children

MDPI

Article

Comparative Evaluation of Children with and Without Speech Disorders Utilizing the Nordic Orofacial Test-Screening and Kotlow's Classification System

Elis Dayan [1,*], Deniz Özkuyucu [1], Melike Balaban [1], Emre Oğuzbal [1], Sibel Emiroğlu [1], Nurcan Alpüran Kocabıyık [2] and Elif Sepet [1]

[1] Department of Pediatric Dentistry, Faculty of Dentistry, İstanbul Kent University, Istanbul 34310, Türkiye; deniz.ozkuyucu@kent.edu.tr (D.Ö.); melike-tandogan@hotmail.com (M.B.); emreoguzbal24@gmail.com (E.O.); sibel.emiroglu@kent.edu.tr (S.E.); elif.sepet@kent.edu.tr (E.S.)

[2] Department of Speech and Language Therapy, Faculty of Health Sciences, İstanbul Kent University, Istanbul 34406, Türkiye; nurcanalpuran@kent.edu.tr

* Correspondence: elis.dayan@kent.edu.tr; Tel.: +90-545-919-1666

Highlights

What are the main findings?

- Children with speech disorders had higher NOT-S total and examination scores, and these differences persisted after adjustment for age, sex, and systemic conditions.
- In this sample, no severity-related association was found between Kotlow class or free tongue length and NOT-S scores; given the small sample, this does not rule out an effect of tongue-tie.

What are the implications of the main findings?

- Anatomical assessment of tongue-tie alone may be insufficient and should be complemented by functional orofacial and speech and language evaluation.
- In children with speech disorders, decisions regarding frenectomy should not be based on frenulum length alone but should include functional and speech and language assessment.

Abstract

Background: Orofacial dysfunction may co-occur with speech and language disorders. This study compared orofacial function in children with and without speech disorders using the Nordic Orofacial Test-Screening (NOT-S) and examined whether Kotlow tongue-tie severity is associated with orofacial function. Methods: This cross-sectional study included 77 children aged 5–13 years (37 with speech and language disorders [SD]; 40 without [N]). Orofacial function was screened with the NOT-S, and free tongue length was classified according to Kotlow. Nonparametric and exact tests, Poisson regression adjusted for age, sex, and systemic conditions, and sensitivity analyses were used. Results: The SD group had higher NOT-S total (median 3 vs. 1; $p < 0.001$; $r = 0.50$) and examination scores ($p < 0.001$; $r = 0.76$) than the N group, whereas interview scores did not differ. After Holm correction, facial expression, oral motor function, and speech remained more frequently impaired. The difference persisted after adjustment (incidence rate ratio 2.21, 95% CI 1.53–3.19), in children without systemic conditions, and after exclusion of the speech domain. Tongue-tie prevalence and free tongue length did not differ between groups, and no severity-related association with NOT-S scores emerged. Conclusions: Children with speech disorders had higher NOT-S scores, which persisted after adjustment for age, sex, and systemic conditions, whereas no statistically significant association between tongue-tie severity and

Check for updates

Academic Editor: Massimo Pisano

Received: 15 September 2026
Revised: 19 October 2026
Accepted: 21 October 2026
Published: 22 October 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

orofacial function was demonstrated in this small sample, which does not rule out an effect. Anatomical frenulum assessment alone may be insufficient and should be complemented by functional and speech and language evaluation.

Keywords: speech disorders; tongue-tie; NOT-S; Kotlow; ankyloglossia; orofacial function

1. Introduction

The orofacial complex is composed of the masticatory and facial expression muscles, bones, joints, ligaments, and teeth. Orofacial functions are the result of the integrated activity of the central nervous system and the neuromuscular system. These functions not only encompass vital actions such as respiration, mastication, and swallowing, but also form the basis of social interaction through speech, sensory communication, facial expression, and physical appearance [1,2]. Orofacial dysfunctions are frequently related to genetic and congenital disorders. However, they may also be observed in otherwise healthy children as a consequence of various diseases, trauma, or habits [2].

Orofacial functions—including mastication, swallowing, breathing, and the precise coordination of tongue, lip, and jaw movements—play a fundamental role in the development of intelligible speech. Disruptions in these functions may interfere with the motor control and articulatory precision required for typical speech production, and several studies have highlighted the close interplay between orofacial competence and speech development. Given this anatomical and functional interdependence, difficulties in orofacial regulation may manifest clinically as speech-related problems, ranging from subtle articulation errors to broader deficits in speech intelligibility [3]. In a cohort of children with speech sound disorders persisting after six years of age, 87% showed orofacial difficulties on the NOT-S, and the majority also had co-existing general motor or neurodevelopmental difficulties [4]. Similarly, children and adolescents with speech sound disorders have been reported to have poorer orofacial function and a higher prevalence of malocclusion than peers with typical speech development [3]. Nevertheless, the relationship between nonspeech oral motor function and speech motor control is complex, and the clinical significance of nonspeech oral motor findings for speech remains debated [5]. Taken together, these findings underscore the importance of evaluating speech within the broader context of orofacial function.

"Speech disorders" is an umbrella term encompassing a broad range of difficulties interfering with the accurate and intelligible production of spoken language. Speech is generated through the coordinated movement of the lips, tongue, velum, and laryngeal structures, and disruptions in the articulation of sounds, voice quality, or speech fluency are collectively classified under this overarching category [6]. Within this broad framework, speech sound disorders (SSD) represent one of the most common subtypes and are characterized by inappropriate or inaccurate production of speech sounds compared with age-matched peers [7]; although SSD are often of unknown origin, they may also occur in association with hearing loss, structural anomalies, or neuromotor and neurodevelopmental conditions [8]. SSD typically include both articulation and phonological disorders, whereas other speech disorders include fluency disorders, such as stuttering, voice disorders, and motor speech disorders, such as childhood apraxia of speech and dysarthria [6]. In clinical practice, speech disorders frequently co-occur with language disorders, and both may be part of the clinical presentation of neurodevelopmental or genetic conditions such as autism spectrum disorder or Down syndrome [4]. In the present study, the term "speech disorders" is therefore used broadly to include speech sound, language, fluency, and motor speech disorders, irrespective of their etiology. This classification provides an essential conceptual

foundation for understanding the diverse mechanisms that may underlie reduced speech intelligibility in children [7,9].

If not addressed early, orofacial dysfunctions can negatively affect quality of life [10]. Although many protocols exist for quantifying orofacial dysfunction, the increasing need for a common language and evidence-based practice in interdisciplinary collaboration led to the development of the Nordic Orofacial Test-Screening (NOT-S) in 2002. It has been recognized as a valid and reliable screening method [11]; it consists of a structured interview and a clinical examination and is used in children aged three years and older with difficulties in speech, chewing, or swallowing [10,11]. As a screening instrument, NOT-S is intended to identify areas of orofacial dysfunction that require further assessment rather than to establish a specific diagnosis. In its original validation, NOT-S showed high sensitivity (0.96) but moderate specificity (0.63), and inter-examiner agreement was moderate before examiner calibration [1]. Since orofacial function and tongue mobility may affect speech production, it is crucial to evaluate these domains using standardized tools and validated classification systems.

Ankyloglossia, commonly known as "tongue-tie," is a congenital disorder characterized by an abnormally short lingual frenulum that restricts tongue mobility. Early identification of individuals with ankyloglossia is of great importance, particularly during the period of craniofacial development [12]. In the presence of evident breastfeeding or speech difficulties in infants or young children, dentists require classification systems for accurate diagnosis and appropriate treatment planning. Various methods have been described to assess the severity of ankyloglossia and limitations in tongue mobility, such as Coryllos, Kotlow, and the Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF) [13]. In this study, the Kotlow Classification of Ankyloglossia was used [14,15]. This classification system was chosen because it is one of the most widely applied clinical methods for assessing tongue-tie severity in pediatric populations, and it has been used in previous studies examining potential speech-related outcomes following frenectomy [16,17]. However, Kotlow's classification is based solely on a static linear measurement of free tongue length and does not evaluate tongue function. No grading system for ankyloglossia has gained general acceptance, and the available assessment tools lack adequate psychometric testing [13,18,19]. Consequently, the reported prevalence of ankyloglossia varies considerably according to the assessment tool used, from approximately 2% to 20% [20]. The relationship between ankyloglossia and speech also remains controversial: systematic reviews have found insufficient evidence that ankyloglossia causes speech disorders or that frenotomy improves speech outcomes [21], and a clinical consensus statement concluded that ankyloglossia does not typically affect speech, while expressing concern about the overdiagnosis and overtreatment of tongue-tie [22]. Although tongue-tie has been widely discussed in relation to breastfeeding and articulation difficulties, its relationship with broader orofacial dysfunction profiles remains unclear [13].

Accurate identification of the etiological factors underlying speech disorders is essential for the effective implementation of multidisciplinary treatments. Pediatric dentists can also contribute to the screening, early identification, and multidisciplinary management of children with speech development disorders. The aims of this study were to compare orofacial function, assessed with the standardized NOT-S, between children diagnosed with speech disorders and children with typical speech development, and to examine whether tongue-tie severity, classified according to Kotlow, is associated with orofacial performance, taking into account the presence of systemic conditions.

2. Materials and Methods

This cross-sectional study was conducted at the Istanbul Kent University Faculty of Dentistry and the Department of Speech and Language Therapy, Faculty of Health Sciences, and included children aged 5 to 13 years with speech disorders (SD group) and without speech disorders (N group).

2.1. Ethics Approval

The study protocol was approved by the Istanbul Kent University Ethics Committee at its meeting no. 23-09 dated 22 December 2023 (reference no. E-10420511-050-28896). The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from the parents of all participants.

2.2. Eligibility Criteria

The inclusion criteria consisted of children aged between 5 and 13 years who presented either to the Faculty of Dentistry or to the Department of Speech and Language Therapy at the Faculty of Health Sciences, Istanbul Kent University, and whose parents provided informed consent. Children diagnosed with speech disorders were evaluated at the Department of Speech and Language Therapy and constituted the study group (SD group), while children without speech disorders who presented to the Faculty of Dentistry formed the control group (N group). The diagnosis of speech disorders was established by a licensed speech and language therapist (N.A.K.) based on a detailed case history, an assessment of hearing function, and standardized tests normed for Turkish-speaking children. All diagnoses had been established by the speech and language therapist before enrollment, as part of routine clinical care, at a median age of approximately 6 years (range, 4.5–12 years). Speech sound disorders were assessed primarily with the Turkish Articulation and Phonology Test (SST) [23], which is standardized for children aged 2–8 years. In older children, the SST subtests were used to identify error patterns and were interpreted descriptively rather than against normative scores, as in a previous study of Turkish-speaking children aged 8, 6–10, and 2 years [24]; when needed, the Ankara Articulation Test (AAT), standardized for children aged 2–12 years [25], was used as a complementary norm-referenced measure. When indicated, phonological awareness was assessed with the Turkish Phonological Awareness Test (FFT; normed for 4;0–8;11 years) [26], and phonological process analysis of speech samples was performed. Language disorders were assessed with the Turkish version of the Test of Early Language Development (TEDİL; normed for 2;0–7;11 years) [27], which was administered within its normative age range in all children, together with language sample analysis. In children with combined speech sound and language disorders, both domains were assessed. Fluency disorders were evaluated through analysis of speech samples and fluency characteristics, and the motor speech disorder through oral motor examination and assessment of motor speech and intelligibility. Norm-referenced scores were interpreted only within the normative age range of each instrument. Diagnoses were categorized as speech sound disorder, combined speech sound and language disorder, language disorder, fluency disorder, motor speech disorder, or speech and language difficulty not further specified (Table 1). Children in the control group were confirmed to have no reported or observed speech difficulties through parental history and clinical interview; they did not undergo a standardized speech and language assessment.

Children were excluded if their parents did not provide consent, if they were younger than 5 or older than 13 years on the day of data collection, or if they were unable to cooperate with the examination procedures. Further exclusion criteria were craniofacial anomalies, a history of frenectomy, and neurological or cognitive conditions severe enough to prevent participation in the assessment procedures. Children with hearing impairment

were included if they had functional hearing with hearing aids or other hearing devices. In these children (n = 2, both in the SD group), hearing impairment was considered part of the etiology of the speech disorder rather than a co-occurring systemic condition and was therefore not included in the systemic condition variable. Children with neurodevelopmental or genetic conditions, such as autism spectrum disorder, developmental delay, or Down syndrome, were included if they were able to understand simple instructions and cooperate with all assessment procedures. Verbal speech was not a requirement for participation; children who did not speak during the examination were therefore included and scored according to the NOT-S manual. All systemic conditions were recorded and accounted for in the statistical analysis. This approach ensured that the sample reflected a clinically meaningful range of pediatric presentations commonly encountered in speech and orofacial evaluations.

Table 1. Demographic and clinical characteristics of the participants.

	SD (n = 37)	**N (n = 40)**	p
Age, years, median (IQR)	7.49 (6.21–8.77)	9.83 (8.24–10.70)	<0.001 [a]
Age, years, mean ± S.D.	7.57 ± 1.81	9.29 ± 1.93	
Sex, n (%)			
Female	12 (32.4)	23 (57.5)	0.039 [b]
Male	25 (67.6)	17 (42.5)	
Systemic condition, n (%)			
Present	20 (54.1)	7 (17.5)	0.001 [b]
Absent	17 (45.9)	33 (82.5)	
Type of systemic condition, n (%)			
Respiratory/allergic	8 (21.6)	4 (10.0)	
Neurodevelopmental	7 (18.9)	1 (2.5)	
Genetic (Down syndrome)	2 (5.4)	0 (0.0)	
Cardiac	3 (8.1)	0 (0.0)	
Other	0 (0.0)	2 (5.0)	
Speech and language diagnosis, n (%)			
Speech sound disorder	10 (27.0)	–	
Combined speech sound and language disorder	6 (16.2)	–	
Language disorder	10 (27.0)	–	
Fluency disorder	4 (10.8)	–	
Motor speech disorder	1 (2.7)	–	
Speech and language difficulty, not further specified	6 (16.2)	–	
Kotlow classification, n (%)			
Normal (>16.0 mm)	11 (29.7)	7 (17.5)	0.141 [c]
Class I (12.0–16.0 mm)	9 (24.3)	18 (45.0)	
Class II (8.0–11.9 mm)	13 (35.1)	14 (35.0)	
Class III (3.0–7.9 mm)	4 (10.8)	1 (2.5)	
Class IV (<3.0 mm)	0 (0.0)	0 (0.0)	
Tongue-tie (≤16.0 mm), n (%)	26 (70.3)	33 (82.5)	0.282 [b]
Free tongue length, mm, median (IQR)	13.40 (9.50–17.20)	14.15 (10.15–15.33)	0.706 [a]

[a] Mann–Whitney U test; [b] Fisher's exact test; [c] Fisher–Freeman–Halton exact test (Monte Carlo, 20,000 permutations). Age was calculated from the dates of birth and examination. Respiratory/allergic: asthma (SD, n = 6; N, n = 4), chronic sinusitis (SD, n = 1) and allergic rhinitis (SD, n = 1); neurodevelopmental: autism spectrum disorder (SD, n = 6), developmental delay (SD, n = 1) and attention difficulty (N, n = 1); other: hemophilia (N, n = 1) and familial Mediterranean fever (N, n = 1). Speech and language diagnoses were established by a speech and language therapist. SD: children with speech and language disorders; N: children without speech disorders; IQR: interquartile range; S.D.: standard deviation.

2.3. Study Population

An a priori sample size estimation was conducted using G*Power 3.1 for the primary comparison of NOT-S scores between the SD group and the N group. Assuming a large effect size (Cohen's d = 0.80), an alpha level of 0.05, and a power of 0.80, the required minimum sample size was 26 participants per group. To ensure adequate power and account for potential data loss, the target sample was increased to at least 35 children per group. The final sample, comprising 37 children in the SD group and 40 children in the N group, met this threshold. This calculation was not designed to provide adequate power for subgroup or Kotlow class comparisons. Participant recruitment and data collection were carried out between February 2024 and June 2025; most children in the SD group were examined in 2024 and most children in the N group were examined in 2025.

Participants were additionally categorized into four subgroups based on the presence of speech disorders and tongue-tie (Kotlow Class I–IV, i.e., free tongue length $\leq$16.0 mm): SD+TT (children with speech disorders and tongue-tie, n = 26), SD–TT (children with speech disorders without tongue-tie, n = 11), N+TT (children with normal speech and tongue-tie, n = 33), and N–TT (children with normal speech and without tongue-tie, n = 7). Because of the unequal and small subgroup sizes, these comparisons were considered exploratory.

2.4. Data Collection

Demographic and clinical information was collected from all participants, including age, sex, systemic health status, and relevant medical history. Age was calculated from the dates of birth and examination. All assessments were conducted during a single clinical visit in a quiet examination room under standardized conditions. Following the demographic interview, each child underwent the structured NOT-S evaluation and the tongue mobility assessment using Kotlow's classification. Data were documented on standardized forms and later transferred to a digital database for analysis. All NOT-S evaluations and Kotlow measurements were conducted by a single researcher (D.Ö.), a dentist experienced in orofacial function assessment and trained in the use of the NOT-S instrument. Because children with speech disorders were recruited from the speech and language therapy department, the examiner was aware of each child's group status, and the assessments were not blinded. Each assessment session lasted approximately 15–20 min, and all children were evaluated in the same standardized order: completion of demographic questions followed by the NOT-S interview, the NOT-S clinical examination, and finally the Kotlow tongue-tie measurement.

2.5. Screening of Orofacial Function

Orofacial dysfunction was screened using the NOT-S. Bergendal et al. [28] reviewed multiple international studies and concluded that the NOT-S is a reliable and standardized tool for assessing orofacial dysfunction. The validated Turkish version of the NOT-S, which has demonstrated acceptable reliability and validity, was used in this study [29]. The NOT-S consists of 12 domains divided into two sections: the interview covers sensory function, breathing, habits, chewing and swallowing, drooling, and dryness of the mouth, and the clinical examination covers face at rest, nose breathing, facial expression, masticatory muscle and jaw function, oral motor function, and speech. Interview questions were addressed directly to children capable of responding, or to their parents when necessary. According to the manual, each item was recorded as dysfunction present, absent, or not assessed; items that the child was unable to perform were recorded as dysfunction. Each domain was scored 1 if at least one item was answered "yes" or if impairment was observed during examination; otherwise, the score was 0. The total NOT-S score ranged from 0 to 12. The speech domain comprises three items: (A) the child does not speak; (B) one or more

indistinct sounds or abnormal nasality while counting to ten; and (C) dysfunction while repeating the sequence /pataka/. If item A is positive, items B and C are not administered. The official NOT-S form and illustrated guide were used.

2.6. Assessment of Ankyloglossia

Ankyloglossia was assessed using Kotlow's classification [15], which is based on free tongue length, defined as the distance from the insertion of the lingual frenulum at the base of the tongue to the tip of the tongue. Measurements were performed with the child seated upright under adequate illumination, with gentle elevation of the tongue, using a digital caliper. A single measurement was obtained for each child. Free tongue length was recorded to the nearest 0.1 mm and classified as normal (>16.0 mm), Class I (mild, 12.0–16.0 mm), Class II (moderate, 8.0–11.9 mm), Class III (severe, 3.0–7.9 mm), or Class IV (complete, <3.0 mm) [14]. Intra- and inter-rater reliability of the measurements were not assessed.

2.7. Statistical Analysis

Analyses were performed using IBM SPSS Statistics 30.0 and Python 3.12 (SciPy and statsmodels). Data are presented as frequencies (%), means ± standard deviations (S.D.), and medians with interquartile ranges (IQR). As NOT-S scores and age were not normally distributed (Shapiro–Wilk test), nonparametric tests were used. The NOT-S total score was the primary outcome. Groups were compared with the Mann–Whitney U test (effect size $r = Z/\sqrt{N}$, with bootstrapped 95% confidence intervals [CI]), and subgroups and Kotlow classes with the Kruskal–Wallis test followed by Dunn's test with Bonferroni correction. Categorical variables were compared with Fisher's exact or Fisher–Freeman–Halton tests. Holm correction was applied to the 12 NOT-S domain comparisons and to the Spearman correlations between free tongue length and NOT-S scores.

To account for confounding, Poisson regression with robust standard errors was used to estimate incidence rate ratios (IRR) for NOT-S scores, adjusted for age, sex, and systemic conditions; free tongue length and its interaction with group were tested in an additional model. Sensitivity analyses were restricted to children without systemic conditions, excluded the speech domain (exploratory scores), restricted the SD group to children with speech sound disorders, alone or with a co-occurring language disorder, excluded children with neurodevelopmental conditions (with and without children with Down syndrome), or were restricted to children aged 8 years and older, the age range in which the Turkish version of the NOT-S was validated. A two-sided $p < 0.05$ was considered statistically significant.

3. Results

A total of 77 children aged 5.1 to 13.0 years were included in the study: 37 in the SD group (12 female and 25 male) and 40 in the N group (23 female and 17 male) (Table 1). Children in the SD group were younger than those in the N group (median 7.49 [IQR 6.21–8.77] vs. 9.83 [IQR 8.24–10.70] years, $p < 0.001$), and the sex distribution differed between the groups ($p = 0.039$). Systemic conditions were more frequent in the SD group (20/37, 54.1%) than in the N group (7/40, 17.5%; $p = 0.001$); the most common were respiratory/allergic ($n = 8$) and neurodevelopmental conditions ($n = 7$) in the SD group and asthma ($n = 4$) in the N group. In the SD group, the most frequent diagnoses were speech sound disorder ($n = 10$) and language disorder ($n = 10$), followed by combined speech sound and language disorder ($n = 6$), speech and language difficulty not further specified ($n = 6$), fluency disorder ($n = 4$), and motor speech disorder ($n = 1$). Tongue-tie (free tongue length ≤16.0 mm) was present in 26 children (70.3%) in the SD group and 33 children

(82.5%) in the N group ($p = 0.282$). Neither the distribution of Kotlow classes ($p = 0.141$) nor free tongue length (median 13.40 vs. 14.15 mm, $p = 0.706$) differed between the groups, and no child had Class IV tongue-tie.

The frequency of dysfunction in each NOT-S domain is presented in Table 2. Before correction for multiple comparisons, four examination domains (nose breathing, facial expression, oral motor function, and speech) were more frequently impaired in the SD group than in the N group. After Holm adjustment, the differences remained significant for facial expression (29.7% vs. 0.0%, adjusted $p = 0.001$), oral motor function (29.7% vs. 0.0%, adjusted $p = 0.001$), and speech (59.5% vs. 0.0%, adjusted $p < 0.001$), but not for nose breathing (13.5% vs. 0.0%, adjusted $p = 0.199$). None of the interview domains differed significantly between the groups.

Table 2. Frequency of orofacial dysfunction in each NOT-S domain in the SD and N groups.

NOT-S Domain	SD ($n = 37$)	N ($n = 40$)	p [a]	Adjusted p [b]
Interview				
I. Sensory function	14 (37.8)	8 (20.0)	0.129	0.904
II. Breathing	11 (29.7)	7 (17.5)	0.282	1.000
III. Habits	20 (54.1)	15 (37.5)	0.173	1.000
IV. Chewing and swallowing	10 (27.0)	13 (32.5)	0.628	1.000
V. Drooling	8 (21.6)	3 (7.5)	0.106	0.849
VI. Dryness of the mouth	9 (24.3)	12 (30.0)	0.617	1.000
Clinical examination				
1. Face at rest	3 (8.1)	1 (2.5)	0.346	1.000
2. Nose breathing	5 (13.5)	0 (0.0)	0.022	0.199
3. Facial expression	11 (29.7)	0 (0.0)	<0.001	0.001
4. Masticatory muscle and jaw function	2 (5.4)	0 (0.0)	0.228	1.000
5. Oral motor function	11 (29.7)	0 (0.0)	<0.001	0.001
6. Speech	22 (59.5)	0 (0.0)	<0.001	<0.001

Values are the number (%) of children with dysfunction in the domain (domain score = 1). A domain was scored as 1 if at least one item within the domain was positive. [a] Fisher's exact test; [b] Holm-adjusted for 12 comparisons.

Within the SD group, 22 children (59.5%) had dysfunction in the speech domain (Table 3). Of these, two children did not speak during the examination, 10 showed dysfunction only while counting to ten (indistinct sounds or abnormal nasality), four only while repeating /pataka/, and six in both tasks. The remaining 15 children (40.5%) in the SD group showed no dysfunction in this domain.

Table 3. Distribution of findings in the NOT-S speech domain (clinical examination, domain 6) in the SD group.

Finding	*n*	% of Children with Speech Domain Dysfunction ($n = 22$)	% of SD Group ($n = 37$)
Does not speak (item A)	2	9.1	5.4
Dysfunction while counting to ten only (item B)	10	45.5	27.0
Dysfunction while repeating /pataka/ only (item C)	4	18.2	10.8
Dysfunction in both tasks (items B and C)	6	27.3	16.2
Total with speech domain dysfunction	22	100.0	59.5
No speech domain dysfunction	15	–	40.5

All items record dysfunction. Item A: the child does not speak (items B and C are then not administered); item B: one or more indistinct sounds or abnormal nasality while counting to ten; item C: dysfunction observed while repeating /pataka/. Descriptive statistics.

The SD group had significantly higher NOT-S total scores, the primary outcome, than the N group (median 3.00 [IQR 2.00–4.00] vs. 1.00 [IQR 0.75–2.00], $p < 0.001$; $r = 0.50$, 95% CI 0.32–0.66), as well as higher examination scores (median 1.00 [IQR 1.00–2.00] vs. 0.00 [IQR 0.00–0.00], $p < 0.001$; $r = 0.76$, 95% CI 0.64–0.86), corresponding to large effect sizes. Interview scores did not differ significantly between the groups ($p = 0.190$; $r = 0.15$, 95% CI −0.07 to 0.36) (Table 4).

Table 4. Comparison of interview, examination, and total NOT-S scores between the SD and N groups.

NOT-S Score	SD (n = 37)		N (n = 40)		p	Effect Size r (95% CI)
	Mean ± S.D.	Median (IQR)	Mean ± S.D.	Median (IQR)		
Interview	1.95 ± 1.56	1.00 (1.00–3.00)	1.45 ± 1.26	1.00 (0.75–2.00)	0.190	0.15 (−0.07 to 0.36)
Examination	1.46 ± 1.37	1.00 (1.00–2.00)	0.03 ± 0.16	0.00 (0.00–0.00)	<0.001	0.76 (0.64 to 0.86)
Total	3.41 ± 2.10	3.00 (2.00–4.00)	1.48 ± 1.28	1.00 (0.75–2.00)	<0.001	0.50 (0.32 to 0.66)

Mann–Whitney U test. Effect size $r = Z/\sqrt{N}$ (0.1 small, 0.3 medium, 0.5 large); 95% confidence intervals were obtained by bootstrapping (2000 resamples). The NOT-S total score was defined as the primary outcome. IQR: interquartile range; CI: confidence interval.

In the exploratory comparison of the four subgroups, examination and total scores differed significantly (both $p < 0.001$), whereas interview scores did not ($p = 0.490$) (Table 5). Post hoc comparisons showed that both SD subgroups had higher examination scores than both N subgroups, while the SD+TT and SD–TT subgroups did not differ from each other ($p = 0.293$), and neither did the N+TT and N–TT subgroups. For total scores, both SD subgroups had higher scores than the N+TT subgroup, whereas the N–TT subgroup, which included only seven children, did not differ significantly from any other subgroup. Within each group, the presence of tongue-tie was therefore not associated with higher NOT-S scores.

Table 5. Comparison of interview, examination, and total NOT-S scores across the four subgroups.

NOT-S Score	SD+TT (n = 26)	SD–TT (n = 11)	N+TT (n = 33)	N–TT (n = 7)	p
Interview	2.00 ± 1.57 1.50 (1.00–3.00)	1.82 ± 1.60 1.00 (1.00–2.50)	1.36 ± 1.19 1.00 (0.00–2.00)	1.86 ± 1.57 1.00 (1.00–3.00)	0.490
Examination	1.12 ± 1.21 [a] 1.00 (0.25–1.00)	2.27 ± 1.42 [a] 2.00 (1.50–3.00)	0.03 ± 0.17 [b] 0.00 (0.00–0.00)	0.00 ± 0.00 [b] 0.00 (0.00–0.00)	<0.001
Total	3.12 ± 1.80 [a] 3.00 (2.00–4.00)	4.09 ± 2.66 [a] 3.00 (2.50–5.50)	1.39 ± 1.22 [b] 1.00 (0.00–2.00)	1.86 ± 1.57 [ab] 1.00 (1.00–3.00)	<0.001

Values are mean ± S.D. (first line) and median (IQR) (second line). Kruskal–Wallis test ($\varepsilon^2 = -0.01$, 0.62 and 0.24 for interview, examination and total scores, respectively) followed by Dunn's post hoc test with Bonferroni correction. Within a row, subgroups sharing a superscript letter do not differ significantly; no post hoc comparisons were performed for interview scores. Subgroup comparisons are exploratory because of the unequal and small subgroup sizes. TT: tongue-tie (free tongue length ≤ 16.0 mm).

Drooling was reported in 8 of 25 boys (32.0%) and in none of the 12 girls in the SD group ($p = 0.036$), whereas no sex difference was observed in the N group ($p = 1.000$) (Table 6). NOT-S interview, examination, and total scores did not differ between boys and girls in the whole sample or within either group (all $p \geq 0.055$).

After adjustment for age, sex, and systemic condition, the SD group remained associated with higher NOT-S total scores, with approximately twice the rate of dysfunction domains compared with the N group (IRR = 2.21, 95% CI 1.53–3.19, $p < 0.001$) (Table 7, Model 1). The group effect was also significant for examination scores ($p < 0.001$), although this estimate was highly imprecise because only one child in the N group had a positive examination domain; no significant group effect was observed for interview scores

(IRR = 1.50, 95% CI 0.93–2.41, $p = 0.094$). In the adjusted model, the presence of a systemic condition was associated with higher examination scores (IRR = 1.75, 95% CI 1.05–2.92, $p = 0.031$), whereas age and sex were not associated with any NOT-S score. When the speech domain was excluded, the SD group still had higher total scores (IRR = 1.76, 95% CI 1.14–2.71, $p = 0.011$). Free tongue length was not associated with NOT-S total scores (IRR per mm = 1.03, 95% CI 0.99–1.07, $p = 0.212$), and the group × free tongue length interaction was not significant ($p = 0.191$).

Table 6. Drooling (NOT-S interview domain V) according to sex in the SD and N groups.

Group	Sex	Drooling Present, *n* (%)	Drooling Absent, *n* (%)	*p*
SD	Female	0 (0.0)	12 (100.0)	0.036
	Male	8 (32.0)	17 (68.0)	
N	Female	2 (8.7)	21 (91.3)	1.000
	Male	1 (5.9)	16 (94.1)	

Fisher's exact test. Percentages are given within rows.

Table 7. Multivariable Poisson regression analyses of NOT-S scores.

Variable	IRR	95% CI	*p*
Model 1: NOT-S total score			
Group (SD vs. N)	2.21	1.53–3.19	<0.001
Age (per year)	1.02	0.93–1.11	0.660
Sex (male vs. female)	0.99	0.73–1.34	0.929
Systemic condition (present vs. absent)	1.25	0.90–1.73	0.189
Model 2: NOT-S interview score			
Group (SD vs. N)	1.50	0.93–2.41	0.094
Age (per year)	1.08	0.97–1.20	0.180
Sex (male vs. female)	0.98	0.69–1.40	0.910
Systemic condition (present vs. absent)	1.06	0.70–1.59	0.787
Model 3: NOT-S examination score [a]			
Group (SD vs. N)	38.07	5.16–280.86	<0.001
Age (per year)	0.88	0.74–1.04	0.140
Sex (male vs. female)	0.98	0.55–1.74	0.939
Systemic condition (present vs. absent)	1.75	1.05–2.92	0.031
Model 4: NOT-S total score excluding the speech domain [b]			
Group (SD vs. N)	1.76	1.14–2.71	0.011
Age (per year)	1.03	0.93–1.14	0.613
Sex (male vs. female)	1.00	0.71–1.41	0.999
Systemic condition (present vs. absent)	1.40	0.94–2.08	0.094
Model 5: NOT-S total score including free tongue length [c]			
Group (SD vs. N)	2.22	1.53–3.23	<0.001
Free tongue length (per mm)	1.03	0.99–1.07	0.212
Age (per year)	1.02	0.93–1.11	0.728
Sex (male vs. female)	0.99	0.73–1.34	0.932
Systemic condition (present vs. absent)	1.22	0.87–1.70	0.248

Poisson regression with robust standard errors; all variables in each model were entered simultaneously. The dispersion ratio (Pearson χ^2/df) ranged from 0.91 to 1.41. [a] Only one child in the N group had a positive examination domain; because of this sparse outcome distribution, the estimate of the group effect on examination scores is highly uncertain (IRR 38.07, 95% CI 5.16–280.86) and should be interpreted with caution. [b] Exploratory analysis. [c] Adding a group × free tongue length interaction term did not improve the model (interaction IRR = 0.93, 95% CI 0.84–1.04, $p = 0.191$). IRR: incidence rate ratio; CI: confidence interval.

Sensitivity analyses are presented in Table 8. When the analysis was restricted to children without systemic conditions (SD, $n = 17$; N, $n = 33$), the SD group still had

significantly higher examination ($p < 0.001$; $r = 0.85$) and total scores ($p = 0.033$; $r = 0.30$). After exclusion of the speech domain, the differences in examination ($p < 0.001$) and total scores ($p = 0.004$) persisted. Children with speech sound disorders only ($n = 10$) had significantly higher examination scores than the N group ($p < 0.001$), whereas the difference in total scores did not reach significance ($p = 0.060$); when children with combined speech sound and language disorders were also included ($n = 16$), both examination ($p < 0.001$) and total scores ($p = 0.013$) were significantly higher. When children with neurodevelopmental conditions were excluded (SD, $n = 30$; N, $n = 39$), the SD group still had significantly higher examination ($p < 0.001$; $r = 0.78$) and total scores ($p < 0.001$; $r = 0.44$), with an adjusted IRR for the total score of 1.95 (95% CI 1.35–2.80, $p < 0.001$); the results were similar when children with Down syndrome were also excluded (SD, $n = 28$; adjusted IRR = 1.93, 95% CI 1.32–2.81, $p < 0.001$). In children aged 8 years and older (SD, $n = 13$; N, $n = 32$), the differences in examination ($p < 0.001$; $r = 0.71$) and total scores ($p = 0.001$; $r = 0.49$) also persisted (adjusted IRR = 2.28, 95% CI 1.43–3.63, $p < 0.001$). Interview scores did not differ between the groups in any sensitivity analysis.

Table 8. Sensitivity analyses of NOT-S scores between the SD and N groups.

Analysis and NOT-S Score	SD, Median (IQR)	N, Median (IQR)	*p*	Effect Size *r* (95% CI)
Children without systemic conditions (SD, *n* = 17; N, *n* = 33)				
Interview	1.00 (0.00–3.00)	1.00 (1.00–2.00)	0.768	−0.04 (−0.36 to 0.26)
Examination	1.00 (1.00–1.00)	0.00 (0.00–0.00)	<0.001	0.85 (0.73 to 0.97)
Total	2.00 (1.00–3.00)	1.00 (1.00–2.00)	0.033	0.30 (0.03 to 0.54)
Speech domain excluded (SD, *n* = 37; N, *n* = 40) [a]				
Examination	0.00 (0.00–1.00)	0.00 (0.00–0.00)	<0.001	0.51 (0.37 to 0.64)
Total	2.00 (1.00–4.00)	1.00 (0.75–2.00)	0.004	0.33 (0.13 to 0.52)
Speech sound disorder only (SD, *n* = 10; N, *n* = 40)				
Interview	1.00 (0.25–1.00)	1.00 (0.75–2.00)	0.520	−0.09 (−0.36 to 0.20)
Examination	1.50 (1.00–2.00)	0.00 (0.00–0.00)	<0.001	0.81 (0.58 to 0.98)
Total	3.00 (1.00–3.00)	1.00 (0.75–2.00)	0.060	0.27 (0.03 to 0.48)
Speech sound disorder with or without language disorder (SD, *n* = 16; N, *n* = 40)				
Interview	1.00 (0.00–2.25)	1.00 (0.75–2.00)	0.672	−0.06 (−0.33 to 0.23)
Examination	1.00 (1.00–2.00)	0.00 (0.00–0.00)	<0.001	0.82 (0.64 to 0.94)
Total	3.00 (1.00–3.00)	1.00 (0.75–2.00)	0.013	0.33 (0.10 to 0.54)
Children without neurodevelopmental conditions (SD, *n* = 30; N, *n* = 39) [b]				
Interview	1.00 (1.00–3.00)	1.00 (1.00–2.00)	0.711	0.05 (−0.19 to 0.28)
Examination	1.00 (1.00–2.00)	0.00 (0.00–0.00)	<0.001	0.78 (0.65 to 0.88)
Total	3.00 (2.00–3.75)	1.00 (1.00–2.00)	<0.001	0.44 (0.24 to 0.62)
Children without neurodevelopmental conditions or Down syndrome (SD, *n* = 28; N, *n* = 39)				
Interview	1.00 (1.00–3.00)	1.00 (1.00–2.00)	0.797	0.03 (−0.22 to 0.28)
Examination	1.00 (1.00–2.00)	0.00 (0.00–0.00)	<0.001	0.80 (0.67 to 0.91)
Total	3.00 (1.75–3.25)	1.00 (1.00–2.00)	<0.001	0.42 (0.20 to 0.61)
Children aged ≥8 years (SD, *n* = 13; N, *n* = 32)				
Interview	3.00 (1.00–4.00)	1.00 (0.75–2.00)	0.061	0.28 (−0.03 to 0.59)
Examination	1.00 (0.00–1.00)	0.00 (0.00–0.00)	<0.001	0.71 (0.48 to 0.93)
Total	4.00 (2.00–5.00)	1.00 (0.75–2.25)	0.001	0.49 (0.26 to 0.68)

Mann–Whitney U test. Effect size $r = Z/\sqrt{N}$; 95% confidence intervals were obtained by bootstrapping (2000 resamples). [a] Exploratory scores calculated without the speech domain (examination score range 0–5; total score range 0–11). IQR: interquartile range; CI: confidence interval. [b] Autism spectrum disorder, developmental delay, and attention difficulty; adjusted incidence rate ratios for these analyses are reported in the text.

NOT-S scores according to Kotlow classification are shown in Table 9. In the whole sample, interview ($p = 0.369$) and total scores ($p = 0.286$) did not differ across Kotlow classes, whereas examination scores did ($p = 0.025$). Post hoc comparisons showed that

this difference was due to higher examination scores in children without tongue-tie than in those with Class I tongue-tie (adjusted $p = 0.017$), with no differences between the other classes. The same pattern was observed within the SD group ($p = 0.016$; normal vs. Class I, adjusted $p = 0.018$), in which 7 of the 11 children without tongue-tie had a systemic condition, compared with 13 of the 26 children with tongue-tie. No differences across Kotlow classes were observed in the N group. Free tongue length was not correlated with any NOT-S score after correction for multiple comparisons. Overall, no severity-related gradient between tongue-tie and orofacial dysfunction was observed.

Table 9. NOT-S scores according to Kotlow classification and their correlation with free tongue length.

NOT-S Score	Normal	Class I	Class II	Class III	p [a]	ρ (p) [b]
All participants ($N = 77$)						
n	18	27	27	5		
Interview	1.83 ± 1.54 1.00 (1.00–2.75)	1.81 ± 1.42 2.00 (1.00–2.50)	1.37 ± 1.39 1.00 (0.00–2.50)	2.20 ± 1.30 2.00 (1.00–3.00)	0.369	0.11 (0.354)
Examination	1.39 ± 1.58 [a] 1.00 (0.00–2.00)	0.26 ± 0.59 [b] 0.00 (0.00–0.00)	0.74 ± 1.26 [ab] 0.00 (0.00–1.00)	0.60 ± 0.55 [ab] 1.00 (0.00–1.00)	0.025	0.05 (0.669)
Total	3.22 ± 2.51 3.00 (1.25–4.00)	2.07 ± 1.36 2.00 (1.00–3.00)	2.11 ± 2.06 1.00 (0.50–3.00)	2.80 ± 1.64 2.00 (2.00–4.00)	0.286	0.14 (0.236)
SD group ($n = 37$)						
n	11	9	13	4		
Interview	1.82 ± 1.60 1.00 (1.00–2.50)	2.00 ± 2.00 1.00 (1.00–3.00)	1.92 ± 1.38 2.00 (1.00–3.00)	2.25 ± 1.50 2.00 (1.00–3.25)	0.947	−0.07 (0.697)
Examination	2.27 ± 1.42 [a] 2.00 (1.50–3.00)	0.67 ± 0.87 [b] 0.00 (0.00–1.00)	1.54 ± 1.45 [ab] 1.00 (1.00–2.00)	0.75 ± 0.50 [ab] 1.00 (0.75–1.00)	0.016	0.27 (0.105)
Total	4.09 ± 2.66 3.00 (2.50–5.50)	2.67 ± 1.66 3.00 (1.00–3.00)	3.46 ± 1.94 3.00 (2.00–5.00)	3.00 ± 1.83 3.00 (1.75–4.25)	0.648	0.04 (0.793)
N group ($n = 40$)						
n	7	18	14	1		
Interview	1.86 ± 1.57 1.00 (1.00–3.00)	1.72 ± 1.07 2.00 (1.00–2.00)	0.86 ± 1.23 0.50 (0.00–1.00)	2.00 ± 0.00 2.00 (2.00–2.00)	0.076	0.36 (0.021)
Examination	0.00 ± 0.00 0.00 (0.00–0.00)	0.06 ± 0.24 0.00 (0.00–0.00)	0.00 ± 0.00 0.00 (0.00–0.00)	0.00 ± 0.00 0.00 (0.00–0.00)	0.748	0.16 (0.325)
Total	1.86 ± 1.57 1.00 (1.00–3.00)	1.78 ± 1.11 2.00 (1.00–2.75)	0.86 ± 1.23 0.50 (0.00–1.00)	2.00 ± 0.00 2.00 (2.00–2.00)	0.075	0.37 (0.018)

Values are mean ± S.D. (first line) and median (IQR) (second line). [a] Kruskal–Wallis test followed by Dunn's post hoc test with Bonferroni correction; within a row, classes sharing a superscript letter do not differ significantly. [b] Spearman correlation between free tongue length (mm) and NOT-S score; after Holm correction for nine correlations, no correlation was significant (all adjusted $p \geq 0.162$). No Class IV cases were observed. Analyses by Kotlow class are exploratory because of the small number of children in Class III.

4. Discussion

The present study examined the clinical utility of the Nordic Orofacial Test-Screening (NOT-S) in identifying orofacial dysfunction among children with speech disorders in comparison with peers who do not have speech disorders and evaluated whether tongue-tie severity, classified according to Kotlow, was associated with orofacial function. Children with speech disorders had significantly higher NOT-S total and examination scores than children with typical speech, with large effect sizes, whereas interview scores did not differ between the groups. This difference remained significant after adjustment for age, sex, and systemic conditions, and it persisted when children with systemic or neurodevelopmental conditions were excluded, when the analysis was restricted to children aged 8 years and older, and when the speech domain was removed from the scores. These findings indicate an association between speech disorders and clinically observed orofacial dysfunction; however, given the cross-sectional design, they do not establish a causal relationship. These results are consistent with previous work by Mogren et al. [3], who reported that children

with speech sound disorders frequently present with deficiencies in multiple orofacial functions and may be at increased risk for compromised oral function and malocclusion relative to their peers, and with their earlier finding that 87% of children with persistent speech sound disorders had orofacial difficulties on the NOT-S [4]. The absence of a difference in interview scores suggests that the dysfunction in the SD group was mainly detected by the clinical examination rather than by parent- or child-reported symptoms.

Speech disorders negatively impact children's cognitive development, socio-emotional well-being, and communication skills, and may reduce overall quality of life [30]. Therefore, early diagnosis and intervention are important to prevent long-term functional and developmental problems. Pediatric dentists hold a key position in the early detection of orofacial dysfunctions and speech delays, and they can facilitate the initiation of timely multidisciplinary interventions. However, the role of tongue-tie in this context remains controversial. Although some studies have reported improvements in articulation after frenotomy or frenuloplasty in selected children [17], systematic reviews have found the evidence insufficient to conclude that ankyloglossia causes speech disorders or that its surgical release improves speech outcomes [21,31,32]. A clinical consensus statement concluded that ankyloglossia does not typically affect speech and recommended consultation with a speech and language therapist before frenotomy is performed for speech concerns in older children [22]. This uncertainty provided the rationale for examining the relationship between tongue-tie severity and orofacial function in the present study.

In the present study, sex was not associated with NOT-S interview, examination, or total scores, either in group-wise comparisons or in the adjusted analyses. Previous studies involving healthy or school-aged children reported no sex-related differences in NOT-S outcomes [29,33]. Drooling was reported more frequently in boys than in girls within the SD group; however, this finding was based on a small number of children, the SD group included more boys than girls, and the study was not designed to examine associations with specific diagnoses. It should therefore be interpreted with caution and verified in larger samples.

Tongue-tie in neonates and infants may result in complications such as breastfeeding difficulties, respiratory issues, and food refusal, while in older children and adolescents speech difficulties have frequently been attributed to it, although this association remains controversial. Restricted tongue mobility may also lead to altered swallowing and chewing patterns, thereby disrupting appropriate muscular coordination [21,34,35]. In the present study, the prevalence and severity of tongue-tie did not differ between the SD and N groups, and free tongue length was similar in both groups (median 13.4 vs. 14.2 mm), whereas orofacial function differed markedly between them. Neither Kotlow class nor free tongue length analyzed as a continuous variable showed a severity-related association with NOT-S scores, and free tongue length was not associated with NOT-S total scores after adjustment for group and potential confounders. Although examination scores differed across Kotlow classes, this difference reflected higher scores in children without tongue-tie than in those with Class I tongue-tie, rather than a gradient of increasing dysfunction with increasing severity; in the SD group, most children without tongue-tie had a systemic condition, which may explain their higher examination scores. Within each group, the presence of tongue-tie was not associated with higher NOT-S scores. The fact that NOT-S scores did not vary according to tongue-tie severity suggests that the presence or anatomical extent of ankyloglossia alone may not adequately explain functional orofacial disorders in this cohort. However, given the small sample, the small number of children with severe tongue-tie, and the absence of Class IV cases, the lack of a statistically significant association does not rule out an effect of tongue-tie on orofacial function. In parallel with our results,

two systematic reviews concluded that there was no clear link between ankyloglossia and speech disorders [31,32].

A possible explanation for this mismatch is that a static, linear measurement of the free tongue does not capture the dynamic aspects of tongue function that are relevant to orofacial performance. Kotlow's classification quantifies the distance between the frenulum insertion and the tongue tip at a single point in time, but it does not assess the range, speed, or coordination of tongue movements, or the compensatory strategies that children may develop. Orofacial functions such as chewing, swallowing, and speech depend on the coordinated activity of multiple muscle groups and on neuromotor control rather than on a single anatomical dimension. Assessment tools that combine anatomical and functional criteria, such as the HATLFF, have been proposed for this reason, and a functional definition of ankyloglossia based on tongue range of motion has been suggested [36]; however, the psychometric properties of the available tools remain insufficiently established [13,19]. A classification framework that integrates anatomical and functional criteria and is designed to predict speech outcomes is therefore still needed [13,14]. From a clinical perspective, our findings are consistent with recent recommendations for caution regarding the overdiagnosis and surgical overtreatment of the lingual frenulum [22,37]. In children with speech disorders, a short lingual frenulum alone should not be considered a sufficient indication for frenectomy without a documented functional limitation and a comprehensive speech and language assessment.

Further limitations of the Kotlow system became apparent in this study. The heterogeneous distribution of tongue-tie severity, the low prevalence of severe cases, and previously documented concerns regarding its subjective nature and limited examiner reliability reduce its usefulness in predicting functional impact [36–40]. In addition, tongue-tie was identified in 77% of the children in our sample (70.3% in the SD group and 82.5% in the N group), which is considerably higher than the pooled prevalence of approximately 5% reported in a recent meta-analysis, in which prevalence varied from 2% to 20% depending on the assessment tool [20]. This high prevalence is likely to reflect methodological factors rather than a true excess of ankyloglossia: Kotlow's thresholds are fixed values that are not adjusted for age or tongue size, the classification relies on a single linear measurement that is sensitive to the degree of tongue elevation and to the stabilization of a flexible muscular organ, and most cases in our sample were mild (Class I) or moderate (Class II). It has been reported that respiratory function contributes to the regulation of intraoral air pressure during speech production [41]; whether intraoral air pressure measurement could complement the assessment of tongue-tie-related speech difficulties is a hypothesis that should be examined in future studies.

The validity and reliability of the Turkish version of the NOT-S were confirmed by a previous study, supporting its clinical use [29]. Our findings support the value of the NOT-S, particularly its clinical examination component, as a screening tool for identifying orofacial dysfunction and supporting referral; however, as a screening instrument, it does not establish a specific diagnosis [1]. Speech disorders encompass a heterogeneous spectrum, such as articulation, phonological, fluency, voice, and motor speech disorders, and the functional impact of tongue-tie likely varies substantially across these categories. In our study, 22 of the 37 children in the SD group had dysfunction in the speech domain, most frequently while counting to ten (Table 3). The /pataka/ task reflects diadochokinetic performance, which is influenced by age, sex, and the speech material used, and children younger than about eight years may not yet have the motor maturity to perform such tasks with speed and accuracy [42,43]. Dysfunction in these brief tasks may therefore reflect articulatory or diadochokinetic difficulties, but it does not in itself establish a motor speech control deficit, which would require a comprehensive motor speech assessment.

Furthermore, the speech domain is not designed to capture phonological patterns, voice quality, fluency, or language, which may explain why 15 children with clinically diagnosed speech or language disorders did not score in this domain. Because speech is both the characteristic defining the study groups and a component of the NOT-S examination, we performed an exploratory analysis excluding the speech domain; the differences between the groups persisted, indicating that the higher NOT-S scores in the SD group were not driven solely by the speech domain. Expanding or supplementing the speech domain to better reflect different types of speech disorders may be considered in future research.

Systemic conditions were significantly more frequent and more diverse in the SD group than in the N group (p = 0.001). Conditions such as autism spectrum disorder, Down syndrome, and respiratory disease may independently affect orofacial muscle tone, coordination, breathing, and saliva control and could therefore confound the comparison between the groups. However, the group difference persisted in the adjusted analyses, in children without systemic conditions, and after the exclusion of children with neurodevelopmental conditions, indicating that it cannot be explained solely by these conditions. At the same time, the presence of a systemic condition was itself associated with higher examination scores in the adjusted model, suggesting that both the speech disorder and co-occurring conditions contribute to orofacial dysfunction. This is in line with the high rate of co-existing general motor and neurodevelopmental difficulties reported in children with persistent speech sound disorders [4]. Because the number of children with each specific condition was small, the effects of individual diagnoses could not be examined separately, and residual confounding cannot be excluded.

The SD group was younger than the N group, and the Turkish version of the NOT-S was validated in children aged 8–14 years [29]. Several findings suggest that these factors do not explain the group differences. First, age was not associated with any NOT-S score in the adjusted models. Second, when the analysis was restricted to children aged 8 years and older, the age range covered by the Turkish validation, the differences in examination and total scores persisted, although this subgroup included only 13 children with speech disorders. Third, the original NOT-S was developed for use in children from three years of age [10,11]. Nevertheless, younger children may find some examination tasks, such as the repetition of /pataka/, more difficult [42,43], and Turkish reference values for children younger than 8 years are lacking; the NOT-S scores of the younger children should therefore be interpreted with caution.

A single assessment protocol may be insufficient to fully evaluate intraoral and orofacial functions in children with speech disorders. Combining complementary tools, such as NOT-S, comprehensive speech and language assessment, and functional tongue assessment, may capture different dimensions of functional impairment; whether such a combined approach improves diagnostic accuracy should be evaluated in future studies. In this regard, the NOT-S can be considered a valuable component of early screening and referral pathways. Its implementation through coordinated efforts among speech and language therapists, pediatric dentists, and pediatricians may contribute to timely identification, targeted intervention, and ultimately improved developmental outcomes for affected children.

Limitations

This study has several limitations. First, the SD group was clinically heterogeneous, including speech sound, language, fluency, and motor speech disorders, as well as six children with speech and language difficulties not further specified; the relationship between orofacial dysfunction and speech may differ across these groups, and the number of children in each diagnostic category was too small for separate analyses. In addition, the

severity of the speech disorders and the history of previous or ongoing speech therapy were not systematically recorded and could therefore not be considered in the analyses. Second, the groups differed in age, sex distribution, and the prevalence of systemic conditions. Although these factors were included in the adjusted and sensitivity analyses, residual confounding cannot be excluded, and the effects of individual systemic conditions could not be examined, apart from a sensitivity analysis excluding children with neurodevelopmental conditions. Third, the groups were recruited from different clinical settings and largely during different periods, which may have introduced selection bias, and children in the control group did not undergo a standardized speech and language assessment, so mild undiagnosed speech or language difficulties cannot be ruled out. Fourth, all assessments were performed by a single examiner who was not blinded to group status, as children with speech disorders were recruited from a speech therapy setting. Although free tongue length was measured with a digital caliper, which provides an objective numerical value, observer bias may have affected the NOT-S clinical examination, which involves observational judgments. Measurements were not repeated, and intra- and inter-rater reliability were not assessed and could not be evaluated retrospectively, because the participants' oral structures may have changed with growth since the examinations; this is particularly relevant given the moderate inter-examiner agreement reported for NOT-S before examiner calibration [1]. Fifth, the Turkish version of NOT-S was validated in children aged 8–14 years [29], whereas our sample included children from 5 years of age; although the group differences persisted in children aged 8 years and older, this subgroup was small. Moreover, in children older than 8 years, SST results were interpreted descriptively rather than against normative scores. In addition, speech and language diagnoses had been established before enrollment, so the interval between diagnosis and the orofacial examination varied among children. Sixth, the speech domain of NOT-S consists of brief screening tasks and cannot distinguish between different types of speech disorders. Seventh, the sample-size calculation was based on the comparison between the SD and N groups; subgroup and Kotlow class analyses were underpowered, with only seven children in the N–TT subgroup, five children with Class III tongue-tie, and no Class IV cases, and these analyses should therefore be regarded as exploratory. Finally, the cross-sectional design does not allow causal inferences regarding the relationships between speech disorders, tongue-tie, and orofacial function. Future studies should include larger and more homogeneous diagnostic groups, standardized speech and language assessment of all participants, blinded assessments by multiple calibrated examiners with reliability analyses, and functional measures of tongue mobility.

5. Conclusions

In summary, children with speech disorders exhibited greater orofacial dysfunction on the NOT-S, particularly in the clinical examination, and this difference persisted after adjustment for age, sex, and systemic conditions. In contrast, no statistically significant association between tongue-tie severity, assessed using Kotlow's classification or free tongue length, and orofacial function was demonstrated in this sample; given the limited sample size and the small number of children with severe tongue-tie, however, an effect cannot be ruled out. These findings suggest that anatomical assessment of the lingual frenulum alone may be insufficient and should be complemented by functional orofacial and comprehensive speech and language evaluation before treatment decisions such as frenectomy are made. Larger, function-focused studies with more homogeneous diagnostic groups are needed to clarify the role of tongue-tie in speech and orofacial development.

Author Contributions: Conceptualization, E.D. and E.S.; methodology, E.D., S.E. and N.A.K.; formal analysis, E.D.; investigation, D.Ö., M.B. and E.O.; data curation, D.Ö., M.B. and E.O.; resources,

N.A.K.; writing—original draft preparation, E.D.; project administration, S.E.; supervision, E.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Istanbul Kent University (meeting no. 23-09, 22 December 2023; reference no. E-10420511-050-28896).

Informed Consent Statement: Written informed consent to participate was obtained from the parents or legal guardians of all participants.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical reasons.

Acknowledgments: This study was presented at the 30th IAPD Congress in Cape Town and was awarded the Runner-up Prize of the Bengt Magnusson Memorial Award in the Child Dental Health category.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

NOT-S	Nordic Orofacial Test-Screening
SSD	Speech sound disorders
HATLFF	Hazelbaker Assessment Tool for Lingual Frenulum Function
SD	Study group (children with speech disorders)
N	Normal group (children without speech disorders)
SD+TT	Study group with tongue-tie
SD–TT	Study group without tongue-tie
N+TT	Normal group with tongue-tie
N–TT	Normal group without tongue-tie
TT	Tongue-tie
S.D.	Standard deviation
IQR	Interquartile range
CI	Confidence interval
IRR	Incidence rate ratio

References

1. Bakke, M.; Bergendal, B.; McAllister, A.; Sjögreen, L.; Åstén, P. Development and evaluation of a comprehensive screening for orofacial dysfunction. *Swed. Dent. J.* **2007**, *31*, 75–84. [PubMed]
2. Alaçam, A. Orofacial Disorders in Children with Disabilities. *Turk. Klin. Pediatr. Dent. Spec. Top.* **2016**, *2*, 18–27.
3. Mogren, Å.; Sand, A.; Havner, C.; Sjögreen, L.; Westerlund, A.; Barr Agholme, M.; McAllister, A. Children and adolescents with speech sound disorders are more likely to have orofacial dysfunction and malocclusion. *Clin. Exp. Dent. Res.* **2022**, *8*, 1130–1141. [CrossRef] [PubMed]
4. Mogren, Å.; Sjögreen, L.; Barr Agholme, M.; McAllister, A. Orofacial function in children with speech sound disorders (SSD) persisting after the age of six years. *Int. J. Speech Lang. Pathol.* **2020**, *22*, 526–536. [CrossRef] [PubMed]
5. Kent, R.D. Nonspeech oral movements and oral motor disorders: A narrative review. *Am. J. Speech Lang. Pathol.* **2015**, *24*, 763–789. [CrossRef] [PubMed]
6. Thakur, S.K.; Kale, A.B.; Swami, T.Y. Classification of speech disorders. *World J. Pharm. Med. Res.* **2023**, *9*, 55–58.
7. Munson, B.; Edwards, J.; Beckman, M.E. Phonological knowledge in typical and atypical speech–sound development. *Top. Lang. Disord.* **2005**, *25*, 190–206. [CrossRef] [PubMed]
8. American Speech-Language-Hearing Association. Speech Sound Disorders: Articulation and Phonology (Practice Portal). Available online: https://www.asha.org/practice-portal/clinical-topics/articulation-and-phonology/ (accessed on 15 October 2026).

9. Berti, L.C.; Guilherme, J.; Esperandino, C.; de Oliveira, A.M. Relationship between speech production and perception in children with Speech Sound Disorders. *J. Port. Linguist.* **2020**, *19*, 13. [CrossRef]
10. Bergendal, B.; McAllister, A.; Stecksén-Blicks, C. Orofacial dysfunction in ectodermal dysplasias measured using the Nordic Orofacial Test-Screening protocol. *Acta Odontol. Scand.* **2009**, *67*, 377–381. [CrossRef] [PubMed]
11. Leme, M.S.; De Souza Barbosa, T.; Gavião, M.B.D. Assessment of orofacial functions in Brazilian children using the Nordic Orofacial Test-Screening (NOT-S). *Rev. Odonto Ciênc.* **2012**, *27*, 108–114. [CrossRef]
12. Messner, A.H.; Lalakea, M.L.; Janelle, A.; Macmahon, J.; Bair, E. Ankyloglossia: Incidence and associated feeding difficulties. *Arch. Otolaryngol. Head Neck Surg.* **2000**, *126*, 36–39. [PubMed]
13. Hatami, A.; Dreyer, C.W.; Meade, M.J.; Kaur, S. Effectiveness of tongue-tie assessment tools in diagnosing and fulfilling lingual frenectomy criteria: A systematic review. *Aust. Dent. J.* **2022**, *67*, 212–219. [CrossRef] [PubMed]
14. Kotlow, L.A. Oral Diagnosis of Abnormal Frenum Attachments in Neonates and Infants: Evaluation and Treatment of the Maxillary and Lingual Frenum using the Erbium:YAG Laser. *Pediatr. Dent. Care* **2004**, *10*, 11–14.
15. Kotlow, L.A. Ankyloglossia (tongue-tie): A diagnostic and treatment quandary. *Quintessence Int.* **1999**, *30*, 259–262. [PubMed]
16. Belmehdi, A.; Harti, K.E.; Wady, W.E. Ankyloglossia as an oral functional problem and its surgical management. *Dent. Med. Probl.* **2018**, *55*, 213–216. [CrossRef] [PubMed]
17. Kim, T.H.; Lee, Y.C.; Yoo, S.D.; Lee, S.A.; Eun, Y.G. Comparison of simple frenotomy with 4-flap Z-frenuloplasty in treatment for ankyloglossia with articulation difficulty: A prospective randomized study. *Int. J. Pediatr. Otorhinolaryngol.* **2020**, *136*, 110146. [CrossRef] [PubMed]
18. Walsh, J.; Tunkel, D. Diagnosis and treatment of ankyloglossia in newborns and infants: A review. *JAMA Otolaryngol. Head Neck Surg.* **2017**, *143*, 1032–1039. [CrossRef] [PubMed]
19. Hill, R.R.; Lee, C.S.; Pados, B.F. The prevalence of ankyloglossia in children aged <1 year: A systematic review and meta-analysis. *Pediatr. Res.* **2021**, *90*, 259–266. [CrossRef] [PubMed]
20. Cruz, P.V.; Souza-Oliveira, A.C.; Notaro, S.Q.; Occhi-Alexandre, I.G.P.; Maia, R.M.; De Luca Canto, G.; Bendo, C.B.; Martins, C.C. Prevalence of ankyloglossia according to different assessment tools: A meta-analysis. *J. Am. Dent. Assoc.* **2022**, *153*, 1026–1040.e31. [CrossRef] [PubMed]
21. Chinnadurai, S.; Francis, D.O.; Epstein, R.A.; Morad, A.; Kohanim, S.; McPheeters, M. Treatment of ankyloglossia for reasons other than breastfeeding: A systematic review. *Pediatrics* **2015**, *135*, e1467–e1474. [CrossRef] [PubMed]
22. Messner, A.H.; Walsh, J.; Rosenfeld, R.M.; Schwartz, S.R.; Ishman, S.L.; Baldassari, C.; Brietzke, S.E.; Darrow, D.H.; Goldstein, N.; Levi, J.; et al. Clinical consensus statement: Ankyloglossia in children. *Otolaryngol. Head Neck Surg.* **2020**, *162*, 597–611. [CrossRef] [PubMed]
23. Topbaş, S. Türkçe Sesletim-Sesbilgisi Testi: Geçerlik-güvenirlik ve standardizasyon çalışması [Turkish Articulation and Phonology Test: Validity, reliability and standardization]. *Türk Psikol. Derg.* **2006**, *21*, 39–56.
24. Girgin, M.C.; Büyükköse, D. İşitme engelli çocukların sesletim ve işitsel ayırt etme gelişim durumlarının incelenmesi [Analyzing the articulation and auditory discrimination development of children with hearing impairment]. *Ahi Evran Üniv. Kırşehir Eğit. Fak. Derg.* **2015**, *16*, 371–387.
25. Ege, P.; Acarlar, F.; Güleryüz, F. *Ankara Artikülasyon Testi [Ankara Articulation Test]*; Key Tasarım: Ankara, Türkiye, 2004.
26. Kazanoğlu, D.; Doğan, M.; Ünal Logacev, Ö. Türkçe Fonolojik Farkındalık Testi: Geliştirilmesi, geçerlilik ve güvenirlilik çalışması [Turkish Phonological Awareness Test: Development, validity and reliability study]. *Turk. Klin. J. Health Sci.* **2020**, *5*, 22–37. [CrossRef]
27. Topbaş, S.; Güven, S. *Türkçe Erken Dil Gelişimi Testi (TEDİL) [Turkish Version of the Test of Early Language Development]*; Detay Yayıncılık: Ankara, Türkiye, 2011.
28. Bergendal, B.; Bakke, M.; McAllister, A.; Sjögreen, L.; Åstén, P. Profiles of orofacial dysfunction in different diagnostic groups using the Nordic Orofacial Test (NOT-S)—A review. *Acta Odontol. Scand.* **2014**, *72*, 578–584. [CrossRef] [PubMed]
29. İncioğlu, Ş.; Alaçam, A. Evaluation of Orofacial Dysfunctions in Healthy Children Using the Turkish Adaptation of the Nordic Orofacial Test-Screening (NOT-S). *Turk. Klin. J. Dent. Sci.* **2022**, *28*, 52–60.
30. Ilic-Savic, I.; Petrovic-Lazic, M. The Influence of Voice and Speech Disorders on the Quality of Life of School-Age Children. *Res. Pedagog.* **2023**, *13*, 88–97. [CrossRef]
31. Wang, J.; Yang, X.; Hao, S.; Wang, Y. The effect of ankyloglossia and tongue-tie division on speech articulation: A systematic review. *Int. J. Paediatr. Dent.* **2022**, *32*, 144–156. [CrossRef] [PubMed]
32. Visconti, A.; Hayes, E.; Ealy, K.; Scarborough, D.R. A systematic review: The effects of frenotomy on breastfeeding and speech in children with ankyloglossia. *Int. J. Speech Lang. Pathol.* **2021**, *23*, 349–358. [CrossRef] [PubMed]
33. Cavalcante-Leão, B.L.; Todero, S.R.B.; Ferreira, F.M.; Gavião, M.B.D.; Fraiz, F.C. Profile of orofacial dysfunction in Brazilian children using the Nordic Orofacial Test-Screening. *Acta Odontol. Scand.* **2017**, *75*, 262–267. [CrossRef] [PubMed]

34. Arena, M.; Micarelli, A.; Guzzo, F.; Misici, I.; Jamshir, D.; Micarelli, B.; Castaldo, A.; di Benedetto, A.; Alessandrini, M. Outcomes of tongue-tie release by means of tongue and frenulum assessment tools: A scoping review on non-infants. *Acta Otorhinolaryngol. Ital.* **2022**, *42*, 492–501. [CrossRef] [PubMed]
35. Illing, S.; Minnee, M.; Wheeler, J.; Illing, L. The value of frenotomy for ankyloglossia from a parental perspective. *N. Z. Med. J.* **2019**, *132*, 70–81. [PubMed]
36. Yoon, A.; Zaghi, S.; Weitzman, R.; Ha, S.; Law, C.S.; Guilleminault, C.; Liu, S.Y.C. Toward a functional definition of ankyloglossia: Validating current grading scales for lingual frenulum length and tongue mobility in 1052 subjects. *Sleep Breath.* **2017**, *21*, 767–775. [CrossRef] [PubMed]
37. Thornton, A.R.; Montgomery, E.A.; Graham, M.E.; Riley, C.A.; Lawlor, C.M. Systematic Review of Tongue-Tie Publications: Exponential Rise in Publications Without Exponential Increase in Evidence. *Otolaryngol. Head Neck Surg.* **2025**, *173*, 324–331. [CrossRef] [PubMed]
38. Briddell, J.W.; Vandjelovic, N.D.; Fromen, C.A.; Peterman, E.L.; Reilly, J.S. Geometric model to predict improvement after lingual frenulectomy for ankyloglossia. *Int. J. Pediatr. Otorhinolaryngol.* **2020**, *134*, 110063. [CrossRef] [PubMed]
39. Baxter, R.; Lashley, A.; Rendell, N.R. Tongue Restriction Questionnaire: A New Screening Tool to Identify Tongue-Tied Patients. *Compend. Contin. Educ. Dent.* **2021**, *42*, e1–e4. [PubMed]
40. Santa Maria, C.; Aby, J.; Truong, M.T.; Thakur, Y.; Rea, S.; Messner, A. The Superior Labial Frenulum in Newborns: What Is Normal? *Glob. Pediatr. Health* **2017**, *4*, 2333794X17718896. [CrossRef] [PubMed]
41. Moon, J.B.; Folkins, J.W.; Smith, A.E.; Luschei, E.S. Air pressure regulation during speech production. *J. Acoust. Soc. Am.* **1993**, *94*, 54–63. [CrossRef] [PubMed]
42. van Haaften, L.; Diepeveen, S.; Terband, H.; de Swart, B.; van den Engel-Hoek, L.; Maassen, B. Maximum repetition rate in a large cross-sectional sample of typically developing Dutch-speaking children. *Int. J. Speech Lang. Pathol.* **2021**, *23*, 508–518. [CrossRef] [PubMed]
43. Tafiadis, D.; Zarokanellou, V.; Prentza, A.; Voniati, L.; Ziavra, N. Oral diadochokinetic rates for real words and non-words in Greek-speaking children. *Open Linguist.* **2021**, *7*, 722–738. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.