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Validity of the Korean Developmental Screening Test for very-low-birth-weight infants

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Purpose: The importance of the neurodevelopmental outcomes of very-low-birth-weight (VLBW) infants has been emphasized as their mortality rate has markedly improved. This study aimed to assess the validity of the Korean Developmental Screening Test (K-DST), a developmental screening tool approved by the Korean Society of Pediatrics, for the timely diagnosis of neurodevelopmental delay in VLBW infants.

Methods: Subjects included VLBW infants enrolled in the Korean Neonatal Network database between January 2012 and December 2014. The collected data were analyzed for sensitivity, specificity, positive predictive value, and negative predictive value (NPV) in the K-DST compared to those in the Bayley Scales of Infant Development-II for VLBW infants.

Results: A total of 173 patients were enrolled. Their mean gestational age and mean birth weight were 27.5±2.8 weeks and 980.5±272.1 g, respectively. The frequency of failed psychomotor developmental index (PDI) <85 was similar to that in at least one domain of K-DST <1 standard deviation. Failure in more than one K-DST domain compared with a mental developmental index (MDI) <85 showed a sensitivity and NPV of 73.2% and 75.0%, respectively. Failure in more than one K-DST domain compared with PDI <85 showed a sensitivity and NPV of 60.3% and 71.6%, respectively. Each K-DST domain had a stronger correlation with predicting a failing MDI <85 than a failing PDI <85 (P<0.05).

Conclusion: K-DST could be a useful screening tool for predicting mental developmental delay in VLBW infants and referring them for neurodevelopmental assessments.

Key words: Very low birth weight, Validity, Korean Developmental Screening Test

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Introduction

Preterm birth is an important cause of perinatal mortality and long-term morbidities.[1-3] The survival rate of preterm infants has steadily increased because of improved prenatal and perinatal medicine. In a previous study, preterm birth rate was approximately 11.5% in the United States (US) and the survival rate among infants born 23–24 weeks in developed countries was approximately 50%.[1] In Korea, the survival rates of very-low- birth-weight (VLBW) infants have also increased; they were 65.8% in the early 1990s and 89.7% in 2009.[2] The importance of neurodevelopmental outcomes of VLBW infants is emphasized as their mortality rate has dramatically improved. The risk of poor neurodevelopmental outcomes remains high in children who are born preterm.[1-3] Approximately 25% of extremely preterm infants born in the 1990s had critical disabilities such as impaired mental development, cerebral palsy, blindness, and deafness at preschool age.[3,4] An early recognition of abnormal neurodevelopment for preterm infants is able to overcome neurodevelopmental delay through specific intervention programs and minimize risks of irreversible dysfunction, eventually improving the quality of life. Thus, neurodevelopmental assessment using appropriate tools is

important.[5]

The Bayley Scales of Infant and Toddler Development-II (BSID-II) is the most widely used measure to assess neurodevelopmental outcome of preterm (gestational age ≤32 weeks) or very low birth weight (VLBW, birth weight ≤1,500 g) infants aged 1 month to 3 years 6 months.[6,7] The BSID-II is composed of 2 types of developmental scores: the Mental Developmental Index (MDI), which evaluates cognitive and language development, and the Psychomotor Developmental Index (PDI), which evaluates motor skills. However, the disadvantages of BSID-II include its long test duration, need for a highly skilled person to interpret results, and low cost-effectiveness.[8,9] Moreover, whether using BSID-II in Korea is appropriate remains uncertain because its original norms are based on the US population.

In Korea, the Ages and Stages Questionnaires (ASQ) developed in the US has been revised into a Korean version (K-ASQ), which has been standardized for assessment of Korean pediatric development since the year 2000.[10] Because the K-ASQ is a domestic version of the ASQ, which was developed in the US as a parent-type infant monitoring system, it is a relatively reliable test for a test that was made for foreign infants who grow up in a culturally different environment. Therefore, it has some deficiencies in social and self-help areas for Korean infants and toddlers, and there are limitations in that it cannot be used on the Web due to the copyright. Therefore, these limitations have increased the need for appropriate testing tools for infants and young children in Korea. The Korean-Developmental Screening Test for infants and children (K-DST), a developmental screening tool acknowledged by the Korean Society of Pediatrics for infant and child health screening, has been available for screening neurodevelopmental delay in Korean children since 2014.[11] This test verifies whether Korean infants have standard development in the 6 domains of gross motor, fine motor, cognition, language, sociality, and self-help.[11] However, only nonpremature infants and children in local clinics due to development problems were enrolled in this study. There are still not enough studies on the usefulness of the K-DST for the assessing the development of VLBW infants. Therefore, the objective of this study was to evaluate the validity of the K-DST for timely diagnosis of neurodevelopmental delay in VLBW infants compared to the BSID-II.

Materials and methods

1. Study design

We retrospectively reviewed the medical records of infants who were enrolled in the Korean Neonatal Network (KNN), a nationwide systemic database, from January 2012 to December 2014. These infants were from 55 neonatal intensive care units (NICUs) of KNN-participating hospitals, were born with birth weights <1,500 g and survived, and had available BSID-II and K-DST scores at corrected age 18–24 months old. Primary caretakers were asked to fill out the K-DST at the time of BSID-II examination from January 2014 to May 2017. For both tests, the tests performed were for the age that corresponded most closely to the infant's corrected age. Exclusion criteria included major congenital anomalies or chromosome abnormalities, and were not having been followed up on until 3 years of age.

Demographic characteristics of subjects included gestational age, birth weight, sex, APGAR scores (1 and 5 minutes), respiratory distress syndrome (RDS), patent ductus arteriosus (PDA), bronchopulmonary dysplasia (BPD, severity defined by criteria of the National Institute of Child Health and Human Development),[12] intraventricular hemorrhage (IVH, grade ≥2, defined by Papile),[13] periventricular leukomalacia, necrotizing enterocolitis (NEC, stage ≥2, defined by Bell),[14] late-onset sepsis defined as a case of positive blood culture after postnatal 7 days,[15] retinopathy of prematurity (ROP, stage ≥2, defined by the International Classification of Retinopathy of Prematurity),[16] congenital hypothyroidism, hearing loss (including mild hearing loss of 20–40 dB), cerebral palsy (diagnosed by a board-certified doctor of pediatric rehabilitation medicine), and hospital days.

Developmental delay for VLBW infants was defined when MDI or PDI scores were less than 85 on BSID-II. They were patients who needed follow-up or further evaluation. To evaluate the ability of the K-DST to identify VLBW infants with developmental delay, critical cutoff scores for 6 domains—gross motor, fine motor, cognition, language, sociality, and self-help—were set at 1 standard deviation (SD) under the mean value. They were also patients who needed follow-up or further evaluation based on the K-DST. The validity of the K-DST was then determined by calculating its sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) compared to MDI or PDI <85 on BSID-II.

Although it could not be precisely distinguished, MDI was compared with cognition, language, the K-DST, and PDI was compared with gross motor, fine motor, and self-help.

2. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA). Results are presented as medians or means±SD for quantitative variables and as percentages for nonquantitative variables. Correlation between BSID-II and K-DST was performed using a chi-square test and Spearman rank-order correlation. Differences were considered significant at $P<0.05$.

3. Ethical statement

The data registry was approved by the Institutional Review Board as each hospital was a participant in the KNN (2013-0370). Informed consent was obtained from all patients through their enrollment in NICUs participating in the KNN.

Results

A total of 196 VLBW infants were enrolled in this study. Of these, 173 VLBW infants (88.3%) were able to be followed up with until a corrected age of 18–24 months. Mean gestational age and birth weight of these infants were 27.5±2.8 weeks and 980.5±272.1 g, respectively (Table 1). Regarding neonatal morbidity, the incidence of RDS, significant PDA, moderate to severe BPD, IVH ≥grade 2, NEC ≥stage 2, and ROP ≥stage 2 was 80.9%, 32.3%, 24.9%, 36.4%, 4.0%, and 18.5%, respectively. The incidence of hearing loss, visual loss, and cerebral palsy was 0%, 0%, and 0.5%, respectively. The mean duration of hospital stay of the infants was 79.4±39.5 days (Table 1).

The mean age at which both BSID-II and K-DST scores were obtained was at corrected 20.9±2.3 months (range, 18–24 months).

The proportion of developmental delay on the BSID-II was 40.5% for MDI and 30.6% for PDI (Table 2). The proportion of developmental delay for the 6 domains of the K-DST was 28.7% on average. Proportions of developmental delay in gross motor, fine motor, cognition, language, sociality, and self-help on the K-DST were 29.6%, 30.1%, 30.1%, 33.2%, 25.5%, and 23.9%, respectively.

Table 3 shows the validity of each of the K-DST domains compared to MDI<85. Sensitivity, specificity, PPV, and NPV of the six domains of the K-DST based on the BSID-II were in the range of 0.256–0.5, 0.829–0.919, 0.538–0.804, and 0.604–0.711, respectively. Sensitivity and NPV for more than one domain failed on the K-DST relative to MDI<85 were 0.732 and 0.750, respectively.

Furthermore, Table 3 shows the validity of each of the K-DST domains compared to PDI<85. Sensitivity, specificity, PPV, and NPV of the 6 K-DST domains based on BSID-II were in the range of 0.175–0.349, 0.762–0.854, 0.314–0.431, and 0.671–0.711, respectively. Sensitivity and NPV for more than one domain failed on the K-DST relative to PDI <85 were 0.603 and 0.716, respectively.

We assessed the correlation between K-DST and BSID-II using Spearman rank-order correlation (Table 4). The Spearman correlation coefficients of all 6 K-DST domains were between 0.170 and 0.615, showing a significant correlation with the four domains (fine motor, cognition, language, and sociality) of the MDI and K-DST. The MDI showed a more significant positive correlation with the K-DST than did the PDI, with higher Spearman's correlation coefficients of MDI than PDI. Language showed a stronger correlation (r=0.526) with the MDI than the other domains did. However, this study did not show a significant correlation between the PDI and K-DST.

Discussion

The objective of this study was to assess the usefulness of the K-DST for VLBW infants born from 2012 to 2014 at 55 NICUs enrolled in KNN. Because the period between 20 and 32 weeks after conception is a period for rapid brain growth and development,[17]

Table 1. Demographic characteristics of enrolled subjects (n=173)

Variable	Value
Gestational age (wk)	27.5±2.8
Birth weight (g)	980.5±272.1
Male sex	89 (51.4)
APGAR score at 1 min	4 (2–7)
APAGR score at 5 min	6 (5–9)
Respiratory distress syndrome	140 (80.9)
Significant patent ductus arteriosus	56 (32.3)
Moderate to severe bronchopulmonary dysplasia	43 (24.9)
Intraventricular hemorrhage (grade ≥2)	63 (36.4)
Periventricular leukomalacia	7 (4.0)
Necrotizing enterocolitis (stage ≥2)	7 (4.0)
Late-onset sepsis	40 (23.1)
Retinopathy of prematurity (stage ≥2)	32 (18.5)
Hearing loss	0 (0)
Visual loss	0 (0)
Cerebral palsy	1 (0.5)
Hospital stay (day)	79.4±39.5

Values are presented as mean±standard deviation, mean (interquartile range), or number (%).

Table 2. Proportion of very-low-birth-weight infants who failed Bayley Scales of Infant and Toddler Development-II (BSID-II) or Korean-Developmental Screening Test (K-DST)

Test	Domain	No. (%)	Index, mean±SD
BSID-II	Mental developmental index <85	70 (40.5)	69.2±11.0
	Psychomotor developmental index <85	53 (30.6)	73.3±9.9
K-DST (<-1SD)	Gross motor	58 (29.6)	17.3±0.7
	Fine motor	59 (30.1)	19.4±2.0
	Cognition	59 (30.1)	11.4±3.1
	Language	65 (33.2)	9.2±3.5
	Sociality	50 (25.5)	11.7±3.3
	Self-help	47 (23.9)	13.7±1.8

SD, standard deviation.

Table 3. Validity of Korean-Developmental Screening Test (K-DST) in comparison to Mental Developmental Index (MDI) and Psychomotor Developmental Index (PDI) of Bayley Scales of Infant and Toddler Development-II

K-DST (<-1SD)	MDI <85				PDI <85			
	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
Gross motor	0.256	0.838	0.538	0.604	0.238	0.815	0.385	0.688
Fine motor	0.354	0.829	0.604	0.634	0.270	0.762	0.354	0.683
Cognition	0.427	0.874	0.714	0.674	0.333	0.785	0.429	0.708
Language	0.500	0.910	0.804	0.711	0.349	0.777	0.431	0.711
Sociality	0.317	0.919	0.743	0.646	0.175	0.815	0.314	0.671
Self-help	0.280	0.919	0.719	0.634	0.206	0.854	0.406	0.689
≥1 Domain failed	0.732	0.595	0.571	0.750	0.603	0.485	0.362	0.716

PPV, positive predictive value; NPV, negative predictive value; SD, standard deviation.

Table 4. Correlation between Korean-Developmental Screening Test (K-DST) domains and Bayley Scales of Infant and Toddler Development-II (BSID-II)

K-DST (<-1SD)	BSID-II			
	MDI		PDI	
	r*	P value	r	P value
Gross motor	0.104	0.149	0.133	0.065
Fine motor	0.200	**0.005**	0.039	0.593
Cognition	0.498	**<0.0001**	0.105	0.147
Language	0.526	**<0.0001**	0.138	0.056
Sociality	0.384	**<0.0001**	0.039	0.594
Self-help	0.319	0.353	0.104	0.150

SD, standard deviation; MDI, mental developmental index; PDI, psychomotor developmental index.
Boldface indicates a statistically significant difference with P<0.05.
*Spearman's rank correlation analysis.

comorbidity, infection, and malnutrition during neonatal care may lead to neurodevelopmental delay in preterm infants. Clinical consequences include serious neuromuscular problems such as cerebral palsy, visual and hearing loss, and learning difficulties and psychological, behavioral, and social difficulties in surviving preterm infants.[18,19] A recent study has demonstrated an association of prematurity with features of autism spectrum.[20] Therefore, regular follow-up assessments of children at risk of neurodevelopmental disabilities may enable appropriate screening of developmental delay, and timely medical, educational, and social policy can be provided.[18-20]

While there is no standard tool for assessing developmental delay, the BSID and its revisions are the most widely used and well-designed tools.[21-23] The second edition of the Bayley scales (BSID-II) has been used in previous studies to determine developmental disabilities in preterm children and perinatal factors associated with poor outcomes.[24-26] A meta-analysis has shown the positive predictive value of the BSID-II for the development of preterm and VLBW children.[27] Neurodevelopmental outcomes of preterm children in Korea are also determined by screening instruments such as the Denver Developmental Screening Test-II (DDST-II) and the Ages

and Stages Questionnaire in Korea (K-ASQ).[10-11,28,29] The DDST-II is widely used as the screening test for evelopmental delay in the four areas of social contact, fine motor skill, gross motor skill, and language.[30] The K-ASQ is a standardized and culturally modified version of the ASQ, which is a parent-completed questionnaire suitable for young children in the US population.[30] The DDST-II and K-ASQ may present some difficulties in reflecting special developments in Korean children. Recently studies reported that the detection rate of neurological impairment for the DDST-II was 50.7% in neurological impairment of Korean infants,[31] and K-ASQ showed low validity for screening neurodevelopmentally delayed premature infants.[9] To reinforce this point, the K-DST was developed with cultural appropriateness in mind by the Korean Society of Pediatrics in 2014.[12] The K-DST, which is suitable for Korean infants and children, generally evaluates standard development.[12,32] Compared to the DDST-II and K-ASQ, the K-DST compensates for unsuitable questions related to the sociality and self-help domains.[29] In Korea, almost all infants and children are now being assessed for their serial developmental status from 4 to 71 months of age using the K-DST at primary care clinics.[29,33] However, the usefulness of the K-DST to evaluate developmental delay in preterm children has not been studied. Having a useful developmental screening test for preterm infants is very important for the early diagnosis of developmental delays, as some cases could resolve to almost normal developmental outcomes when early intervention and rehabilitation programs are used.[11,31]

In this study, the specificity of the individual K-DST domains compared to the BSID-II MDI and PDI was more than 70% in VLBW infants. Previous studies have demonstrated that sensitivity and specificity levels of 70% to 80% and PPV and NPV levels of at least 80% are deemed acceptable for developmental screening tests.[10,34,35] However, the sensitivity of the K-DST compared to the BSID-II MDI and PDI was low (less than 70%). Correlation analysis of the individual domains of the K-DST and BSID-II showed that four of the domains (fine motor, cognition, language, and sociality) on the K-DST were significantly associated with delayed BSID-II MDI scores, but not associated with delayed BSID-II PDI scores.

This discrepancy may have arisen from cultural differences between Korea and the US. Each K-DST domain was more significantly associated with predicting failing the MDI than failing the PDI. In particular, the cognition, language, and sociality domains of the K-DST had stronger correlations with the MDI. However, when we evaluated the validity of the K-DST for 196 VLBW infants who survived and whose BSID-II and K-DST were available at a corrected age of 18–41 months, the Spearman correlation coefficients of all 6 K-DST domains showed a significant correlation between the MDI or PDI and the K-DST, although the results were not shown in this study.

There are several limitations in our study. First, the study population involved a small number of infants and toddlers with a wide range of corrected age. Second, although this study reviewed data from 55 NICUs in Korea, the testing ability of Bayley examiners has not been standardized, which may have caused inter-observer discrepancies. Third, The BSID-II assesses the cognitive component by a combined measure of cognition and language.[19] If the results were evaluated using the BSID-II, which was developed to separate MDI into cognitive delay and language delay and separate PDI into gross and fine, it would have increased sensitivity. Lastly, developmental questionnaires were performed by primary caretakers, usually parents, which may have caused recall bias as well. However, our study has strength in that it is the first study that demonstrates the validity of the K-DST among VLBW infants in Korea.

In conclusion, preliminary results of this study indicate that the K-DST could be useful as a screening tool for the accurate and timely diagnosis of mental developmental delay in VLBW infants. Other prospective clinical trials are required to find the validity of the K-DST compared to the Korean version of the BSID-II or the BSID-III.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

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