Published in final edited form as:

Am J Perinatol. 2019 April ; 36(5): 505–510. doi:10.1055/s-0038-1669946.

Increased Frequency of Skin-to-Skin Contact Is Associated with Enhanced Vagal Tone and Improved Health Outcomes in Preterm Neonates

Megan M. Marvin, MS¹, Fumiyuki C. Gardner, PhD¹, Kristin M. Sarsfield¹, R. Alberto Travaglini, PhD², and Kim K. Doheny, PhD, NNP-BC^{1,2}

¹Division of Neonatal-Perinatal Medicine, Department of Pediatrics, The Pennsylvania State University, College of Medicine, Hershey, Pennsylvania

²Department of Neural and Behavioral Sciences, The Pennsylvania State University, College of Medicine, Hershey, Pennsylvania

Abstract

Objective—An estimation of the individual's ability to cope to environmental adversity, that is, stress resiliency, can be extrapolated by measuring cardiac vagal tone, that is, high-frequency heart rate variability (HF-HRV); indeed, higher HF-HRV is associated with health and developmental advantages for preterm neonates. Previous studies show skin-to-skin contact (SSC) improves stress resiliency; however, linkages between SSC and HF-HRV on outcomes have not been assessed. We aimed to test the hypothesis that increased SSC frequency would enhance HF-HRV, reduce neonatal morbidity, and improve developmental outcomes.

Study Design—Weekly electrocardiograms and clinical data were obtained from 101 preterm neonates. SSC frequency was determined from the electronic medical record.

Results—At postnatal week 1, frequency of SSC and HF-HRV were positively correlated ($p = .02$); further, multiple stepwise regressions showed higher HF-HRV and SSC predicted reduced days on ventilation and oxygen, and shorter hospital stay ($p < 0.001$). Higher HF-HRV predicted lower postmenstrual age (PMA) at discharge ($p < 0.01$).

Conclusion—Higher SSC frequency was associated with increased HF-HRV during the first postnatal week. SSC and HF-HRV uniquely predicted diminished neonatal morbidity throughout

Address for correspondence Kim K. Doheny, PhD, NNP-BC, Clinical Research and the Newborn Biobehavioral Laboratory, Division of Neonatal-Perinatal Medicine, Department of Pediatrics and Neural and Behavioral Sciences, Penn State College of Medicine, P.O. Box 0850, Hershey, PA 17033 (kkh1@psu.edu).

Authors' Contributions

M.M.M. participated in the execution of the study, conducted data analysis, wrote the first draft of the article, and reviewed and revised the article. F.C.G. participated in execution of the study, assisted in data analysis, contributed to the writing of the article, and reviewed and revised the article. K.M.S. participated in the execution of the study, contributed to the writing of the article, and reviewed the article. A.T. made important scientific contributions to protocol development, interpretation of the findings, and reviewing and approving the article. K.K.D. had primary responsibility for scientific oversight and fidelity of the research study protocol development, data analysis, and writing and revising the article. All authors approved the final version of the article prior to submission and agree to be accountable for all aspects of the work.

Conflict of Interest

None.

hospitalization. Additionally, HF-HRV uniquely predicted earlier PMA at discharge. Augmenting SSC early in life enhances stress resiliency and improves health outcomes.

Keywords

HF-HRV; preterm neonates; skin-to-skin contact; stress resiliency

The developmentally taxing environment of the neonatal intensive care unit (NICU) endured by preterm neonates is remarkably different compared with the security and familiarity provided in utero. Medical care provided in the NICU exposes neonates to a myriad of environmental stressors, for example, frequent painful procedures, handling, and bright lights. Protracted and/or repeated stressors are known to negatively impact later neurocognitive and behavioral outcomes, with those neonates born most premature and with highest acuity of illness to be at considerable risk for developmental delays. Stress resiliency represents the individual's ability to sustain positive outcomes through flexible adaptation in spite of environmental adversity. Despite the advantages that stress resiliency affords, there has been limited research investigating the impact of skin-to-skin contact (SSC) on enhancing the stress resiliency of newborns as measured by cardiac vagal tone or high-frequency heart rate variability (HF-HRV). Indeed, enhanced HF-HRV is associated with stress resiliency, prosocial behavior, emotional regulation, improved health, and developmental outcomes.¹

In general, preterm neonates tend to have significantly lower HF-HRV than full-term neonates, placing them at risk for emotional and social regulation issues because of decreased stress resiliency. In theory, SSC should heighten vagal, parasympathetic activity thereby reducing allostatic load and enhancing stress adaptation.² In neonates, SSC has been shown to increase breastfeeding rates, decrease pain response to procedures, reduce harmful bacteria in the oral microbiome, increase oxytocin levels, and lower incidences of hospital readmission.³ SSC has also been shown to strengthen the bond between infant and mother, reduce symptoms of postpartum depression, and increase sensitivity to infant cues. Additionally, SSC has been associated with decreased mortality rates and several improved short- and long-term developmental outcomes through the first decade of life.⁴ The effects of SSC in neonates appear to endure into adolescence, with notable improvements in cerebral motor functioning being observed in a SSC group versus control group. Despite the advantages that SSC is known to provide, SSC has been slow to become standard practice. One study conducted in sleeping, unhandled preterm neonates, reported a positive correlation between SSC and HF-HRV. To our knowledge, however, no studies to date have evaluated the relationship between the frequency of SSC per week and its relationship with vagal, parasympathetic activity as measured by HF-HRV. The aim of the study was to test the hypothesis that increased SSC frequency results in enhanced HF-HRV, reduced neonatal morbidity, and improved developmental outcomes.

Methods

Participants

Research was conducted on 110 preterm infants enrolled from March 2014 to May 2017 within a level IV NICU in south central Pennsylvania. Eligible participants consisted of medically stable preterm neonates ranging from 26 to 34 weeks post-menstrual age (PMA) at birth. Informed consent was obtained from neonates' parents within the first week of life. Exclusion criteria for enrollment included the following conditions: congenital anomalies, grade III+ intraventricular hemorrhage, invasive ventilation through day 5 of life, known active maternal TORCH infections, maternal autoimmune conditions, and prenatal exposure to illicit drugs as these conditions are known to impact autonomic system functioning.

After enrollment, the score for neonatal acute physiology (SNAP) was calculated by trained coders using electronic medical record (EMR) data to classify participants by morbidity/mortality risk. SNAP is determined using 34 physiologic measurements from clinical tests and vital signs obtained in the first 24 hours postbirth. Each SNAP item is scored between 0 and 5 points with the total score representing the severity of illness, and total scores less than 9 suggest low morbidity risk. SNAP has been demonstrated as an independent predictor of morbidity/mortality risk among preterm neonates, and adds prognostic value to other perinatal risk factors.

Study Design

This study was a secondary analysis of a larger prospective study. This larger study's research protocol was approved by the Institutional Review Board affiliated with an academic college of medicine. SSC was a standard of care in the NICU and involved a mother or father holding their unclothed newborn prone and directly against their own bare chest. For each session, nursing staff strongly encouraged parents to maintain SSC for a minimum of 1 hour with focused attention and nurturing toward the neonate. Heart rate variability (HRV) data were collected prospectively using electrocardiogram, R-R wave data from neonates' bedside monitor while the neonate was in a light sleep state. Postprandial HRV data were obtained in two consecutive afternoons between noon and 5 pm for 30 to 40 minutes between days 5 and 8 of life and weekly thereafter until 35 weeks PMA using a portable data acquisition system with BioBench (National Instruments, Austin, TX) software and later analyzed by spectral analysis offline using MindWare HRV version 2.51 (MindWare Technologies, LTD, Gahanna, OH). Neonatal morbidity outcomes (i.e., total days on ventilation, total days on oxygen, and length of hospital stay) and short-term developmental outcomes (i.e., PMA at full oral feedings and PMA at discharge) were recorded from infants' EMR weekly from birth through discharge. SSC information was documented by nursing and inventoried retrospectively by research staff from birth through day 21 of life from infants' EMR.

The frequency range of HRV spectral analysis is dependent on the developmental age of participants. For this study, cardiac vagal tone as measured by HF-HRV was the parameter of interest for analysis. Accordingly, the following frequency range was utilized while analyzing preterm neonates' cardiac vagal tone: high-frequency (HF)/respiratory sinus

arrhythmia band = 0.3 to 1.3 Hz, to correlate with the faster resting breathing rates of 20 to 80 breaths/min in the preterm neonates in our sample population. Using fast Fourier transform, spectral analysis was conducted on a mean of 13 120-second segments of R-R wave data collected from two consecutive afternoons during 30 to 40 minutes HRV measurement sessions. Each segmental analysis was manually screened to be free from movement artifact and ectopic beats. These artifact free segments were averaged to calculate mean HF-HRV.

Statistical Analysis

SPSS version 24 (IBM Corporation, Armonk, NY) was utilized for data entry and analyses. For each variable, descriptive statistics (e.g., mean, standard error, and range) were calculated and outliers and normality were checked before analyses. Correlation coefficients were used to examine the relationships between frequency of SSC and HF-HRV, measures of neonatal morbidity, and short-term developmental outcomes. Significant correlations were further analyzed using stepwise multiple regression models to examine the causal relationships between independent (i.e., SSC, HF-HRV, and SNAP) and outcome variables (i.e., measures of neonatal morbidity and PMA at discharge). Raw HF data were natural log transformed prior to their use in multiple regressions to correct for skewness of the data on tests of normality. All tests were two tailed at a 5% significance level.

Results

The study's sample consisted of 101 neonates between 26 and 34 weeks' PMA who received SSC at least once during their first 3 weeks of life. Nine participants did not receive any SSC during their NICU stay and thus were excluded from analysis as our primary interest was testing the contribution of SSC frequency on outcomes. Characteristics of the full sample ($N = 101$) are that 55 were male and born to mothers with a mean maternal age of 29 years. The mean PMA of neonates was 31 weeks, with a birth weight of 1.6 kg, and a SNAP of 10.8 (►Table 1).

Neonates received SSC for an average of 1 hour per session during their first week of life with SSC frequency ranging from 0 to 23 sessions. The total number of days that SSC was provided during the first week of life ranged from 0 to 8 days (including day of birth).

As demonstrated in ►Table 2, during the first week of life, the frequency of SSC and HF-HRV were directly correlated, $r_s(97) = 0.23$, $p = 0.02$, such that higher frequency of SSC was associated with enhanced HF-HRV. This association was stronger in a subset of neonates with higher acuity of illness (a SNAP of 10 or greater; $n = 55$, SNAP range: 10–25), $r_s(55) = 0.382$, $p = 0.004$, see ►Figs. 1 and 2. In the full sample, frequency of SSC during week 1 was significantly associated with lower neonatal morbidity as measured by total days on ventilation, $r_s(99) = -0.38$, $p < 0.001$, total days on oxygen, $r_s(99) = -0.35$, $p < 0.001$, and length of hospital stay, $r_s(95) = -0.34$, $p = 0.001$. Furthermore, SSC at week 1 was significantly associated with lower PMA at discharge, $r_s(95) = -0.23$, $p = 0.03$. For additional descriptive statistics pertaining to predictor or outcome variables, refer to ►Table 3.

Stepwise regressions were conducted to further evaluate the contributions of frequency of SSC and HF-HRV at week 1 of life on measures of neonatal health outcomes (i.e., days on ventilation, days on oxygen, and length of hospital stay) and a short-term developmental outcome (i.e., PMA at discharge) (►Table 4). Additionally, SNAP was included in the regression models to account for the effect of neonatal morbidity at birth on outcome variables. The final model for days on ventilation only included frequency of SSC and HF-HRV at week 1 of life as significant predictor variables ($p < 0.05$ for each variable). The final model with these two predictor variables accounted for 16% of the variance for days on ventilation, $F(2, 92) = 8.68$, $p < 0.001$, $R^2 = 0.16$. For days on oxygen, all three predictor variables (i.e., frequency of SSC, HF-HRV, and SNAP) had a unique significant contribution in the final regression model ($p < 0.05$), which accounted for 30% of the variance in outcome, $F(3, 91) = 13.21$, $p < 0.001$, $R^2 = 0.30$. For length of hospital stay, the final model again included all three predictor variables with each predictor variable contributing significantly to the outcome ($p < 0.01$). The three predictor model accounted for 41% of the variance in length of hospital stay, $F(3, 87) = 20.38$, $p < 0.001$, $R^2 = 0.41$. Finally, the final model for PMA at discharge retained only HF-HRV at week 1 as a significantly contributing predictor variable ($p < 0.01$). The final model accounted for 9% of the variance in PMA at discharge, $F(1, 89) = 9.25$, $p < 0.01$, $R^2 = 0.09$.

Discussion

Findings from this study support the hypothesis that greater frequency of SSC is associated with enhanced HF-HRV. In fact, we demonstrate that especially in the sickest and most vulnerable neonates, those with a SNAP of 10 or higher, SSC promotes stress resiliency as measured by higher HF-HRV. These findings support previous research that HF-HRV is heightened among preterm neonates receiving SSC for at least 1 hour daily for a minimum of 14 consecutive days. This finding corroborates with ours to show that increasing the frequency of SSC during the first week of life is useful as an intervention to enhance the stress resiliency of preterm neonates. While additional studies exploring the effects of SSC on HF-HRV in preterm neonates exist, the methodologies vary too greatly for comparison to our results, that is, measurement during transition from SSC to the incubator, and using HF-HRV bandwidth spectrum ranges appropriate for adults, but that do not consider the neonates faster breathing rate.

We found that heightened HF-HRV at week 1 of life predicted significantly fewer days on ventilation, fewer days on oxygen, reduced length of hospital stay, and lower PMA at discharge. Furthermore, although increased neonatal morbidity at birth (i.e., SNAP) was found to predict increased days on oxygen and length of hospital stay, heightened stress resiliency at the first week of life was a stronger predictor of improvement on all measures of neonatal morbidity and PMA at discharge. These findings support a large body of research associating heightened HF-HRV with numerous improved health and developmental outcomes.⁷ Additionally, these results highlight the importance of identifying interventions, such as increased SSC frequency during the first week of life, to enhance the vagal tone of premature infants, as stress resiliency at the first week of life is a greater predictor of neonatal morbidity and PMA at discharge than SNAP.

Greater SSC frequency during the first week of life predicted significantly fewer days on ventilation, fewer days on oxygen, and reduced length of hospital stay. Additionally, greater frequency of SSC was associated with earlier PMA at discharge. These findings further support our hypothesis and support findings from several reviews evaluating the influence of SSC on health and developmental outcomes of preterm infants. Our study is one of the first to evaluate linkages between SSC and HF-HRV in relation to measures of neonatal morbidity or developmental outcome.

One limitation of this study is its single-center investigation which limits the generalizability of research findings. Other limitations include the retrospective nature of the SSC portion of data collection and the inability to control the consistency of SSC implementation or its documentation by nursing in the neonates' EMR. As SSC was a standard of care in the NICU, the quality of its implementation reflected standard practice rather than a treatment administered within an intervention study. Despite these limitations, our research offers several strengths that are worth discussing. The first strength was the prospective nature of the HRV and clinical outcome portions of this research. Second, by standardizing HRV data collection to the afternoon approximately an hour after care and feeding while neonates were in a sleep state, the research protocol exerted control over known confounding variables to HF-HRV such as infant state and circadian influences. Third, the sample size of 101 generously exceeds the number of participants recommended to determine a medium effect size. Finally, a frequency range of 0.3 to 1.3 Hz was utilized during HF-HRV spectral analysis which is an appropriate frequency range given the developmental age and respiration rate of the study's sample population. This is necessary given the respiratory driven component of parasympathetic activity (HF-HRV) contributing to stress resiliency.

Conclusion

Here, we provide further evidence that the frequency of parent/infant SSC enhances neonatal cardiac vagal tone during the first week of life and significantly reduces neonatal morbidity. This research suggests that while SSC is an important intervention for preterm infants, more specifically, the frequency of SSC during the first week of life may be paramount to aiding in the maturation of the vagal system, thus increasing stress resiliency and improving health outcomes during this critical developmental period. Given the advantageous influence of heightened vagal tone on health and developmental outcomes, further research investigating additional interventions for enhancing stress resiliency as measured by HF-HRV during preterm neonates' first week of life is strongly encouraged.

Acknowledgments

We would like to thank A.C. Hozella and S.N. Horschler, Research Technologists, Newborn Biobehavioral Laboratory, Penn State College of Medicine for helping to recruit participants, assisting in HRV data collection, and aiding in the documenting of neonatal morbidity and short-term developmental variables. We also thank the parents of infants who provided consent for their infants to participate in the research and the nursing staff who encouraged and supported parents to provide skin-to-skin contact.

Funding

This study was supported in part by grants from the National Institutes of Health (R01DK099350) awarded to R.A.T. and K.K.D. and the Children's Miracle Network awarded to K.K.D.

References

1. Doheny KK. Long-term consequences of pain and stress in neonates. In: Buonocore G, Bellieni CV, eds. *Neonatal Pain: Suffering, Pain, and Risk of Brain Damage in the Fetus and Newborn*, 2nd ed. Cham, Switzerland: Springer International; 2017:213–225
2. McEwen BS, Gray J, Nasca C. Recognizing resilience: Learning from the effects of stress on the brain. *Neurobiol Stress* 2015;1:1–11 [PubMed: 25506601]
3. Porges SW. *The Polyvagal Theory: Neurophysiological Foundations of Emotions, Attachment, Communication, and Self-regulation*. New York: W.W. Norton & Company; 2011
4. Geisler FC, Kubiak T, Siewert K, Weber H. Cardiac vagal tone is associated with social engagement and self-regulation. *Biol Psychol* 2013;93(02):279–286 [PubMed: 23466587]
5. Hastings PD, Nuselovici JN, Utendale WT, Coutya J, McShane KE, Sullivan C. Applying the polyvagal theory to children's emotion regulation: social context, socialization, and adjustment. *Biol Psychol* 2008;79(03):299–306 [PubMed: 18722499]
6. Doussard-Roosevelt JA, McClenny BD, Porges SW. Neonatal cardiac vagal tone and school-age developmental outcome in very low birth weight infants. *Dev Psychobiol* 2001;38(01):56–66 [PubMed: 11150061]
7. Patural H, Pichot V, Jaziri F, et al. Autonomic cardiac control of very preterm newborns: a prolonged dysfunction. *Early Hum Dev* 2008;84(10):681–687 [PubMed: 18556151]
8. Beckie TM. A systematic review of allostatic load, health, and health disparities. *Biol Res Nurs* 2012;14(04):311–346 [PubMed: 23007870]
9. McEwen BS. Allostasis and the epigenetics of brain and body health over the life course: the brain on stress. *JAMA Psychiatry* 2017;74(06):551–552 [PubMed: 28445556]
10. Cong X, Ludington-Hoe SM, McCain G, Fu P. Kangaroo care modifies preterm infant heart rate variability in response to heel stick pain: pilot study. *Early Hum Dev* 2009;85(09):561–567 [PubMed: 19505775]
11. Vittner D, McGrath J, Robinson J, et al. Increase in oxytocin from skin-to-skin contact enhances development of parent-infant relationship. *Biol Res Nurs* 2018;20(01):54–62 [PubMed: 29017336]
12. Feldman R. Sensitive periods in human social development: new insights from research on oxytocin, synchrony, and high-risk parenting. *Dev Psychopathol* 2015;27(02):369–395 [PubMed: 25997760]
13. Boundy EO, Dastjerdi R, Spiegelman D, et al. Kangaroo mother care and neonatal outcomes: a meta-analysis. *Pediatrics* 2016; 137(01):1–16
14. Hendricks-Muñoz KD, Xu J, Parikh HI, et al. Skin-to-skin care and the development of the preterm infant oral microbiome. *Am J Perinatol* 2015;32(13):1205–1216 [PubMed: 26007311]
15. Nyqvist KH, Anderson GC, Bergman N, et al. Towards universal kangaroo mother care: recommendations and report from the first European conference and seventh international workshop on kangaroo mother care. *Acta Paediatr* 2010;99(06):820–826 [PubMed: 20219044]
16. Conde-Agudelo A, Belizán JM, Diaz-Rossello J. Kangaroo mother care to reduce morbidity and mortality in low birthweight infants. *Cochrane Database Syst Rev* 2011;3(03):CD002771
17. Lawn JE, Mwansa-Kambafwile J, Horta BL, Barros FC, Cousens S. 'Kangaroo mother care' to prevent neonatal deaths due to preterm birth complications. *Int J Epidemiol* 2010;39(Suppl 1): i144–i154 [PubMed: 20348117]
18. 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(01):56–64 [PubMed: 24094511]
19. Schneider C, Chorpak N, Ruiz-Peláez JG, Tessier R. Cerebral motor function in very premature-at-birth adolescents: a brain stimulation exploration of kangaroo mother care effects. *Acta Paediatr* 2012;101(10):1045–1053 [PubMed: 22734793]
20. Nyqvist KH. Given the benefits of kangaroo mother care, why has its routine uptake been so slow? *Acta Paediatr* 2016;105(04): 341–342 [PubMed: 26946234]

21. Feldman R, Eidelman AI. Skin-to-skin contact (kangaroo care) accelerates autonomic and neurobehavioural maturation in preterm infants. *Dev Med Child Neurol* 2003;45(04):274–281 [PubMed: 12647930]
22. Richardson DK, Gray JE, McCormick MC, Workman K, Goldmann DA. Score for neonatal acute physiology: a physiologic severity index for neonatal intensive care. *Pediatrics* 1993;91(03): 617–623 [PubMed: 8441569]
23. Li Y, Yan J, Li M, et al. Addition of SNAP to perinatal risk factors improves the prediction of bronchopulmonary dysplasia or death in critically ill preterm infants. *BMC Pediatr* 2013;13:138 [PubMed: 24020335]
24. Gardner FC, Adkins CS, Hart SE, Travagli RA, Doheny KK. Preterm stress behaviors, autonomic indices, and maternal perceptions of infant colic. *Adv Neonatal Care* 2018;18(01):49–57 [PubMed: 29261561]
25. Verklan MT Padhye NS. Spectral analysis of heart rate variability: an emerging tool for assessing stability during transition to extrauterine life. *J Obstet Gynecol Neonatal Nurs* 2004;33(02): 256–265
26. Porges SW. The polyvagal perspective. *Biol Psychol* 2007;74(02): 116–143 [PubMed: 17049418]
27. Dodd VL. Implications of kangaroo care for growth and development in preterm infants. *J Obstet Gynecol Neonatal Nurs* 2005;34 (02):218–232
28. Laborde S, Mosley E, Thayer JF. Heart rate variability and cardiac vagal tone in psychophysiological research – recommendations for experiment planning, data analysis, and data reporting. *Front Psychol* 2017;8:213 [PubMed: 28265249]

Fig. 1.

The neonates at greatest risk, that is, those with the highest morbidity index (10 or greater), as measured by the score for neonatal acute physiology, were found to have a significant relationship between the number of times they received skin-to-skin contact (SSC) during their first week of life and cardiac vagal tone (high-frequency heart rate variability [HF-HRV]). $r_s(55) = 0.382$, $p = 0.004$.

Fig. 2.

Neonates with the highest morbidity index (10 or greater), as measured by the score for neonatal acute physiology, were found to have a significant relationship between the number of times they received skin-to-skin contact (SSC) during their first week of life and their length of hospital stay. $r_s(55) = -0.419$, $p = 0.001$.

Table 1

Characteristics of participants

Total sample (N = 101)				
	Mean	SE	Min	Max
Male gender (%)	54	–	–	–
SNAP	10.8	0.6	0	25
PMA at birth (wk)	31.2	0.2	26	34.9
Birth weight (kg)	1.6	0.1	0.7	2.6
Maternal age (y)	29.3	0.6	16	42
Maternal race (% white, non-Hispanic, or Latino)	75.3	–	–	–

Abbreviations: PMA, postmenstrual age; SNAP, score for neonatal acute physiology; SE, standard error.

Bivariate correlations^a of frequency of SSC and HF-HRV during week 1, and measures of morbidity and short-term developmental outcomes ($N = 101$)

Table 2

Measure	1. Week 1 SSC (times per week)	2. Week 1 HF-HRV (ms^2)	3. Days on vent	4. Days on oxygen	5. LOS (d)	6. PMA full PO (wk)	7. PMA at D/C (wk)
1. Week 1 SSC (times per week)	–						
2. Week 1 HF-HRV (ms^2)	0.23 ^b	–					
3. Days on vent	–0.38 ^c	–0.50 ^c	–				
4. Days on oxygen	–0.35 ^c	–0.62 ^c	0.68 ^c	–			
5. LOS (d)	–0.34 ^c	–0.60 ^c	0.57 ^c	0.78 ^c	–		
6. PMA full PO (wk)	–0.12	–0.29 ^c	0.27 ^c	0.45 ^c	0.63 ^c	–	
7. PMA at D/C (wk)	–0.23 ^b	–0.30 ^c	0.33 ^c	0.47 ^c	0.71 ^c	0.94 ^c	–

Abbreviations: D/C, discharge; HF-HRV, high-frequency heart rate variability; LOS, length of hospital stay; PMA, postmenstrual age; PO, by mouth; SSC, skin-to-skin contact.

^a Bivariate correlations were done using Spearman's correlation coefficients.

^b $p < 0.05$.

^c $p < 0.01$.

Table 3

Descriptive characteristics of predictor and outcome variables

Total sample (N = 101)				
	Mean	SE	Min	Max
Week 1 SSC (times per week)	5.56	0.45	0	23
HF-HRV (ms ²)	8.44	0.94	0.35	41.64
Days on ventilation	1.97	0.51	0	33
Days on oxygen	16.76	2.72	0	134
LOS (d)	39.43	2.54	8	134
PMA at discharge (wk)	36.83	0.19	34.71	47.57

Abbreviations: HF-HRV, high-frequency heart rate variability; LOS, length of hospital stay; PMA, postmenstrual age; SE, standard error; SSC, skin-to-skin contact.

Stepwise regression analysis of frequency of SSC, HF-HRV, and SNAP on measures of morbidity and short-term developmental outcomes ($N = 101$)

Table 4

Outcome variables	Significant predictors	Standardized coefficient (beta)	t-value	Significance	Model R^2	F-value
Days on ventilation	HF-HRV	-0.31	-3.22	0.002	0.16	8.68 ^a
	Frequency of SSC	-0.20	-2.10	0.039		
Days on oxygen	HF-HRV	-0.34	-3.57	0.001	0.30	13.21 ^a
	Frequency of SSC	-0.22	-2.52	0.013		
	SNAP	0.22	2.28	0.025		
Length of hospitalization	HF-HRV	-0.41	-4.59	0.000	0.41	20.38 ^a
	Frequency of SSC	-0.28	-2.85	0.005		
	SNAP	0.25	2.77	0.007		
PMA at discharge	HF-HRV	-0.31	-3.04	0.003	0.09	9.25 ^b

Abbreviations: HF-HRV, high-frequency heart rate variability; PMA, postmenstrual age; SNAP, score for neonatal acute physiology; SSC, skin-to-skin contact.

^a $p < 0.001$.

^b $p < 0.01$.