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Psychometric testing of the developmental care scale for neonates with congenital heart disease

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Abstract

Purpose: Developmental care of neonates with CHD is essential for proper neurodevelopment. Measurement of developmental care specific to these neonates is needed to ensure consistent implementation within and across cardiac ICUs. The purpose of this study was to psychometrically test the Developmental Care Scale for Neonates with Congenital Heart Disease, which measures the quality of developmental care provided by bedside nurses to neonates in the cardiac ICU. *Methods:* Psychometric testing was conducted with 119 cardiac ICU nurses to provide evidence of internal consistency reliability and construct validity. Participants were predominantly young (median = 32 years), white (90%) females (93%) with bachelor's degrees (78%) and a median experience in the cardiac ICU of 7 years. *Results:* Evidence of internal consistency reliability (α =.89) was provided with corrected item-total correlations ranging from .31 to .77. Exploratory factor analysis provided evidence of construct validity as a unidimensional scale, as well as a multidimensional scale consisting of four subscales: creating the external environment, assessment of family well-being, caregiver activities toward the neonate, and basic human needs. *Conclusions:* Evidence of reliability and validity of the 31-item Developmental Care Scale for Neonates with Congenital Heart Disease was established with nurses caring for neonates in the cardiac ICU. This instrument will serve as a valuable outcome measure tasked with improving developmental care performance and makes it possible to identify relationships between developmental care performance and neonatal neurodevelopmental outcomes in future research.

Approximately 1% of babies born annually have a CHD.[1] CHDs span a wide range of severity, and approximately 25% undergo palliative/corrective surgery in the first year of life.[1] With improvements in medical and surgical care, survival rates have improved considerably.[2] Although there are differences in survival rates based on complexity, the current long-term survival (>18 years) for children with severe CHD is approximately 90%.[3] Now that most patients with CHD are surviving into adulthood, priorities have shifted toward the prevention and mitigation of long-term morbidities. Poor neurodevelopmental outcomes are the most common long-term morbidity of this population, and the incidence is rising as more patients survive into adulthood.[4] Poor neurodevelopmental outcomes are of great concern as they can have a profound impact on an individual's ability to learn, socialise, and behave in accordance with societal norms.[5] While there is not yet a full understanding of the underlying causal mechanisms of poor neurodevelopment, some factors have emerged as strong predictors. The length of hospital stay is one factor that predicts worse neurodevelopmental outcomes.[6] One reason for this correlation could be that children with more complex and critical conditions require longer hospital treatments. Another explanation is that the hospital environment itself is not conducive to healthy neurodevelopment.

One way to ameliorate the effects of the hospital environment on neurodevelopment is by implementing developmental care, which is conceptually defined as age-appropriate care that focuses on the human needs of the patient population served independent of the presenting disease process.[7] It is a complex concept which can be further divided into five subcategories: protected sleep, pain and stress assessment and management, activities of daily living, family-centred care, and the healing environment.[7] Developmental care is associated with overall improved neurodevelopment,[8] and most cardiac ICUs already implement it, but there is wide variation in practice within and among cardiac ICUs.[9] As such, there is growing consensus that more effort is needed in the systematic implementation of developmental care in the cardiac ICU. An essential step in the systematic implementation requires creating outcome measures, so developmental care performance can be consistently evaluated within and between cardiac ICUs. While several developmental care measures exist, none of them are specific to nurses caring for full-term neonates with CHD in the cardiac ICU environment, and none of the existing self-assessment measurements found in the literature have been psychometrically tested.[10,11]

The Developmental Care Scale for Neonates with CHD was specifically created to measure the quality of developmental care provided by bedside nurses to neonates with CHD in the

cardiac ICU. Item development and content validity of the Developmental Care Scale for Neonates with CHD have been previously described.[12] The purpose of this study was to psychometrically test the Developmental Care Scale for Neonates with CHD with bedside nurses in the cardiac ICU setting.

Materials and methods

This psychometric study examined item analysis, internal consistency reliability, and construct validity of the Developmental Care Scale for Neonates with CHD. Descriptive statistics (e.g. frequencies, percentage, means, standard deviations, and ranges) were used to describe the sample and item analyses. Internal consistency reliability was evaluated by Cronbach's alpha coefficient and item-to-total correlations. Construct validity was assessed through exploratory factor analysis using principal axis factoring with direct oblimin rotation to evaluate the dimensionality of the scale. Exploratory factor analysis statistically assesses correlation among items, resulting in a factor structure or grouping of items into subscales based on strong correlations. The Developmental Care Scale for Neonates with CHD was originally created based on a theoretical definition of developmental care, which identified five "core measures" or groupings of items. Performing exploratory factor analysis could result in a different number of correlated item groupings, also known as factors or subscales.

Procedure

Approval of the University of Cincinnati Institutional Review Board for the protection of patients was obtained before the start of the study, with all participants indicating informed consent by completing the anonymous questionnaires. Participants were eligible if they were registered nurses older than 20 years of age and working at the bedside caring for neonates with CHD in the cardiac ICU. Participants were excluded if they were still in orientation or training or had not cared for a neonate in the cardiac ICU within 2 weeks of completing the study questionnaires. Two weeks was considered an appropriate cut-off for exclusion to recruit an ample number of nurses while reducing recall bias of the care provided to their neonatal patients.[13] A total of 119 participants were recruited from 30 cardiac ICUs in the United States between August, 2017 and February, 2018 through communication with cardiac ICU Directors of Nursing, the Pediatric Cardiac Intensive Care Society, and the Society of Pediatric Cardiovascular Nurses. Participants accessed study questionnaires via a web link contained at the end of the Institutional Review Board consent sheet in the recruitment e-mail.

All data were collected and recorded in REDCap, a secure, web-based application designed to support data capture from research projects.

Measures

Demographics were measured by a data form detailing bedside nurse characteristics (see Table 1). Information regarding the neonatal patient for whom participants cared was also collected, including age, number of days post-operation, and the type of CHD. Developmental care performance was assessed by having participants self-evaluate performance of certain behaviours and tasks included in the 41-item Developmental Care Scale for Neonates with CHD. The scale contains five core measures, including protected sleep, pain and stress management, activities of daily living, family-centred care, and the healing environment. Items were scored using a five-point response scale with choices ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Higher scores were indicative of better developmental care performance.

Table 1. Demographics table

Nurse demographics, n = 119	
Age	Median (Range): 32 years (23–65 years)
Gender n (%)	Male: 8 (7%)
	Female: 111 (93%)
Ethnicity n (%)	Hispanic: 5 (4%)
	Non-Hispanic: 114 (96%)
Race n (%)	African American: 0 (0%)
	American Indian/Alaskan Native: 0 (0%)
	Asian: 6 (5%)
	Native Hawaiian/Pacific Islander: 0 (0%)
	White: 107 (90%)
	Mixed: 5 (4%)
	Other: 1 (1%)
Pediatric RN experience	Median (Range): 10 years (1–40 years)
Cardiac ICU RN experience	Median (Range): 7 years (1–38 years)
Certification n (%)	CCRN: 37 (31%)
	CPN: 23 (20%)
	Other: 10 (8%)
Education n (%)	Associate: 6 (5%)
	Bachelor: 93 (78%)
	Master: 17 (15%)
	Doctorate: 3 (2%)
Number of beds in cardiac ICU	Median (Range): 25 beds (9–36 beds)
Familiarity with developmental care	Mean (SD): 73 (18)
Patient demographics	
Patient age	Median (Range): 12 days (0–31 days)
Days post-operation	Median (Range): 4 days (0–23 days)
Congenital heart defect category n (%)	Increased pulmonary blood flow: 10 (9%)
	Obstruction to blood flow from ventricles: 19 (16%)
	Decreased pulmonary blood flow: 21 (17%)
	Mixed blood flow: 63 (52%)
	Arrhythmia: 2 (2%)
	Other: 4 (4%)

Results

Sample characteristics

Sample characteristics of the participants are summarised in Table 1. Among the 119 participants, ages ranged from 23 to 65 years (median = 32 years). Most were female (93%), identifying as

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non-Hispanic (96%). Most were also white (90%), with 5% Asian, 4% mixed, and 1% other. Median experience as a paediatric nurse was 10 years (range = 1–40 years). Median experience working in a paediatric cardiac ICU was 7 years (range = 1–38 years), and 70 respondents reported having a nursing certification. Most respondents had a bachelor's degree as their highest level of education (78%), followed by a master's degree (15%), associate degree (5%), and doctoral degree (2%). Participants worked in 30 different cardiac ICUs, and number of beds ranged from 9 to 36 per unit.

Regarding patient demographics, median age of patient was 12 days (range: 0–31 days), 4 days post-operation (range: 0–23 day) with a mixed blood flow CHD (51%). Regarding developmental care, on a scale from 0 to 100 (0 being no familiarity and 100 being extremely familiar with developmental care), respondents rated their familiarity on average at 73 (SD = 18). The most commonly cited way respondents learned about developmental care was through cardiac ICU orientation/preceptor (78%), through unit education (68%), and from peers (46%).

Of the total 119 participants, 109 filled out the study questionnaires. No more than five cases were missing from any subscale (five cases from creating the external environment, one case from caregiver activities toward the neonate, and three cases from basic human needs). Missing cases were deleted from analyses, resulting in 100 completed questionnaires used for analyses.

Item analysis

For the 41 items assessed, mean scores ranged from 2.45 to 4.31. There was good variability in relation to the means (SDs ranged from .54 to 1.26) with a score range of 1–5. The highest ceiling effect was 39.3%, and the highest floor effect was 18.8% (see Table 2). Four items listed next with low factor loadings were deleted from the Developmental Care Scale for Neonates with CHD:

- The nurse participated in daily interprofessional care rounds,
- The skin surface was protected from lines, tubes, drains, and airways,
- Pharmacologic measures were used as needed to minimise distress, and
- Families were informed about available support groups.

Internal consistency reliability

Six items, listed next, with inter-item correlations below .3 or above .7 were deleted:

- Routine care was provided when the neonate was awake or emerging from sleep,
- Safe sleep (A. B. C. Alone, on his or her back, in a crib) was maintained,
- Bathing frequency was individualised to the neonate's needs and skin integrity,
- The neonate's state of stress guided routine care,
- Individualised pain-relieving interventions were added to plan of care, and
- Opportunities were provided for family to provide comfort to the neonate.

Correlations greater than .7 were found between two pair of items in the Assessment of Family Well-Being subscale. Due to their theoretical importance, the decision was made to keep them in the scale for now, with the potential to combine each pair into one item in the future. Corrected item-total correlations were acceptable and ranged from .31 to .77. Internal consistency reliability was calculated for the remaining 31 items (see Table 3) and supported with a Cronbach's alpha coefficient of .89 (N = 100). Internal consistency reliability was also supported for all subscales with Cronbach's alphas ranging from .74 to .87.

Construct validity using exploratory factor analysis

The 31-items of the Developmental Care Scale for Neonates with CHD were subjected to principal component analysis. With 31 items being tested for construct validity, 100 participants were deemed to be an adequate sample size for factor analysis, with sources recommending three to five participants per item.[14] The Kaiser-Meyer-Olkin value of .77 and Bartlett's Test of Sphericity ($p = 0.000$) supported the use of factor analysis.[15] Loadings are shown in Table 4. Exploratory factor analysis using a rotated four-factor solution supported the dimensionality of the Developmental Care Scale for Neonates with CHD with factor loadings ranging from .418 to .823 and 52% of the variance explained by the first four factors. Assessment of factor correlations demonstrated little to no correlation between them, indicating that the direct oblimin rotation was appropriate to use.

Exploratory factor analysis using an unrotated one-factor solution additionally supported unidimensionality of the Developmental Care Scale for Neonates with CHD total score with factor loadings ranging from .300 to .643 explaining 24% of the variance. This finding suggests that the Developmental Care Scale for Neonates with CHD total score has relevance as a measure of overall developmental care behaviours in addition to assessing specific aspects of developmental care using the four individual subscale scores. The results of this analysis support the use of a multidimensional four-factor solution that can be used as four individual subscale scores, or as one total score, providing evidence of construct validity for the 31-item Developmental Care Scale for Neonates with CHD.

Discussion

Bedside nurses play a vital role in developmental care of neonates with CHD. However, much of the existing developmental care research focuses on the unit as a whole with little attention focused on individuals at the bedside. Because of the important role bedside nurses play, a tool that focused on developmental care interventions within the control of bedside nurses was needed. The scale reflects aspects of developmental care that are important to be implemented with neonates with CHD. However, parents/family members play an integral role in care of the hospitalised neonate as well and should be active participants in developmental care implementation. Findings from this study provided evidence of reliability and validity for the 31-item Developmental Care Scale for Neonates with CHD, which measures the quality of developmental care provided to neonates with CHD in the cardiac ICU.

Item analyses revealed important findings. Thirteen out of the final 31-items had high ceiling effects (>15%). One possible reason for high ceiling effects is social desirability bias. Another possibility is that some of the items reflected basic neonatal care, which may already be a standard practice in cardiac ICUs. Three items with the highest ceiling effects were the daily plan of care was communicated to the family; air temperature was stable, consistent, and appropriate for maintaining neonate's well-being; and the neonate

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Table 2. Item statistics and analyses

Developmental care for the neonate with CHD item	Mean (SD)	% Ceiling	% Floor	Corrected item-to-total correlation	Alpha if item deleted
Factor 1 Creating the external environment (alpha = .87)					
Environment 1 Efforts were made to protect the neonate from light while sleeping.	3.84 (.95)	17.9%	2.7%	.70	.86
Environment 2 Muted, indirect light was provided when the neonate was awake.	3.57 (.97)	9.8%	2.7%	.61	.87
Environment 3 Room lighting was individualised based on the neonate's sleep/awake state.	3.43 (1.12)	11.7%	4.5%	.71	.86
Environment 4 Quiet voices were used while in the neonate's room.	3.49 (1.08)	14.4%	2.7%	.67	.86
Environment 5 Sounds from other unit-related activities were reduced.	2.84 (1.17)	8.1%	9%	.72	.86
Environment 6 Calming sounds (e.g. music, voices, womb noises) were played at the bedside based on cues from the neonate.	3.73 (.97)	15.3%	2.7%	.50	.87
Environment 7 Air temperature was stable, consistent, and appropriate for maintaining neonate's well-being.	4.12 (.79)	28.8%	0.9%	.48	.70
Environment 8 Sleep-wake state was assessed before every interaction with the neonate.	3.34 (1.16)	12.5%	4.5%	.48	.88
Environment 9 Individualised activities that promote sleep were implemented.	3.54 (1.05)	12.5%	3.6%	.68	.86
Environment 10 Care was clustered to minimise interruptions in sleep.	3.91 (.96)	24.1%	1.8%	.47	.87
Environment 11 The skin surface was protected during the use of adhesive products.	3.89 (.87)	18.9%	0.9%	.50	.87
Factor 2 Assessment of family well-being (alpha = .87)					
Family 1 Mother's physical health and well-being was assessed.	3.6 (.93)	11.7%	1.8%	.74	.83
Family 2 Mother's emotional health and well-being were assessed.	3.61 (.90)	10.8%	1.8%	.77	.82
Family 3 Referrals were made as needed based on assessment of mother's health and well-being.	3.34 (.94)	6.3%	2.7%	.65	.84
Family 4 Family satisfaction with the neonate's care was assessed.	3.64 (.80)	8.9%	0%	.60	.85
Family 5 Family resource needs were assessed.	3.68 (.84)	11.7%	0%	.62	.85
Family 6 Referrals were made as needed based on the family resource assessment.	3.57 (.94)	12.5%	1.8%	.66	.84
Factor 3 Caregiver activities toward the neonate (alpha = .81)					
Caregiver 1 Opportunities were created for the neonate to be held based on cues from the neonate.	3.15 (1.26)	10.8%	12.6%	.60	.78
Caregiver 2 The neonate was swaddled without completely immobilising the extremities.	3.51 (1.14)	17%	5.4%	.62	.78
Caregiver 3 Non-nutritive sucking was guided by cues of interest.	3.41 (1.07)	8.9%	4.5%	.63	.78
Caregiver 4 Opportunities were created for the neonate to be held skin-to-skin.	2.45 (1.11)	4.5%	18.8%	.51	.79
Caregiver 5 Family was involved in creating the pain management plan of care.	2.96 (1.13)	3.6%	11.7%	.55	.79
Caregiver 6 Visual stimuli were provided (e.g. mirror, black/white images, faces) based on the neonate's cues of interest.	2.95 (1.15)	6.3%	8.9%	.43	.80
Caregiver 7 Caregiving was provided in collaboration with family as appropriate.	3.81 (.81)	12.5%	1.8%	.48	.80

(*Continued*)

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Table 2. (*Continued*)

Developmental care for the neonate with CHD item	Mean (SD)	% Ceiling	% Floor	Corrected item-to-total correlation	Alpha if item deleted
Caregiver 8 Mother's feeding preference was included in the plan of care.	3.68 (.98)	15.3%	2.7%	.36	.81
Caregiver 9 Family education on safe sleep (A.B.C. Alone, on their back, in a crib) has been provided.	2.69 (1.06)	3.6%	10.7%	.34	.81
Factor 4 Basic needs (alpha = .74)					
Needs 1 The daily plan of care was communicated to the family.	4.31 (.54)	33.6%	0%	.48	.71
Needs 2 The neonate was positioned with extremities midline and semi-flexed.	3.87 (.89)	21.4%	0%	.58	.65
Needs 3 The neonate was positioned with neck and shoulders in alignment with the rest of the body.	4.08 (.73)	25.2%	0%	.65	.68
Needs 4 Gentle, smooth, supportive touch was used during care.	4.11 (.57)	20.7%	0%	.37	.73
Needs 5 Non-pharmacologic measures were used to minimise distress.	4.04 (.77)	22.5%	0.9%	.41	.80

Table 3. Descriptive statistics for the developmental scale for neonates with CHD and subscales

Measure	No. of items	n	M(SD)	Possible range	Actual range	Cronbach's alpha
Total scale	31	100	110.4 (14.4)	(31–155)	71–151	.89
Creating the external environment	11	104	39.8 (7.3)	(11–55)	19–55	.87
Assessment of family well-being	6	109	21.4 (4.2)	(6–30)	9–30	.87
Caregiver activities toward the neonate	9	108	28.6 (6.1)	(9–45)	11–41	.81
Basic needs	5	106	20.5 (2.5)	(5–25)	13–25	.74

M: mean score; n = number of participants; SD: standard deviation.

was positioned with neck and shoulders in alignment with the rest of the body. All of these items could be considered basic neonatal care, which would already be a standard practice in the cardiac ICU. There is also a possibility that the item response choices of "strongly agree" to "strongly disagree" did not capture the essential aspects of developmental care, which is a continuous practice, integrated into all facets of nursing care. Revising item responses from "Not at all in my shift" to "consistently throughout my entire shift" could potentially enhance the ability of the instrument to discriminate between frequencies of developmental care practices and reduce high ceiling effects. The decision was made to not delete all items with high ceiling effects, as these items most likely reflect the issues presented earlier rather than concern with the underlying construct. Because these items are important to the construct of developmental care, they will be kept and can be reworded in the future.

Only one item, opportunities were created for the neonate to be held skin-to-skin, had a large floor effect (18.8%). One possible explanation for this is that there is not much expectation to perform skin-to-skin care in the cardiac ICU. Given these results, it would be important in future research to develop interventions for changing unit culture to embrace skin-to-skin holding as a standard practice.

Evidence of construct validity of the Developmental Care Scale for Neonates with CHD as a unidimensional measurement of overall developmental care and as a multidimensional measurement of the different components of developmental care was provided through exploratory factor analysis. Initially, exploratory factor analysis using principal component analysis without forcing any factors resulted in a 10-factor solution using the eigenvalue and scree plot methods. Only parallel analysis resulted in a four-factor solution. It came as no surprise that a scale attempting to measure developmental care behaviours resulted in a large number of factors, as much literature documents the breadth of this construct.[16] The broadness of this construct could be one explanation for the discrepancy between content validity indicating a five-factor structure[12] and exploratory factor analysis indicating a four-factor structure. At this point, the four-component structure appears to be the best model for the Developmental Care Scale for Neonates with CHD. However, future research may shed light on additional items that should be included to continue to improve the scale, such as feeding, thermoregulation, or behavioural assessment-related items and how additional items change the best-fit model.

Once it was determined that the four-factor model was the best fit, factors were renamed to reflect the new organisation of items on each factor: creating the external environment, assessment of family well-being, caregiver activities toward the neonate, and basic human needs. The original item pool was largely based on a theoretical definition of developmental care[7] and accordingly categorised into five domains: protected sleep, pain and stress assessment and management, age-appropriate activities of daily living, family-centred care, and the healing environment. Interestingly, once names were given to each of the newly created

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Table 4. Factor loadings of developmental care scale for neonates with CHD items

	1	2	3	4
Environment 5	.812			
Environment 3	.784			
Environment 1	.771			
Environment 4	.753			
Environment 9	.712			
Environment 2	.678			
Environment 6	.665			
Environment 8	.519			
Environment 11	.502			
Environment 7	.441			.425
Environment 10	.418			.301
Family 2		.823		
Family 1		.815		
Family 3		.775		
Family 6		.763		
Family 5		.706		
Family 4		.704		
Caregiving 1			.805	
Caregiving 2			.720	.363
Caregiving 3			.710	
Caregiving 4			.665	
Caregiving 5			.599	
Caregiving 8		.363	.448	
Caregiving 6			.437	
Caregiving 9			.427	
Caregiving 7		.322	.426	
Needs 2				.770
Needs 3				.683
Needs 1				.634
Needs 4				.558
Needs 5			.450	.476

factors, it now more closely resembles a condensed version of the NIDCAP Nursery Certification Program Nursery Assessment Manual. The NIDCAP Nursery Certification Program Nursery Assessment Manual consists of 121 items organised into four subscales: Physical Environment, Infant Care, Family Care, and Care of Professionals and Staff.[17] This is important to note, as the NIDCAP Nursery Certification Program Nursery Assessment Manual could be used to test criterion validity in future studies.

Limitations

The findings of this study are limited by the use of a convenience sample. Participants were recruited from 30 different sites, which should have led to better representation of developmental care practices across the United States. However, generalisability may be limited due to lack of representation by African American participants, overrepresentation of white participants, and high education levels.

Another potential limitation was social desirability bias on the part of participants. It is difficult to self-evaluate objectively, especially on sensitive matters such as job performance. Participant responses were anonymous and reported only in an aggregate form as an attempt to reduce the risk of social desirability bias. However, the large number of items with high ceiling effects signifies social desirability bias that potentially played a role in study results. Going forward, future research should include an observation of nurses performing developmental care, possibly with simulation, to control for the confounding effect of social desirability and determine accurate ceiling effects of Developmental Care Scale for Neonates with CHD items.

Reliability and validity testing examined in this study has resulted in the refinement of a developmental care performance tool with a strong psychometric foundation. However, future research is necessary to improve its ability to discriminate between good- or poor-quality developmental care, specifically in items with a high ceiling effect. Furthermore, items need to be added and tested to better reflect the full scope of developmental care practices that have been described in the literature for infants with CHD and their families.

Summary

This study reported findings from psychometric testing of the Developmental Care Scale for Neonates with CHD, which measures the quality of developmental care provided by bedside nurses to neonates with CHD in the cardiac ICU. Developing a reliable and valid instrument allows for the identification of areas of developmental care in need of improvement. It also allows the ability to correlate developmental care performance to neonatal neurodevelopmental outcomes in future research.

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Conflicts of Interest. None.

Ethical Standards. This study was approved by the University of Cincinnati's Institutional Review Board (reference no. 2017-2189).

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