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Speech Sound Development in Preterm Children Aged 3–4 Years: A Retrospective Observational Study

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ABSTRACT

Purpose: Despite advancements in improving survival rates, children born prematurely face high risks of neurodevelopmental delays, including speech sound disorders. This study aimed to (a) identify speech sound development trajectories in preterm children, (b) examine associated clinical and developmental characteristics, (c) analyze factors related to speech sound abilities, and (d) identify predictors of speech sound normalization.
Method: In this retrospective longitudinal study, 80 preterm children (born < 37 weeks of gestation, birth weight < 2.5 kg) were assessed for speech sound development. Based on percent consonants correct (PCC) scores at ages 3 and 4 years, children were categorized into four trajectory groups: normal, abnormal, catch-up, and growing into deficit. Analyses included trajectory comparisons, correlations between PCC and gestational age, birth weight, and cognitive/motor/language abilities, as well as examination of predictors of speech sound normalization.
Results: Over half of the children (51.3%) exhibited an abnormal trajectory, while 26.2% showed normal development, 20.0% demonstrated a catch-up trajectory, and 2.5% followed a growing-into-deficit pattern. Significant group differences were observed for sex, history of language intervention, and language abilities. PCC was significantly correlated with language quotients across ages. No significant factors predicted the normalization of speech sounds from ages 3 to 4 years.
Conclusions: Preterm children are at considerable risk for persistent speech sound difficulties, which are closely linked to speech-language abilities. Given the lack of predictors of normalization outcomes, universal monitoring and comprehensive language-based interventions are recommended for preterm children with and without delayed speech sound development at age 3 years.

Advances in perinatal medicine have significantly improved the survival rates of premature infants. However, major concerns remain regarding the neurodevelopmental outcomes of these children, who are at heightened risk for cognitive, motor, and language difficulties compared to full-term peers (Chung et al., 2020; Pierrat et al., 2021; Voss et al., 2016). These risks are exacerbated by lower gestational age and birth weight, and medical complications such as bronchopulmonary dysplasia (BPD) and intraventricular hemorrhage (IVH; Bolisetty et al., 2014; Gallini et al., 2021; Volpe, 2019; Zhou et al., 2024).

Among neurodevelopmental domains, language development in preterm children has been extensively studied.

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Meta-analyses confirm that preterm children exhibit significantly lower receptive and expressive language abilities than their full-term peers, with deficits emerging very early and often persisting into school age (Barre et al., 2011; van Noort-van der Spek et al., 2012; Zimmerman, 2018).

Language development and speech sound development are closely intertwined, as consistently reported in prior research (Choi et al., 2019; van Noort-van der Spek et al., 2022). This interdependence is further supported by the comorbidity between language and speech sound disorders (SSDs). Ko et al. (2017) reported that approximately 60% of children with SSDs also had co-occurring language impairments. These findings underscore the importance of examining speech sound development in preterm children in greater depth.

However, speech sound development in preterm children has received less attention and demonstrated inconsistent findings. While some studies report higher rates of speech sound production problems among preterm children, others find no significant group differences (Imgrund et al., 2023; Jennische & Sedin, 2001; Lewis et al., 2002; Sanchez et al., 2020; Shahramnia et al., 2023; Wolke et al., 2008).

These discrepancies likely reflect methodological differences and the inherent heterogeneity of preterm populations. For example, variations in speech assessment tasks can impact findings: Naturalistic speech samples may better detect phonological difficulties, whereas articulation tasks involving spontaneous or imitated productions may primarily reflect articulatory accuracy (van Noort-van der Spek et al., 2022). These task-related differences in what aspects of speech are measured may partly explain the variability in reported outcomes. Shahramnia et al. (2023) further supported this task-dependent variability, showing preterm children underperformed on single-word task, story-retelling task, and isolated and sequenced oral–motor movements, but not on one of the diadochokinetic tasks.

Gestational age also contributes to the heterogeneity of neurodevelopmental risks (Pierrat et al., 2021), particularly in preterm speech sound developmental deficits. Wolke et al. (2008) found that children born before 25 weeks of gestation were 4.4 times more likely to have speech sound problems than full-term peers. In contrast, studies that reported no group differences often included children born closer to term, with mean gestational ages of 31 weeks or < 30 weeks (Imgrund et al., 2023; Sanchez et al., 2020).

Interestingly, Jennische and Sedin (2001) reported findings that were even more paradoxical. They found more pronounced deviations–such as speech motor function or formal aspects of spontaneous speech–in moderately preterm children (born at 32 weeks of gestation or later) compared to extremely preterm infants (born < 32 weeks). These observations suggest that extremely preterm infants may benefit from more intensive medical care and early intervention, potentially mitigating developmental risks, while moderately preterm infants may receive less systematic attention. These findings highlight a complex, nonlinear relationship between gestational age and speech sound development outcomes.

Medical complications further compound this complexity. For instance, Lewis et al. (2002) found that very low birth weight children with BPD had significantly lower articulation scores than those without BPD, while very low birth weight children without BPD performed similarly to full-term controls. The study also revealed differing rates of IVH across groups: 44% of children with BPD had a history of IVH, compared to only 7% in the non-BPD very low birth weight group, and none in the full-term group. Although groupings were based on BPD status, the variation in IVH prevalence suggests a frequent co-occurrence of BPD and IVH in preterm infants. This overlap complicates the interpretation of speech sound outcomes, as it becomes difficult to determine whether speech sound differences are due to BPD, IVH, or their combined effects. These findings highlight the need to consider both the independent and interactive contributions of co-occurring medical complications, such as BPD and IVH, when examining speech sound development in preterm children.

In addition to medical complications, individual characteristics such as early cognitive or motor development may also influence speech sound outcomes. While no studies have directly examined these associations in preterm infants, research in general pediatric cohorts indicates that early cognitive and motor abilities are considered risk factors for later speech sound difficulties (Eadie et al., 2015; Pi & Ha, 2021). Similarly, male sex may also be associated with variability in speech sound development among preterm children. Research in general pediatric populations consistently shows that boys have a higher prevalence of SSDs than girls (Aslam et al., 2020; Campbell et al., 2003; Choo et al., 2022; Kim et al., 2015).

Collectively, these findings suggest that speech sound production abilities in preterm children can be influenced by various factors, including assessment methods, gestational age, medical complications, and individual characteristics. This complexity reflects the inherently heterogeneous nature of SSDs. To better understand the underlying causes of speech sound difficulties and to support diagnostic accuracy and intervention planning, ongoing efforts have been made to classify SSD subtypes (Waring & Knight, 2013). Among these efforts, widely recognized classification systems include the following:

Shriberg's Speech Disorders Classification System (SDCS) provides an etiological framework that categorizes

SSDs into three main classes: speech delay (SD), speech errors (SEs), and motor speech disorders (MSDs). Within this system, SD refers to age-inappropriate deletions and/or substitutions of speech sound, while SE involves age-inappropriate speech sound distortions. MSD includes childhood apraxia of speech (CAS), childhood dysarthria, and speech motor delay (SMD; Shriberg et al., 2017, 2019). The SDCS emphasizes underlying pathophysiological mechanisms and provides standardized diagnostic markers for each subtype. Dodd's Classification System (Dodd, 2014) organizes SSDs based on developmental patterns and underlying processing deficits: (a) articulation disorder–consistent substitutions or distortions of specific sounds; (b) phonological delay–typical, but age-inappropriate developmental patterns; (c) consistent phonological disorder–atypical and nondevelopmental patterns; (d) inconsistent phonological disorder–variable realizations of the same target words; and (e) CAS deficits in complex motor planning and programming.

Despite their usefulness, these systems present limitations in applicability across contexts and in capturing co-occurring difficulties. To address these limitations, Stringer et al. (2024) recently proposed a three-level terminology framework to standardize SSD classification. At Level 1, the term "speech sound disorder" serves as a broad diagnostic label. Level 2 distinguishes between SSDs of unknown origin and those associated with medical conditions. Level 3 further differentiates between motor/phonetic and linguistic/phonological difficulties to support clinical decision-making and intervention planning. This framework enhances diagnostic precision and may support more targeted interventions.

This study focuses on preterm children without structural or functional oral–motor abnormalities, enabling the investigation of speech sound development primarily from a phonological perspective. This aligns with Stringer et al.'s Level 3 classification, emphasizing phonological-level impairments. Given the high prevalence of medical complications in preterm populations, such conditions were not set as exclusion criteria. Instead, their potential impact on speech sound development will be examined. Should SSDs be identified, they will be interpreted within the Level 2 framework of Stringer et al.'s system.

A longitudinal approach is particularly valuable in preterm children, where developmental trajectories are often nonlinear and variable. Unlike cross-sectional studies, a longitudinal approach can capture dynamic changes such as recovery, plateauing, or emerging deficits. Developmental cascade models further suggest that early competence in one domain can influence outcomes in others over time, underscoring the importance of examining both timing and directionality in developmental change (Bornstein & Putnick, 2012; Masten & Cicchetti, 2010). These insights are essential for the early identification of children at risk and for guiding timely interventions.

From a clinical standpoint, understanding speech sound development trajectories in preterm children has significant implications for early identification and intervention. Early prediction of which children are likely to experience persistent difficulties versus those who will recover spontaneously is essential for optimizing the timing and allocation of supports. In general pediatric populations with SSDs, To et al. (2022) found that stimulability and intelligibility were stronger predictors of natural speech normalization than atypical error patterns or expressive language ability. However, it remains unclear whether these predictors apply similarly to preterm populations, who may have distinct neurodevelopmental profiles. Identifying factors associated with positive developmental trajectories in preterm children is therefore essential for developing evidence-based intervention strategies.

van Noort-van der Spek et al. (2022) conducted the first longitudinal study analyzing SSD trajectories in preterm children born at < 32 weeks gestation, from ages 2 to 4 years. They identified four distinct speech sound production trajectories: (a) normal trajectory–consistent typical development, (b) abnormal trajectory–persistent atypical speech sound production, (c) catch-up trajectory–early difficulties followed by normalization, and (d) growing-into-deficit trajectory–emergence of difficulties after initially typical development. The study also demonstrated significant associations between early speech sound production and later expressive language abilities, reinforcing the interconnected nature of these developmental domains.

Although informative, this study had some limitations. It included only very preterm children (< 32 weeks), thereby excluding the broader spectrum of preterm births. In addition, speech sound assessment methods differed between ages 2 and 4 years: Connected speech samples were used at age 2 years, whereas single-word tasks were employed at age 4 years, limiting the comparability of results. Finally, language abilities at age 4 years were not comprehensively assessed—receptive language was omitted, and expressive language was limited to word and sentence production tasks. Moreover, since sentence production was measured via imitation tasks, the influence of short-term memory rather than syntactic abilities could not be ruled out.

This study addresses these limitations by including preterm children across the full gestational age range, applying consistent standardized assessment methods across time points, and incorporating a comprehensive evaluation of both cognitive-motor development at age 2 years and language abilities at ages 3 and 4 years. Percentage of consonants correct (PCC) was selected as the primary outcome measure, based on established Korean normative data (Kim & Shin, 2005), which provide standardized developmental benchmarks and reliable −2 *SD* cutoffs for identifying SSDs at each age.

By systematically analyzing the effects of clinical and developmental characteristics on speech sound trajectories, this study aims to advance our understanding of the complex factors influencing speech sound development in preterm children. This study aims to (a) identify and classify speech sound development trajectories in preterm children from ages 3 to 4 years, and examine their distribution patterns (i.e., normal, abnormal, catch-up, and growing-into-deficit); (b) examine differences in clinical (i.e., sex, gestational age, birth weight, and history of BPD, IVH, and language intervention) and developmental characteristics (i.e., cognitive, motor, and language abilities) across speech sound development trajectory groups; (c) investigate factors associated with speech sound production abilities at ages 3 and 4 years in preterm children; and (d) identify predictors of speech sound normalization at age 4 years among preterm children with atypical speech sound production at age 3 years. Based on existing evidence and the exploratory nature of this study, we hypothesize that (a) preterm children would be classified into one of the four proposed developmental trajectories; (b) speech sound development trajectories would differ in medical complications (i.e., BPD and IVH) and developmental characteristics, particularly language abilities; (c) language abilities would be associated with speech sound production abilities at ages 3 and 4 years; and (d) the normalization of speech sound production deficits at age 4 years would be predicted by a combination of clinical and developmental factors, such as BPD, IVH, and language abilities.

Method

Participants

This retrospective study included preterm children who attended the Department of Rehabilitation Medicine at Asan Medical Center in Seoul, South Korea, between January 2014 and December 2023. Eligible participants met the following inclusion criteria: (a) Korean-speaking children born before 37 weeks of gestation with a birth weight under 2,500 g; (b) completion of a standardized developmental assessment at age 2 years; (c) completion of speech and language evaluations at ages 3 and 4 years; (d) absence of hearing impairment; (e) absence of congenital anomalies affecting speech (e.g., cleft lip and/or palate); (f) ability to perform oral feeding without difficulty, and no structural or functional oral–motor abnormalities, based on clinical observation of isolated oral–motor movements involving the lips and tongue; (g) no diagnosis of cerebral palsy; and (h) no dysarthric speech documented in medical records.

A total of 84 preterm children underwent a developmental assessment at age 2 years and completed speech and language evaluations at ages 3 and 4 years. However, four were excluded due to conditions known to impact speech sound production–including hearing impairment (*n* = 1), cleft palate (*n* = 2), and cerebral palsy with dysarthric speech (*n* = 1)—yielding a final sample of 80 preterm children (45 boys and 35 girls). The mean gestational age was 29.6 weeks (*SD* = 3.5), and the mean birth weight was 1,290.6 g (*SD* = 507.6). A history of BPD was reported in 30 children, while 34 had a history of Grades I–II IVH. Sixty-five children had received language intervention, and 15 had not. Their clinical characteristics are summarized in Table 1, with their developmental outcomes shown in Table 2.

Procedure and Measures

This study retrospectively analyzed medical records of eligible preterm children. Ethical approval was obtained from the institutional review board of the Asan Medical Center (IRB No. 2023–1549).

Variables for data collection were chosen based on the analysis by Pi and Ha (2021) of the risk factors for SSDs, including sex, early life factors (gestational age and birth weight), medical complications (history of BPD and IVH), developmental abilities (language, cognitive, and motor skills), and history of language intervention. BPD

Table 1. Clinical characteristics of participants (*n* = 80).

Category	Subcategory	Value
Sex	Boy	45 (56.25%)
	Girl	35 (43.75%)
GA	*Mdn*	30 weeks
	M (*SD*)	29.6 (3.5) weeks
	< 28 weeks	24 (30.0%)
	28–32 weeks	32 (40.0%)
	32–37 weeks	24 (30.0%)
BW	*Mdn*	1,260 g
	M (*SD*)	1,290.6 (507.6) g
	< 1 kg	28 (35.0%)
	1–1.5 kg	24 (30.0%)
	1.5–2.5 kg	28 (35.0%)
BPD	Yes	30 (37.5%)
	No	50 (62.5%)
IVH	Yes	34 (42.5%)
	No	46 (57.5%)
Language intervention	Yes	65 (81.25%)
	No	15 (18.75%)

Note. GA = gestational age; *Mdn* = median; BW = birth weight; BPD = bronchopulmonary dysplasia; IVH = intraventricular hemorrhage.

Table 2. Developmental outcomes of participants (n = 80).

Variable	2 years	3 years	4 years
Eval. age			
Mdn	26 months	39 months	51 months
M (*SD*)	25.9 (1.1) months	39.8 (3.2) months	51.6 (3.1) months
MDI			
Mdn	84		
M (*SD*)	84.6 (15.8)		
≥ 85	39 (48.75%)		
70–84	31 (38.75%)		
≤ 69	10 (12.5%)		
PDI			
Mdn	85		
M (*SD*)	83.6 (17.2)		
≥ 85	41 (51.25%)		
70–84	25 (31.25%)		
≤ 69	14 (17.5%)		
RLQ			
Mdn		100	100
M (*SD*)		95.1 (14.3)	98.7 (13.3)
≥ 85		63 (78.75%)	70 (87.5%)
< 85		17 (21.25%)	10 (12.5%)
ELQ			
Mdn		92.3	100
M (*SD*)		90.2 (14.7)	97.9 (13.8)
≥ 85		54 (67.5%)	68 (85.0%)
< 85		26 (32.5%)	12 (15.0%)
PCC			
Mdn		70.92%	83.72%
M (*SD*)		67.58 (17.9)%	82.10 (14.3)%
> −2 *SD*		23 (28.75%)	37 (46.25%)
≤ −2 *SD*		57 (71.25%)	43 (53.75%)

Note. *Mdn* = median; MDI = mental development index; PDI = psychomotor development index; RLQ = receptive language quotient; ELQ = expressive language quotient; PCC = percentage of consonants correct.

refers to a chronic lung condition common in preterm infants, and IVH refers to bleeding into the brain's ventricular system. Language intervention in this context is aimed at supporting language development. All data were collected using standardized clinical assessment tools used routinely in developmental follow-up at the institution.

According to Asan Medical Center's institutional follow-up protocol for preterm infants, comprehensive developmental and language assessments are conducted at age 2 years. In addition, annual speech and language evaluations are recommended from ages 3 to 6 years.

Developmental Assessment at Age 2 Years

Cognitive and motor abilities were assessed at age 2 years using the Bayley Scales of Infant and Toddler Development–Second Edition (BSID-II; Bayley, 1993). This standardized tool assesses overall developmental functioning in infants and toddlers, including cognitive abilities and both gross and fine motor skills. The assessment was administered by a licensed occupational therapist with over 10 years of clinical experience. As per the BSID-II manual, scores ≥ 85 on the mental development index (MDI) and psychomotor development index (PDI) are considered within the normal range.

Speech Sound Evaluation at Ages 3 and 4 Years

Speech evaluation consisted of two steps. First, oral–motor structure and functions were screened through clinical observation of isolated oral–motor movements. The assessment included lip opening, closure, protrusion, and retraction, as well as tongue protrusion, lateralization, and elevation. Movements were rated on a pass/fail basis based on the child's ability to follow instructions.

Second, speech sound production was evaluated using the Urimal Test of Articulation and Phonology (U-TAP; Kim & Shin, 2005), a standardized articulation and phonology test for Korean-speaking children aged 3–6 years. The test involves naming 30 target words through picture stimuli, allowing the natural production of consonants in initial, medial, and final positions. The assessment was conducted in real time by a Level 1–certified speech-language pathologist with over 10 years of clinical experience.

The primary measure of speech sound production was the PCC, which was calculated based on accurate production of Korean consonants across word positions. According to U-TAP normative data, children with PCC scores more than 2 *SD* below the age-specific mean were classified as having articulation-phonological disorders. The normative PCC values and cutoffs are age 3 years (M = 92.25%, −2 *SD* cutoff = 80.53%) and age 4 years (M = 95.23%, −2 *SD* cutoff = 86.29%).

Language Assessment at Ages 3 and 4 Years

Receptive and expressive language skills were assessed using the Preschool Receptive-Expressive Language Scale (Kim et al., 2003). This tool provides a comprehensive evaluation of language development, including semantics, syntax, phonology, and pragmatics in both receptive and expressive domains. Assessments were conducted by a Level 1–certified speech-language pathologist with over 10 years of clinical experience.

Language quotients were computed as follows: LQ = (Developmental Age/Chronological Age) × 100. According to Han and Kim (2021), children with LQ ≥ 85 were considered to have typical language development.

Speech Sound Development Trajectory Classification

Based on PCC scores at ages 3 and 4 years, participants were classified into one of four developmental trajectories: (a) Trajectory I (normal trajectory)—PCC at ages 3 and 4 years above −2 *SD* from the age-specific norm; (b) Trajectory II (abnormal trajectory)—PCC at ages 3 and 4 years below −2 *SD* from the age-specific norm; (c) Trajectory III (catch-up trajectory)—PCC below −2 *SD* at age 3 years but above −2 *SD* at age 4 years; and (d) Trajectory IV (growing-into-deficit trajectory)—PCC above −2 *SD* at age 3 years but below −2 *SD* at age 4 years.

Data Extraction and Verification

Data were retrospectively extracted from electronic medical records using a predefined coding framework by the primary investigator. To ensure accuracy and consistency, a second independent reviewer cross-checked all records. Complete agreement was observed between the two reviewers, confirming the reliability of the data extraction process.

Statistical Analysis

All statistical analyses were performed using SPSS Statistics Version 20.0 (IBM Corp., 2011). Descriptive statistics were used to summarize the distribution and characteristics of the four speech sound development trajectories. Due to the small number of participants in the growing-into-deficit trajectory (Trajectory IV, n = 2), this group was excluded from comparative analyses. Chi-square tests were used for comparing categorical variables (i.e., sex, BPD, IVH, and language intervention history) across trajectories. One-way analysis of variance was used to compare continuous variables (i.e., MDI and PDI at age 2 years; receptive and expressive language quotient [RLQ, ELQ] at ages 3 and 4 years). Post hoc analyses using Bonferroni correction were applied for variables showing statistically significant group differences.

To explore factors associated with speech sound production abilities at ages 3 and 4 years, Pearson correlation analyses were conducted for all 80 participants. The strength of correlations was interpreted according to Cohen's (1988) criteria (small: r = .10–0.29, medium: r = .30–0.49, large: $r \geq .50$). Additionally, to identify predictors of typical speech sound production at age 4 years in children with below-normal speech sound production at age 3 years, binary logistic regression analysis was performed on 57 children from the abnormal (Trajectory II) and catch-up (Trajectory III) groups.

Results

Distribution and Characteristics of Speech Sound Development Trajectories

Among the 80 preterm children included in the study, four speech sound development trajectories were identified: normal trajectory (Trajectory I: 21 children, 26.2%), abnormal trajectory (Trajectory II: 41 children, 51.3%), catch-up trajectory (Trajectory III: 16 children, 20%), growing-into-deficit trajectory (Trajectory IV: two children, 2.5%). Participant clinical characteristics (i.e., sex, gestational age, birth weight, history of BPD, IVH, and language intervention) are summarized in Table 3. Developmental information, including MDI and PDI at age 2 years, RLQ and ELQ at ages 3 and 4 years, and PCC scores, is detailed in Table 4.

Differences Across Speech Sound Development Trajectories

Statistical analyses were conducted to examine differences in clinical and developmental profiles across the four trajectories. The results revealed significant differences in sex distribution (χ^2 = 8.462, p = .015), history of language intervention (χ^2 = 8.901, p = .012), ELQ at age 3 years (p = .010), RLQ at age 4 years (p = .011), and ELQ at age 4 years (p = .004) across trajectories.

Post hoc analyses revealed a higher proportion of boys in the catch-up trajectory (Trajectory III) compared

Table 3. Clinical characteristics by speech sound development trajectory in preterm children.

Characteristics	Trajectory I (n = 21)	Trajectory II (n = 41)	Trajectory III (n = 16)	Trajectory IV (n = 2)
Sex				
Boy	7 (33.3%)	23 (56.1%)	13 (81.2%)	2 (100.0%)
Girl	14 (66.7%)	18 (43.9%)	3 (18.8%)	0 (0.0%)
GA				
Mdn	31 weeks	30 weeks	28.5 weeks	30 weeks
M (*SD*)	29.7 (3.1) weeks	30.1 (3.6) weeks	28.3 (3.3) weeks	30.0 (4.0) weeks
< 28 weeks	7 (33.3%)	10 (24.4%)	6 (37.5%)	1 (50.0%)
28–32 weeks	9 (42.9%)	17 (41.5%)	6 (37.5%)	0 (0.0%)
32–37 weeks	5 (23.8%)	14 (34.1%)	4 (25.0%)	1 (50.0%)
BW				
Mdn	1,310 g	1,380 g	1,000 g	1,190 g
M (*SD*)	1,329.1 (545.3) g	1,352.7 (534.7) g	1,093.6 (376.9) g	1,190.0 (80.0) g
< 1 kg	8 (38.1%)	12 (29.3%)	8 (50.0%)	0 (0.0%)
1–1.5 kg	5 (23.8%)	11 (26.8%)	6 (37.5%)	2 (100.0%)
1.5–2.5 kg	8 (38.1%)	18 (43.9%)	2 (12.5%)	0 (0.0%)
BPD				
Yes	6 (28.6%)	14 (34.1%)	9 (56.3%)	1 (50.0%)
No	15 (71.4%)	27 (65.9%)	7 (43.7%)	1 (50.0%)
IVH				
Yes	11 (52.4%)	14 (34.1%)	8 (50.0%)	1 (50.0%)
No	10 (47.6%)	27 (65.9%)	8 (50.0%)	1 (50.0%)
LI				
Yes	13 (61.9%)	38 (92.7%)	12 (75.0%)	2 (100.0%)
No	8 (38.1%)	3 (7.3%)	4 (25.0%)	0 (0.0%)

Note. GA = gestational age; *Mdn* = median; BW = birth weight; BPD = bronchopulmonary dysplasia; IVH = intraventricular hemorrhage; LI = language intervention.

to the normal trajectory (Trajectory I; p = .004). More children in the abnormal trajectory (Trajectory II) received language intervention compared with those in the normal trajectory (p = .005). Children in the abnormal trajectory (Trajectory II) had significantly lower ELQ at both age 3 years (p = .012) and age 4 years (p = .008), and lower RLQ at age 4 years (p = .012) compared to those in the normal trajectory (Trajectory I).

In contrast, no significant differences were observed across trajectories in: gestational age (p = .188), birth weight (p = .218), history of BPD (p = .190), IVH (p = .304), MDI at age 2 years (p = .711), PDI at age 2 years (p = .410), and RLQ at age 3 years (p = .243). Complete results of these comparisons are summarized in Table 5.

Factors Associated With Speech Sound Production

Pearson correlation analyses examined the factors associated with speech sound production abilities at ages 3 and 4 years among the 80 preterm children. Results showed that PCC at age 3 years was significantly correlated with ELQ at age 3 years (r = .500, p < .01; large), RLQ at age 4 years (r = .268, p < .05; small), and ELQ at age 4 years (r = .343, p < .01; medium), while PCC at age 4 years was significantly correlated with RLQ at age 3 years (r = .273, p < .05; small), ELQ at age 3 years (r = .460, p < .01; medium), RLQ at age 4 years (r = .442, p < .01; medium), and ELQ at age 4 years (r = .460, p < .01; medium). Additionally, a strong correlation was found between PCC at age 3 years and PCC at age 4 years (r = .654, p < .01; large), suggesting a strong relationship between speech sound production abilities over time. The results are presented in Table 6.

Predictors of Speech Sound Outcomes

To identify predictors of typical speech sound production at age 4 years among preterm children who showed below-typical performance at age 3 years (i.e., children in the abnormal and catch-up trajectories), a binary logistic regression analysis was conducted (n = 57). The dependent variable was PCC at age 4 years, and

Table 4. Developmental characteristics by speech sound development trajectory in preterm children.

Variable	Trajectory I (n = 21)	Trajectory II (n = 41)	Trajectory III (n = 16)	Trajectory IV (n = 2)
MDI at 2				
Mdn	84.0	85.0	83.5	73.5
M (*SD*)	86.0 (19.4)	83.5 (15.3)	87.1 (12.9)	73.5 (1.5)
≥ 85	10 (47.6%)	22 (53.7%)	7 (43.8%)	0 (0.0%)
70–84	8 (38.1%)	13 (31.7%)	8 (50.0%)	2 (100.0%)
≤ 69	3 (14.3%)	6 (14.6%)	1 (6.2%)	0 (0.0%)
PDI at 2				
Mdn	85.0	84.0	85.5	78.0
M (*SD*)	88.1 (17.7)	82.0 (17.1)	82.8 (17.6)	78.0 (5.0)
≥ 85	12 (57.1%)	20 (48.8%)	9 (56.2%)	0 (0.0%)
70–84	5 (23.8%)	14 (34.1%)	4 (25.0%)	2 (100.0%)
≤ 69	4 (19.0%)	7 (17.1%)	3 (18.8%)	0 (0.0%)
RLQ at 3				
Mdn	100.0	100.0	102.5	86.4
M (*SD*)	97.8 (13.5)	92.7 (15.4)	98.7 (12.2)	86.4 (5.9)
≥ 85	18 (85.7%)	30 (73.2%)	14 (87.5%)	1 (50.0%)
< 85	3 (14.3%)	11 (26.8%)	2 (12.5%)	1 (50.0%)
ELQ at 3				
Mdn	100.0	90.2	95.0	73.2
M (*SD*)	97.1 (9.9)	86.1 (16.4)	93.9 (10.9)	73.2 (3.7)
≥ 85	18 (85.7%)	23 (56.1%)	13 (81.2%)	0 (0.0%)
< 85	3 (14.3%)	18 (43.9%)	3 (18.8%)	2 (100.0%)
PCC at 3				
Mdn	83.7%	62.8%	72.1%	82.6%
M (*SD*)	86.2 (5.4)%	56.9 (16.6)%	68.7 (9.4)%	82.6 (1.2)%
RLQ at 4				
Mdn	100.0	100.0	100.0	99.2
M (*SD*)	104.7 (10.7)	94.5 (14.5)	101.5 (9.8)	99.2 (10.8)
≥ 85	20 (95.2%)	33 (80.5%)	15 (93.8%)	2 (100.0%)
< 85	1 (4.8%)	8 (19.5%)	1 (6.2%)	0 (0.0%)
ELQ at 4				
Mdn	101.7	100.0	100.0	92.5
M (*SD*)	104.0 (12.1)	93.3 (13.5)	102.5 (12.1)	92.5 (17.5)
≥ 85	20 (95.2%)	32 (78.0%)	15 (93.8%)	1 (50.0%)
< 85	1 (4.8%)	9 (22.0%)	1 (6.2%)	1 (50.0%)
PCC at 4				
Mdn	93.0%	72.1%	95.3%	84.88%
M (*SD*)	94.4 (4.1)%	71.0 (11.1)%	94.3 (4.1)%	84.88 (1.2)%

Note. MDI = mental development index; *Mdn* = median; PDI = psychomotor development index; RLQ = receptive language quotient; ELQ = expressive language quotient; PCC = percentage of consonants correct.

predictors included: sex, gestational age, birth weight, history of BPD, IVH, and language intervention, MDI and PDI at age 2 years, and RLQ and ELQ at age 3 years.

Neither univariate nor multivariable logistic regression analyses identified any statistically significant predictors for achieving typical speech sound production at age 4 years. The results of the regression analyses are presented in Table 7.

Discussion

Distribution and Characteristics of Speech Sound Development Trajectories

This is the first longitudinal study to systematically examine speech sound development trajectories in preterm children aged 3–4 years in Korea. Our analysis identified four distinct trajectories, underscoring the heterogeneity of this population. Notably, 73% (57 of 80) of preterm

Table 5. Differences in clinical and developmental characteristics by speech sound development trajectory.

Variables	Trajectory I (*n* = 21)	Trajectory II (*n* = 41)	Trajectory III (*n* = 16)	χ^2/F	*p* value	Post hoc analysis
Sex (boy)	7 (33.3%)	23 (56.1%)	13 (81.2%)	8.462*	.015	Trajectory I vs. Trajectory III**
GA (weeks)	29.7 (3.1)	30.1 (3.6)	28.3 (3.3)	1.708	.188	
BW (g)	1,329.1 (545.3)	1,352.7 (534.7)	1,093.6 (376.9)	1.555	.218	
BPD (yes)	6 (28.6%)	14 (34.1%)	9 (56.3%)	3.319	.190	
IVH (yes)	11 (52.4%)	14 (34.1%)	8 (50.0%)	2.380	.304	
LI (yes)	13 (61.9%)	38 (92.7%)	12 (75.0%)	8.901*	.012	Trajectory I vs. Trajectory II**
MDI at 2	86.0 (19.4)	83.5 (15.3)	87.1 (12.9)	0.342	.711	
PDI at 2	88.1 (17.7)	82.0 (17.1)	82.8 (17.6)	0.901	.410	
RLQ at 3	97.8 (13.5)	92.7 (15.4)	98.7 (12.2)	1.442	.243	
ELQ at 3	97.1 (9.9)	86.1 (16.4)	93.9 (10.9)	4.944*	.010	Trajectory I vs. Trajectory II**
RLQ at 4	104.7 (10.7)	94.5 (14.5)	101.5 (9.8)	4.824*	.011	Trajectory I vs. Trajectory II**
ELQ at 4	104.0 (12.1)	93.3 (13.5)	102.5 (12.1)	6.015**	.004	Trajectory I vs. Trajectory II**

Note. χ^2 = chi-square value; *F* = *F* value from one-way analysis of variance; GA = gestational age; BW = birth weight; BPD = bronchopulmonary dysplasia; IVH = intraventricular hemorrhage; LI = language intervention; MDI = mental development index; PDI = psychomotor development index; RLQ = receptive language quotient; ELQ = expressive language quotient.

*$p < .05$. **$p < .01$.

children exhibited deficits in speech sound production at age 3 years, among whom 28% (16 of 57) showed normalization by age 4 years. This finding indicates a potential catch-up in speech sound production that may extend beyond early preschool years. The predominance of the abnormal trajectory (51.3%) aligns with prior findings linking prematurity and low birth weight to an elevated risk of SSDs (Fox et al., 2002).

In contrast to our results, van Noort-van der Spek et al. (2022) reported a higher prevalence of the normal trajectory (51%). This discrepancy may partially stem from differences in sample characteristics and the methodological design. This retrospective study analyzed data from preterm children who underwent routine developmental follow-up at a tertiary center. This structure and the protocol of this setting may naturally engage families who are more vigilant in tracking developmental outcomes, thereby increasing the likelihood of identifying children with subtle or emerging concerns. Therefore, this recruitment context should be considered when interpreting the generalizability of our findings in relation to the broader preterm population.

Table 6. Factors associated with speech sound production ability in preterm children (*n* = 80).

Factors	PCC at 3 years	PCC at 4 years
GA	−0.096	−0.019
BW	−0.152	−0.035
MDI at 2	0.130	0.204
PDI at 2	0.128	0.150
RLQ at 3	0.172	0.273*
ELQ at 3	0.500**	0.460**
PCC at 3	1	0.654**
RLQ at 4	0.268*	0.442**
ELQ at 4	0.343**	0.460**
PCC at 4	0.654**	1

Note. PCC = percentage of consonants correct; GA = gestational age; BW = birth weight; MDI = mental development index; PDI = psychomotor development index; RLQ = receptive language quotient; ELQ = expressive language quotient.

*$p < .05$. **$p < .01$.

In addition, the shorter observation window in our study, which only covered development from 3 to 4 years of age, may partly explain the lower proportion of individuals following the catch-up trajectory. In contrast, the previous study by van Noort-van der Spek et al. (2022) assessed children at ages 2 and 4 years. Direct comparison of trajectory distributions is limited as they did not include an assessment at age 3 years. Nevertheless, the longer observation period in their study may have increased the likelihood of detecting children who exhibited difficulties at age 2 years but had normalized by age 4 years.

One finding of particular interest in this study was the identification of a small subgroup (2.5%) that followed a growing-into-deficit trajectory. These two children were both extremely low birth weight boys who demonstrated normal speech sound production at age 3 years but fell below the −2 *SD* cutoff by age 4 years. Their borderline consonant accuracies at age 3 years of 81.4% and 83.72%

Table 7. Binary logistic regression predicting normalization of speech sound production at age 4 years (n = 57).

Variables	Odds ratio	95% confidence interval	p value
Sex (boy)	5.500	[0.821, 36.822]	.079
GA	0.855	[0.634, 1.154]	.306
BW	0.999	[0.997, 1.002]	.611
BPD (yes)	0.614	[0.071, 5.338]	.659
IVH (yes)	1.396	[0.301, 6.476]	.670
LI (yes)	0.244	[0.032, 1.854]	.173
MDI at 2	0.985	[0.917, 1.059]	.686
PDI at 2	0.996	[0.946, 1.050]	.894
RLQ at 3	1.010	[0.924, 1.105]	.822
ELQ at 3	1.045	[0.951, 1.148]	.364

Note. GA = gestational age; BW = birth weight; BPD = bronchopulmonary dysplasia; IVH = intraventricular hemorrhage; LI = language intervention; MDI = mental development index; PDI = psychomotor development index; RLQ = receptive language quotient; ELQ = expressive language quotient.

were just over the threshold of 80.53% to meet the criteria for −2 *SD*. Despite appearing normal at age 3 years, both children showed mild delays in cognitive and motor development at age 2 years (MDI: 75 and 72; PDI: 83 and 73) and expressive language delays at age 3 years (ELQ: 77 and 72). These findings may be explained by the developmental cascade theory (Bornstein & Putnick, 2012; Masten & Cicchetti, 2010), which posits that early deficits in one domain can lead to cascading difficulties in others. The developmental course of these two children illustrates this process, showing how early vulnerabilities in cognitive and motor domains, followed by language delays, can ultimately manifest as speech sound difficulties. These findings further highlight the importance of monitoring trajectory direction over time rather than focusing on a single time point.

From a clinical perspective, this trajectory emphasizes the importance of ongoing developmental surveillance, even among children who initially appear to be developing within normal limits. Children with borderline scores or subtle early vulnerabilities should therefore be considered at risk and monitored more closely. This is important because overt speech sound deficits may not emerge until later, thus supporting the need for individualized monitoring protocols.

In Korea, children are most commonly referred for evaluation or intervention for speech sound problems at 4–5 years of age (Kim et al., 2015). However, given the high prevalence and persistence of speech sound difficulties among preterm children observed in this study, earlier identification and intervention are crucial to prevent these difficulties from becoming entrenched.

Differences Across Speech Sound Development Trajectories

The second objective of this study, which was to explore differences in clinical and developmental characteristics across trajectories, revealed several key patterns. The proportion of boys was significantly higher in the catch-up trajectory (Trajectory III) than in the normal trajectory (Trajectory I). Although evidence indicates higher rates of SSDs in boys (Aslam et al., 2020; Campbell et al., 2003; Choo et al., 2022; Kim et al., 2015), Korean normative data suggest that boys may exhibit more delayed but steeper developmental gains. For example, although boys initially lag behind girls in consonant accuracy at ages 3 and 4 years (91.75% vs. 92.58%; 94.16% vs. 96.17%, respectively), they tend to surpass girls by ages 5 and 6 years (98.26% vs. 96.27%, 98.43% vs. 97.50%, respectively; Kim & Shin, 2005). This developmental pattern may help explain the overrepresentation of boys in the catch-up trajectory observed in the present study.

A significant difference in language intervention experience between trajectories (92.7% vs. 61.9% in abnormal and normal trajectories, respectively) showed that a higher proportion of children in the abnormal trajectory (Trajectory II) received language intervention. This likely reflects the lower ELQ at age 3 years and both RLQ and ELQ at age 4 years in this group. Language ability appeared to differentiate the trajectories, with statistical significance observed only between normal and abnormal trajectories. Children in the catch-up trajectory (Trajectory III) displayed mean language scores that were intermediate between the two groups. However, these differences were not statistically significant. Collectively, these results suggest that language differences emerged primarily between the normal and abnormal trajectories, underscoring language abilities as an important marker for distinguishing between typical and atypical groups of speech sound development.

No significant differences were observed in BPD, IVH, or developmental indices (MDI or PDI). This may be because of the limited variability of the sample, as all children with IVH had only mild grades (I–II), and developmental scores at age 2 years were largely within the borderline-to-normal range (≥ 85), thereby limiting the statistical power to detect differences. These findings suggest that, within the context of this sample, mild IVH or BPD may not substantially contribute to variations in speech sound development trajectories.

From the perspective of Stringer et al.'s (2024) three-level terminology model, the trajectory patterns observed in preterm children in this study can be interpreted as follows. All trajectories except the normal trajectory (Trajectory I) fall within the broad Level 1 category of SSD. In our sample, however, Level 2 etiological factors such as BPD and IVH did not differentiate the trajectories within Level 1. Finally, although children with structural or functional oral–motor abnormalities were excluded, detailed error analyses were not conducted. Therefore, the possibility of MSDs such as CAS or SMD cannot be fully ruled out, and the findings should be interpreted with caution.

Factors Associated With Speech Sound Production

The third objective was to examine the factors associated with speech sound production at ages 3 and 4 years. When examining concurrent associations, PCC at age 3 years was significantly associated only with ELQ, while no significant correlation was observed with RLQ. By age 4 years, PCC was related to both RLQ and ELQ, although the strength of these associations was modest. Choi et al. (2019) reported strong correlations between consonant accuracy and both receptive and expressive language development. Although the associations observed in the present study were modest, it is noteworthy that similar relationships between speech sound production and language abilities were confirmed within a preterm cohort. In addition, Ko et al. (2017) observed that children with SSDs more frequently exhibited co-occurring expressive language delays than receptive delays. Our finding that PCC at age 3 years was significantly related to ELQ, but not to RLQ, supports their observation.

When considering cross-age associations, PCC at age 3 years was significantly associated with RLQ and ELQ at age 4 years, while PCC at age 4 years was also related to RLQ and ELQ at age 3 years, with stronger associations for ELQ. These results support the findings of van Noort-van der Spek et al. (2022), who reported that early speech sound production predicted expressive language at 4 years of age in preterm children.

Together, these findings indicate that speech and language development in preterm children are closely interconnected, with associations evident not only concurrently but also across ages. This pattern suggests that speech and language may interact in a bidirectional manner over time.

From a clinical standpoint, these findings emphasize the importance of incorporating both speech and language measures in assessment. Recognizing their interconnections may help provide a more comprehensive understanding of developmental profiles in preterm children.

Predictors of Speech Sound Outcomes

The final objective, to identify predictors of speech sound normalization at age 4 among children who were delayed at age 3 years, yielded no significant predictors. This result points to the challenges of identifying predictors of speech sound outcomes in preterm children. However, the absence of significant predictors does not necessarily indicate that speech sound normalization is inherently multifactorial, particularly given that not all potential predictors were measured. Prior studies have identified several relevant predictors of speech sound outcomes that were not assessed in the present study, including stimulability and intelligibility (To et al., 2022) as well as environmental factors such as socioeconomic status, maternal vocabulary, and family history of speech or language difficulties (Eadie et al., 2015). The lack of these data may have masked potential predictive relationships.

Additionally, limitations such as the homogeneity of our sample (e.g., mild complications only) likely contributed to the lack of significant findings. For example, although some participants experienced IVH, all cases were classified as Grade I or II, defined as those involving minimal to mild bleeding confined to the germinal matrix or ventricles without ventricular dilation. Unlike Grade III or IV hemorrhages, lower grade hemorrhages typically resolve without significant long-term neurological sequelae (Legge et al., 2022).

Ultimately, owing to the heterogeneous nature of SSDs and the inability to identify clear predictors, universal and ongoing monitoring of all preterm children with speech sound delays at age 3 years is necessary, regardless of individual profiles. This highlights the importance of using comprehensive approaches rather than selective therapy based on limited risk indicators.

Clinical Implications and Recommendations

This study emphasizes the critical need for longitudinal monitoring and early intervention for speech sound development in preterm children. The high prevalence of persistent speech difficulties underscores the importance of early and intensive speech sound therapy. The emergence of a growing-into-deficit trajectory highlights that continued assessment of speech sound production is necessary during the transition from ages 3 to 4 years, even when early evaluations indicate normality. Importantly, some borderline-normal preterm children require closer monitoring than those with clearly typical skills.

The significant associations between speech sound development and language abilities reinforce the need to integrate both domains in clinical decision making. The absence of clear predictors of normalization further supports the need for comprehensive and universal follow-up protocols rather than relying on early risk stratification alone.

Limitations and Future Research Directions

This study had some limitations. First, the single-center, retrospective design with recruitment from a tertiary medical center limits the generalizability of our results. Second, the relatively short follow-up period (ages 3–4 years) may not fully capture the developmental trajectories that typically stabilize at approximately age 5 years. Third, oral–motor function was evaluated using isolated movements rather than speech motor tasks (e.g., diadochokinetic rates), potentially overlooking subtle speech motor deficits that could have influenced the trajectory patterns. Fourth, because speech productions were transcribed in real time without audio recordings, transcription reliability could not be assessed. Furthermore, this study did not include an analysis of specific phonological error patterns, thus limiting insights into the underlying phonological processes that distinguish the different trajectories and identify possible predictors. Finally, potentially relevant predictors such as stimulability and intelligibility were not included, and environmental factors such as home language environment and intervention dosage or intensity were not systematically captured.

Despite these limitations, the present study offers novel longitudinal data on speech sound development trajectories in preterm children and highlights clinically relevant associations that can inform assessment and intervention planning. Further studies should adopt multi-center, prospective designs with extended follow-up through age 6 years, as well as incorporate audio-recorded transcription procedures to ensure reliability, comprehensive speech motor assessments (including diadochokinetic tasks), detailed phonological error pattern analysis, and systematic assessment of other unmeasured factors. These enhancements would improve the ability to distinguish between phonological and motor-based disorders, identify the phonological processes associated with each trajectory, and clarify the factors contributing to successful recovery in the catch-up group.

Conclusions

This study identified four distinct speech sound development trajectories in preterm children between the ages of 3 and 4 years, with more than half showing persistent difficulties. Significant associations between speech and language development underscore the need for integrated assessment strategies in clinical practice. Given the variability and the difficulty of identifying clear predictors of normalization, universal monitoring and early intervention are recommended for all preterm children with speech sound delays, irrespective of initial risk factors. These findings offer valuable insights to inform evidence-based practices aimed at optimizing communication outcomes in this high-risk population.

Data Availability Statement

The de-identified data generated and analyzed in this study are available from the corresponding authors upon reasonable request.

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