (CLAMS) uses parent report and, when possible, clinician observation to assess expressive and receptive language skills (eg, "makes razzing sounds," "orients to bell laterally"). Quantitative developmental quotients (DQ = developmental age/adjusted age × 100) are derived separately for the CAT and the CLAMS and DQs are averaged to derive the composite score.[20] Age, adjusted for the number of weeks preterm at birth, was used to calculate developmental quotient scores. Given previous reports of high interclass correlations across the 2 subscales, a single score was used if infants were missing scores on either test.[21] A DQ ≤ 70 suggests delays.[19] Prior work has demonstrated the Capute Scales have strong concurrent and predictive validity in relation to other standardized assessments, such as the Bayley Scales of Infant Development.[22]

Statistical Analysis

All analyses were conducted in R version 4.3.1. We examined descriptive statistics for visitation frequency, each metric of skin-to-skin care, and neurodevelopmental scores. All variables were inspected for outliers and tested for normality. Any variable with a value above or below 3 standard deviations (SDs) from the mean was winsorized. Shapiro-Wilk tests identified skin-to-skin care rate and frequency as nonnormal, so they were transformed using a base 10 log. Zero-order correlations inspected relations between predictors and 12-month neurodevelopmental scores. A hierarchical linear regression examined the relation between skin-to-skin care rate and 12-month neurodevelopmental scores when adjusting for covariates. We chose GA, SES, and health acuity as covariates because we expected *a priori* that these factors would be associated with outcomes. We included visitation frequency as a covariate to distinguish the effects of skin-to-skin care from a general proxy of family presence or involvement. Additional analysis included 6-month scores as a covariate because earlier scores are likely to be related to later scores due to continuity across development and stable features of the child/family. Thus, adjusting for 6-month scores allowed us to determine if benefits of skin-to-skin care extended to child neurodevelopmental outcomes at 12 months. Follow-up analyses also examined skin-to-skin care frequency and duration as predictors of neurodevelopmental scores.

We performed several additional regressions to test the robustness of these findings and to account for potential confounders. Given missing data in 1 subscale of our outcome measure, we reran all analyses only including infants who had both subscales (n = 148). Given that rates of all types of developmental care, including skin-to-skin care, are known to have been impacted by the COVID pandemic[23] and the possibility that COVID also impacted follow-up assessments, we re-ran regression analyses including a factor capturing dates of hospitalization and follow-up assessments as a covariate. Infants were grouped according to whether their entire hospital stay and follow-up testing occurred prior to 3/8/2020 (n = 89; 44%), whether their hospital stay occurred prior to 3/8/2020 but follow-up testing occurred on or after 3/8/2020 (n = 9; 4%), or whether any portion of their hospital stay and all follow-up testing occurred on or after 3/8/2020 (n = 106; 52%). Finally, to account for the possibility that younger or sicker babies at higher risk factors for adverse neurodevelopmental outcomes or may have had had more contraindications to receiving skin-to-skin care, we tested GA and health acuity as moderators of the relations between skin-to-skin care rate and 12-month outcomes. Moderation analysis was performed using the PROCESS macro in R.[24] All significance levels were set at $P < .05$.

Results

Table I summarizes the clinical and demographic characteristics of the sample. The sample included an equal number of females as males; approximately half of the sample had public (rather than private) insurance. All children were born preterm with a mean GA of approximately 28 weeks and a mean birth weight of approximately 1116 g. The mean length of hospital stay was about 2.6 months. About half the infants in the sample presented with one or more of the four health conditions.

Table I also reports visitation frequency and skin-to-skin care rates. A visitation frequency of 1.0 would indicate that visitation occurred daily. Here, families visited almost every day, on average, though some families visited more than

Table I. Descriptive statistics of the sample (n = 181)

Variable	M (SD) or n (%)	Min	Max
Female	85 (46.96)	-	-
SES (public insurance)*	83 (45.86)	-	-
Gestational age (weeks)	28.26 (2.53)	22.10	31.80
Weight at birth (g)	1116.67 (389.70)	410.00	2059.90
Length of stay (days)	79.65 (43.88)	23.30	240.21
Health acuity†	90 (49.72)	-	-
BPD	49 (27.07)	-	-
IVH	47 (25.97)	-	-
NEC	35 (19.33)	-	-
Sepsis	19 (10.50)	-	-
Visitation frequency‡	0.99 (.45)	0.06	2.54
Skin-to-skin care rate§	17.65 (16.62)	0.00	83.38
Six-month score¶	94.68 (14.00)	39.42	135.00
Twelve-month score**	91.64 (14.93)	52.00	136.00

*SES as defined by the percentage of families with public (1) vs private (0) health insurance.
†Health acuity score reflecting diagnoses of one or more of the following conditions: bronchopulmonary dysplasia (BPD), intraventricular hemorrhage (IVH), necrotizing enterocolitis (NEC), sepsis.
‡Number of instances of family visitation/number of days of inpatient hospital stay.
§Number of minutes of skin-to-skin care/number of days of inpatient hospital stay.
¶Six-month developmental quotient scores on the Capute Scales (calculated using adjusted age) (n = 166).
**Twelve-month developmental quotient scores on the Capute Scales (calculated using adjusted age).

twice a day. Over their entire stay, on average, infants received 18 minutes/day of skin-to-skin care. A total of 14 infants (8%) received more than 50 minutes/day; 13 families (7%) did not engage in any skin-to-skin care. Families engaged in skin-to-skin care less than 2 instances/week (M = 0.25, SD = 0.23) on average. Instances of skin-to-skin care lasted a mean of 70 minutes (SD = 15.78), with a range of 30 to 123 minutes/session. Infants from higher SES families experienced more minutes of skin-to-skin care per day (M = 23.18, SD = 17.57), compared with those from low SES families (M = 11.12, SD = 12.71) (t = 5.34 P < .001). Visitation frequency was positively associated with skin-to-skin care rate (r = 0.35, P < .001); families who visited more frequently tended to perform skin-to-skin care for more minutes/day.

A total of 92% (n = 166) of our final sample had available 6-month Capute scores and were thus included in analysis adjusting for 6-month outcomes. There were no significant clinical or demographic differences between the infants who had both 6 and 12-month scores (n = 166) and those who did not have Capute scores at 6 months (n = 15). No infants had missing scores on the CLAMS at 6 or 12 months. A total of 18% (n = 33) of infants were missing CAT scores at 12 months and 12% (n = 20) were missing CAT scores at 6 months. Infants who had missing scores on the CAT were not demographically or clinically different than those with complete scores at either time point, although they were more likely to have undergone assessment in the acute phase of the COVID pandemic (χ^2 = 20.627, P < .001). Critically, CAT and CLAMS scores were significantly correlated (r = 0.50, P < .001), and there were also no statistical differences in Capute scores between those whose scores were calculated using both CAT and CLAMs compared with those using only CLAMS scores.

The average adjusted age at the initial follow-up visit was 5.50 months (SD = 0.82) and 13.32 months (SD = 1.46) at the second visit. As shown in Table I, developmental quotients varied substantially across infants. At 6 months, 4 (3%) infants had scores suggesting developmental delay (<70); at 12 months, 10 (6%) infants fell into this range. Skin-to-skin care rate was associated with 6-month scores, such that infants who experienced more minutes of skin-to-skin care during their hospital stay tended to have higher scores at 6 months of age (r = 0.19, P = .02). Skin-to-skin care was related to 12-month scores, such that infants who experienced more minutes of skin-to-skin care during their NICU stay had higher neurodevelopmental scores (r = 0.25, P < .001).

Table II documents the unique contribution of skin-to-skin care rate to neurodevelopmental outcomes. Model 1 shows that the covariates accounted for approximately 7% of the variance in child outcomes. Model 2 demonstrates that skin-to-skin rate uniquely predicted 12-month neurodevelopmental scores after GA, SES, health acuity, and family visitation, with skin-to-skin rate accounting for approximately 6% unique variance. A 1% increase in skin-to-skin care was associated with 0.09-point increase in 12-month scores. Thus, on average, a 20-minute increase in the amount of average daily skin-to-skin care was associated with a 10.09-point increase in scores on 12-month neurodevelopmental assessments, more than two-thirds of an SD increase. Model 4 demonstrates that skin-to-skin care rate was also uniquely predictive of 12-month scores even when including 6-month scores as a covariate. Figure illustrates the association of skin-to-skin care rate with neurodevelopmental scores, after adjusting for covariates.

We ran sensitivity analyses to test the robustness of the observed association between skin-to-skin care rate and 12-month outcomes, accounting for potential confounders. To account for missing data on the cognitive adaptive subscale of the Capute, we reran Model 2 including only infants (n = 148) who had complete data on both the CAT and the CLAMs assessments. Results were stronger than those in the original model, with skin-to-skin care rate accounting

Table II. Multiple regression models (unstandardized coefficients) predicting 12-month neurodevelopmental scores (n = 181)

	Model 1	Model 2	Model 3	Model 4
Predictor	**B (95% CI)**	**B (95% CI)**	**B (95% CI)**	**B (95% CI)**
Gestational age	0.55 (−0.47 to 1.57)	0.57 (−0.43 to 1.56)	0.37 (−0.66 to 1.40)	0.39 (−0.62 to 1.40)
SES*	−2.01 (−6.30 to 2.27)	1.23 (−3.30 to 5.76)	−2.47 (−6.70 to 1.77)	0.15 (−4.41 to 4.70)
Health acuity†	−5.72* (−10.95 to −0.49)	−4.63 (−9.74 to 0.48)	−6.28* (−11.45 to −1.11)	−5.65* (−10.74 to −0.56)
Visitation‡	−0.24 (−5.09 to 4.60)	−3.45 (−8.47 to 1.57)	1.31 (−3.51 to 6.12)	−1.16 (−6.19 to 3.88)
Six-month score§	-	-	0.33*** (0.18–0.49)	0.29*** (0.14–0.45)
Skin-to-skin Care Rate¶	-	8.90*** (3.94–13.87)	-	7.03** (1.99–12.07)
Observations (n)	181	181	166	166
R^2	0.07*	0.13***	0.19***	0.23***
r^2 Δ**	-	0.06***	-	.04**

*P < .05; **P < .01; ***P < .001.
*Public (1) vs private (0) health insurance.
†Diagnosis of 1 or more of the following conditions: bronchopulmonary dysplasia (BPD), intraventricular hemorrhage (IVH), necrotizing enterocolitis (NEC), sepsis.
‡Number of instances of visitation/number of days of inpatient hospital stay.
§Developmental quotient scores on the Capute Scales, adjusted for prematurity.
¶Number of minutes of Skin-to-skin care/number of days of inpatient hospital stay.
**r^2 Δ for Model 2 is in reference to Model 1; r^2 Δ for Model 4 is in reference to Model 3.

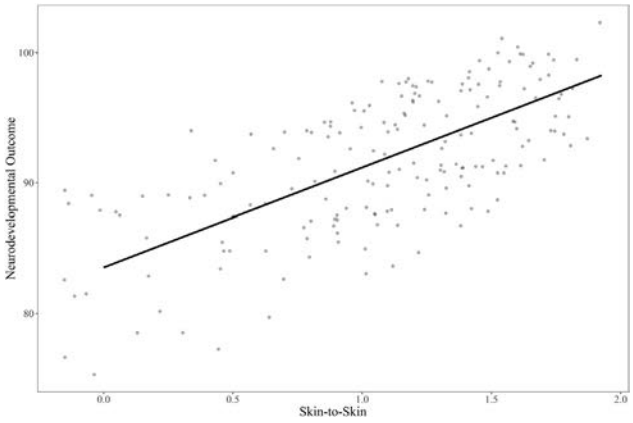

Figure. Scatterplot of the association between skin-to-skin care rate and 12-month neurodevelopmental scores, after adjusting for covariates (Model 2).

for 9.3 percent unique variance in developmental scores (B = 9.71, 95% CI 4.90-14.54, r^2 Δ = 0.09). Rerunning Model 2 including birth during COVID as a covariate did not alter the amount of variance in neurodevelopmental scores predicted by skin-to-skin care rate (B = 9.20, 95% CI 4.23-14.18, r^2 Δ = 0.06). Finally, adding GA and health acuity as interaction terms to Model 2 demonstrated that infant health and developmental age did not significantly moderate or change the relations between skin-to-skin care rate and neurodevelopmental outcomes (all interaction terms $P > .1$). Simple slopes describing the relationship between skin-to-skin care rate and outcomes were positive and significant ($P < .05$) at all levels of infant health acuity and gestational age, suggesting that relations between skin-to-skin care rates and 12-month neurodevelopmental outcomes were similar for all infants regardless of GA or health acuity.

Additional analyses demonstrated that skin-to-skin care frequency and duration similarly predicted 12-month outcomes, adjusting for GA, SES, health acuity, and family visitation. Skin-to-skin care frequency accounted for 4% unique variance. A 20-percent increase in the frequency with which families engaged in skin-to-skin care corresponded to a mean 9.6-point increase in neurodevelopmental scores at 12 months (B = 48.43, 95% CI 13.87-82.99). Skin-to-skin duration accounted for 3% unique variance. An increase in the duration of skin-to-skin care instances by 20 minutes/session was associated with a 3.74-point increase in neurodevelopmental scores (B = 0.19, 95% CI 0.03-0.34), more than a quarter of a SD increase.

Discussion

This study contributes to a growing body of evidence that skin-to-skin care may serve as a neuroprotective strategy for preterm infants at risk of developmental delay. Consistent with our hypotheses, infants who experienced more skin-to-skin care over their hospital stay had higher scores on a standardized measure of neurodevelopmental abilities at 12 months. The magnitude of our observed effect size (two-thirds of an SD in neurodevelopmental scores) is noteworthy given that meta-analyses of other interventions specifically targeted at cognition have shown an average of 0.42 SDs in score improvement.[25] These relations remained when adjusting for clinical, demographic, and developmental predictors that may influence neurodevelopmental abilities. Additionally, relations between skin-to-skin care and neurodevelopmental scores did not differ based on infants' GA at birth, or health status, suggesting that skin-to-skin care may be beneficial for children from a range of health backgrounds. Skin-to-skin care rate predicted outcomes over and above frequency of family visitation, suggesting that specifically having families actively engage in skin-to-skin activities may contribute to positive neurodevelopmental outcomes to a greater extent than simply encouraging families to visit the hospital without engaging in skin-to-skin care. Finally, we found that skin-to-skin care contributed to child outcomes even after adjusting for prior neurodevelopmental scores, suggesting that the effects of skin-to-skin care during hospitalization are long-lasting and persist at least until 12 months beyond factors that are attributable to stable features of the child and/or family context.

The present findings are generally consistent with previous observational studies showing positive relationships between amounts of parental skin-to-skin care and gross motor development,[16] as well as amounts of parent holding activities and emergent language abilities in preterm infants.[26] Additionally, work from Lester and colleagues[27] demonstrated an association between maternal engagement in the NICU and cognitive scores at 18 months which was driven by skin-to-skin care. The current study adds to this

work by emphasizing the specificity of in-hospital experiences of skin-to-skin care for predicting later neurocognitive outcomes in preterm infants. The design and conception of the present study also closely resembles that of Gonya et al,[28] who reported positive relations between parental skin-to-skin care and cognitive outcomes. However, the associations did not reach statistical significance in their study, possibly because their measure of skin-to-skin care was tracked at the hour level and developmental outcomes were categorized into high/low binary groups. One strength of the current study is the specificity and robustness of our minute-level skin-to-skin metrics and continuous measurement of neurodevelopmental scores, distinctions that give us more power to detect significant associations.

Prior evidence for the long-term protective properties of skin-to-skin care on neurodevelopment comes from randomized controlled trials.[29,30] Such studies addressed the issue of causality and established efficacy of skin-to-skin care as a medical intervention for supporting longer-term outcomes. However, such studies do not necessarily reflect the real-life variation of skin-to-skin care that exists outside of stringent experimental settings. Using a retrospective cohort design, we were able to examine variations in patterns of family skin-to-skin care that occurred naturally during hospitalization, independent of any explicit study involvement. Therefore, our results complement these earlier efficacy studies by documenting the effectiveness of skin-to-skin care as a potential clinical intervention for supporting neurocognitive development. Our findings add to a growing body of literature documenting the neuroprotective benefits of family-centered care practices for supporting health outcomes of preterm infants.[31,32]

The level of explanatory power captured in our study is particularly noteworthy, given the relatively small amounts of skin-to-skin care that families provided. On average, infants experienced skin-to-skin care for less than 20 minutes/day, 2 days/week, and for sessions that lasted about 1 hour. Given that transitioning babies from their cribs may be potentially stressful and disruptive, and considering infant's natural sleep cycles, our current hospital protocols recommend the skin-to-skin sessions should last at least 60 minutes. Many sessions failed to reach this 1-hour benchmark. It is impressive that variation in levels of skin-to-skin activity even in these low ranges can nevertheless contribute predictive utility to neurodevelopmental outcomes at 12 months of age. Future research should explore the possibilities of a threshold-dose effect or if amounts of skin-to-skin care at higher baseline levels would show similar or possibly even greater effects.

Several mechanisms may be at play to explain the observed relations between skin-to-skin care and better neurodevelopmental scores. First, skin-to-skin care has been related to stress reduction and autonomic regulation[10,11] both of which affect neurodevelopment.[12,13] Additionally, skin-to-skin care may provide a formative bonding experience for infants and their caregivers,[6] which in turn, may facilitate dyads' capacities for exploration, teaching, and shared attention later in infancy.[33] Skin-to-skin care may also directly contribute to brain maturation and emergent neurocognitive abilities by providing nonnoxious sensorimotor neural stimulation.[14] Future studies should investigate these potential mechanisms more thoroughly.

This study had limitations. First, because it was a retrospective study, we were limited to data collected as part of routine clinical care. We did not have information about other factors that may have contributed to infants' neurodevelopmental outcomes, such as caregiver education level or caregiving activities in the home. We cannot rule out the possibility that caregivers who engaged in more skin-to-skin care may have also engaged in more stimulating activities in the home environment after hospital discharge. However, in this scenario, caregiver involvement in skin-to-skin care may serve as an important early clinical marker for parental engagement that would identify infants or families who may require assistance or interventions to promote neurodevelopment in the home environment. We also did not have information about factors that may have impacted caregiver's opportunity (eg, access to paid family leave, childcare for other children, transportation) to perform skin-to-skin care. More research is needed to understand whether modifying such factors can be beneficial in promoting access to skin-to-skin care. An additional limitation was that our measures of skin-to-skin care relied on clinical charting. However, clinical staff members are specifically trained and have been routinely charting developmental care practices since 2018. Furthermore, we have reason to believe that the charting of skin-to-skin care is particularly reliable because clinical staff need to be involved in transferring babies to their parents and back to the crib/isolette, thereby triggering reminders to chart. Finally, given that skin-to-skin care happens less than once per day it is not a particularly heavy charting burden compared with other aspects of clinical record keeping. We did not rely on parental report as in previous studies,[26,34,35] which can be prone to reporting biases.

The retrospective cohort design conferred a significant strength: generalizability. Because active participation was not required, our sample captured occurrences of skin-to-skin care as implemented *in situ* in the daily lives of all families in the NICU, barring just a few exclusionary cases. Thus, our sample included many individuals who would otherwise go unstudied due to self-selection bias or financial/social circumstances.

Overall, the findings argue in favor of increasing institutional and societal supports to promote opportunities for families to engage more directly and regularly in the care of their preterm infants. Many parents of hospitalized infants feel that their role as a parent is diminished because they lack the agency and expertise to care for their child.[36] Increased institutional support and education about the benefits of family-administered skin-to-skin care may help families in the NICU feel more empowered in their unique ability to support their baby's health both in the

short and long term. Clinical staff may be reluctant to support family engagement in skin-to-skin care because of the misconception that any potential benefits have not been based on scientific evidence.[37] The present study may help to dispel this notion if results are discussed in evidence-based training on the benefits of skin-to-skin care. Increased societal support, such as expanded paid parental leave policies, would also be an important component of providing families with more equitable opportunities to provide skin-to-skin care to their hospitalized infants. Such supports are likely to be important factors in mitigating the negative long-term consequences of preterm birth on neurodevelopment that disproportionately affect lower-income and non-White families.[38,39] The results of this study contribute to growing evidence for the broad implementation of in-hospital skin-to-skin care as a low-cost, family-centered intervention to promote short- and long-term benefits in VPT infants. ■

CRediT authorship contribution statement

Molly F. Lazarus: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Virginia A. Marchman:** Writing – review & editing, Validation, Supervision, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Edith Brignoni-Pérez:** Validation, Methodology, Data curation, Conceptualization. **Sarah Dubner:** Supervision, Methodology, Investigation, Data curation, Conceptualization. **Heidi M. Feldman:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Melissa Scala:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Katherine E. Travis:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of Competing Interest

This research work was supported by grants from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (K.E. Travis, PI: 5R00-HD84749; H.M. Feldman, PI: 2R01-HD069150) and the National Institute of Mental Health Postdoctoral Research Training in Child Psychiatry and Neurodevelopment (A. Reiss, PI: T32-MH019908).

Submitted for publication Apr 10, 2024; last revision received Jun 24, 2024; accepted Jul 8, 2024.

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Data Statement

Data sharing statement available at www.jpeds.com.

References

1. Boundy EO, Dastjerdi R, Spiegelman D, Fawzi WW, Missmer SA, Lieberman E, et al. Kangaroo mother care and neonatal outcomes: a meta-analysis. Pediatrics 2016;137:e20152238.
2. Campbell-Yeo ML, Disher TC, Benoit BL, Johnston CC. Understanding kangaroo care and its benefits to preterm infants. Pediatr Health Med Ther 2015;6:15-32.
3. Cong X, Cusson RM, Walsh S, Hussain N, Ludington-Hoe SM, Zhang D. Effects of skin-to-skin contact on autonomic pain responses in preterm infants. J Pain 2012;13:636-45.
4. Conde-Agudelo A, Díaz-Rossello JL. Kangaroo mother care to reduce morbidity and mortality in low birthweight infants. Cochrane Database Syst Rev 2016;2016:CD002771.
5. Feldman R, Eidelman AI. Direct and indirect effects of breast milk on the neurobehavioral and cognitive development of premature infants. Dev Psychobiol 2003;43:109-19.
6. Gathwala G, Singh B, Balhara B. KMC facilitates mother baby attachment in low birth weight infants. Indian J Pediatr 2008;75:43-7.
7. Jefferies AL. Kangaroo care for the preterm infant and family. Pediatr Child Health 2012;17:141-6.
8. Klawetter S, Greenfield JC, Speer SR, Brown K, Hwang SS. An integrative review: maternal engagement in the neonatal intensive care unit and health outcomes for U.S.-born preterm infants and their parents. AIMS Public Health 2019;6:160-83.
9. Ohgi S, Fukuda M, Moriuchi H, Kusumoto T, Akiyama T, Nugent JK, et al. Comparison of kangaroo care and standard care: behavioral organization, development, and temperament in healthy, low-birth-weight infants through 1 year. J Perinatol 2002;22:374-9.
10. Pados BF, Hess F. Systematic review of the effects of skin-to-skin care on short-term physiologic stress outcomes in preterm infants in the neonatal intensive care unit. Adv Neonatal Care 2020;20:48-58.
11. Ludington-Hoe S, Anderson GC, Swinth J, Thompson C, Hadeed A. Randomized controlled trial of kangaroo care: cardiorespiratory and thermal effects on healthy preterm infants. Neonatal Netw 2004;23:39-48.
12. Capuana LJ, Dywan J, Tays WJ, Elmers JL, Witherspoon R, Segalowitz SJ. Factors influencing the role of cardiac autonomic regulation in the service of cognitive control. Biol Psychol 2014;102:88-97.
13. McEwen BS, Sapolsky RM. Stress and cognitive function. Curr Opin Neurobiol 1995;5:205-16.
14. Charpak N, Tessier R, Ruiz JG, Uriza F, Hernandez JT, Cortes D, et al. Kangaroo mother care had a protective effect on the volume of brain structures in young adults born preterm. Acta Paediatr 2022;111:1004-14.
15. Head LM. The effect of kangaroo care on neurodevelopmental outcomes in preterm infants. J Perinat Neonatal Nurs 2014;28:290-9.
16. Pineda R, Bender J, Hall B, Shabosky L, Annecca A, Smith J. Parent participation in the neonatal intensive care unit: predictors and relationships to neurobehavior and developmental outcomes. Early Hum Dev 2018;117:32-8.
17. Papile LA, Burstein J, Burstein R, Koffler H. Incidence and evolution of subependymal and intraventricular hemorrhage: a study of infants with birth weights less than 1,500 gm. J Pediatr 1978;92:529-34.
18. Byrne E, Hunt K, Frecerro A, Scala M. Introducing the i-rainbow©- an evidence-based, parent-friendly care pathway designed for even the most critically ill infant in the neonatal intensive care setting. Pediatr Phys Ther 2024;36:266-73.
19. Accardo PJ, Capute AJ. The capute scales: Cognitive adaptive test/clinical linguistic & auditory milestone scale (CAT/CLAMS). Baltimore: Paul H. Brookes Pub. Co; 2005. p. 115.
20. O'Connor Leppert ML, Shank TP, Shapiro BK, Capute AJ. The capute scales: CAT/CLAMS—a pediatric assessment tool for the early detection

of mental retardation and communicative disorders. Ment Retard Dev Disabil Res Rev 1998;4:14-9.
21. Visintainer PF, Leppert M, Bennett A, Accardo PJ. Standardization of the capute scales: methods and results. J Child Neurol 2004;19:967-72.
22. Voigt RG, Brown FR, Fraley JK, Liorente AM, Rozelle J, Turcich M, et al. Concurrent and predictive validity of the Cognitive Adaptive Test/Clinical Linguistic and Auditory Milestone Scale (CAT/CLAMS) and the mental developmental index of the bayley scales of infant development. Clin Pediatr (Phila) 2003;42:427-32.
23. Scala M, Marchman VA, Brignoni-Pérez E, Morales MC, Dubner SE, Travis KE. Impact of the COVID-19 pandemic on developmental care practices for infants born preterm. Early Hum Dev 2021;163:105483.
24. Hayes AF. Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York: The Guilford Press; 2013. p. 507 (Methodology in the social sciences).
25. Orton J, Spittle A, Doyle L, Anderson P, Boyd R. Do early intervention programmes improve cognitive and motor outcomes for preterm infants after discharge? A systematic review: early intervention for preterm infants. Dev Med Child Neurol 2009;51:851-9.
26. Ståhlberg-Forsén E, Latva R, Aija A, Lehtonen L, Stolt S. Language environment and parent-infant close contact in neonatal care and emerging lexical abilities of very preterm children–a longitudinal study. Acta Paediatr 2023;112:659-66.
27. Lester BM, Salisbury AL, Hawes K, Dansereau LM, Bigsby R, Laptook A, et al. 18-month follow-up of infants cared for in a single-family room neonatal intensive care unit. J Pediatr 2016;177:84-9.
28. Gonya J, Ray WC, Rumpf RW, Brock G. Investigating skin-to-skin care patterns with extremely preterm infants in the NICU and their effect on early cognitive and communication performance: a retrospective cohort study. BMJ Open 2017;7:e012985.
29. Feldman R, Rosenthal Z, Eidelman AI. Maternal-preterm skin-to-skin contact enhances child physiologic organization and cognitive control across the first 10 years of life. Biol Psychiatry 2014;75:56-64.
30. Tessier R, Cristo MB, Velez S, Giron M, Nadeau L, Figueroa de Calume Z, et al. Kangaroo mother care: a method for protecting high-risk low-birth-weight and premature infants against developmental delay. Infant Behav Dev 2003;26:384-97.
31. O'Brien K, Robson K, Bracht M, Cruz M, Lui K, Alvaro R, et al. Effectiveness of family integrated care in neonatal intensive care units on infant and parent outcomes: a multicentre, multinational, cluster-randomised controlled trial. Lancet Child Adolesc Health 2018;2:245-54.
32. Ortenstrand A, Westrup B, Broström EB, Sarman I, Akerström S, Brune T, et al. The Stockholm Neonatal Family Centered Care Study: effects on length of stay and infant morbidity. Pediatrics 2010;125:e278-85.
33. O'Connor E, McCartney K. Attachment and cognitive skills: an investigation of mediating mechanisms. J Appl Dev Psychol 2007;28:458-76.
34. Bigelow A, Power M, MacLellan-Peters J, Alex M, McDonald C. Effect of mother/infant skin-to-skin contact on postpartum depressive symptoms and maternal physiological stress. J Obstet Gynecol Neonatal Nurs 2012;41:369-82.
35. Hardin JS, Jones NA, Mize KD, Platt M. Parent-training with kangaroo care impacts infant neurophysiological development & mother-infant neuroendocrine activity. Infant Behav Dev 2020;58:101416.
36. Lasiuk GC, Comeau T, Newburn-Cook C. Unexpected: an interpretive description of parental traumas' associated with preterm birth. BMC Pregnancy Childbirth 2013;13(S1):S13.
37. Chan G, Bergelson I, Smith ER, Skotnes T, Wall S. Barriers and enablers of kangaroo mother care implementation from a health systems perspective: a systematic review. Health Policy Plan 2017;32:1466-75.
38. Brooks_Gunn J, Klebanov PK, Duncan GJ. Ethnic differences in children's intelligence test scores: role of economic deprivation, home environment, and maternal characteristics. Child Dev 1996;67:396-408.
39. Manuck TA. Racial and ethnic differences in preterm birth: a complex, multifactorial problem. Semin Perinatol 2017;41:511-8.