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Predictors of Functional Communication Outcomes in Children With Idiopathic Motor Speech Disorders

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ABSTRACT

Purpose: The purpose of the study was to investigate child- and intervention-level factors that predict improvements in functional communication outcomes in children with motor-based speech sound disorders.
Method: Eighty-five preschool-age children with childhood apraxia of speech (n = 37) and speech motor delay (n = 48) participated. Multivariable logistic regression models estimated odds ratios and 95% confidence intervals for the association between minimal clinically important difference in the Focus on the Outcomes of Communication Under Six scores and multiple child-level (e.g., age, sex, speech intelligibility, Kaufman Speech Praxis Test diagnostic rating scale) and intervention-level predictors (dose frequency and home practice duration).
Results: Overall, 65% of participants demonstrated minimal clinically important difference changes in the functional communication outcomes. Kaufman Speech Praxis Test rating scale was significantly associated with higher odds of noticeable change in functional communication outcomes in children. There is some evidence that delivering the intervention for 2 times per week for 10 weeks provides benefit.
Conclusion: A rating scale based on task complexity has the potential for serving as a screening tool to triage children for intervention from waitlist and/or determining service delivery for this population.

Speech sound disorders (SSD) encompass speech production disorders in children that may be linguistically and/or articulation based. Prevalence studies estimate that up to 24.6% of children may present with SSD (Wren et al., 2016), and 36%–46% of speech-language pathologists' (SLPs') caseload comprise this population (Farquharson et al., 2020). Several factors such as demographics (sex, socioeconomic status), gross- and fine-motor skills, prelinguistic vocalizations (e.g., babbling), sucking habits, cognition (IQ), linguistic factors (e.g., morpheme use), family history, and neurobiological (e.g., genetic) factors have been proposed to play a role in predicting the persistence of SSD at older ages (e.g., Wren et al., 2016). Furthermore, as children with SSD are a heterogeneous group (Farquharson et al., 2020), there is no single gold-standard intervention that fits all. Instead, studies have shown that success in intervention for children with SSD depends on the correct alignment between child-level factors (e.g., underlying proximal and distal deficits, age, sex, severity of speech issues, expressive language morphology; Preston

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et al., 2013; Tyler et al., 2003; Wren et al., 2016) and intervention-level factors (Crosbie et al., 2005; Farquharson et al., 2020). Intervention-level factors may include therapy approach chosen (Crosbie et al., 2005), dose parameters (e.g., frequency and intensity of treatment; Kaipa & Peterson, 2016; Namasivayam, Pukonen, Goshulak, et al., 2015; Preston et al., 2013), and quality and quantity of home practice delivered (Günther & Hautvast, 2010; Namasivayam et al., 2018; van Otterloo et al., 2006).

For example, a recent study (Farquharson et al., 2020) examined the impact of three child-level factors and four therapy-level factors on the gains in percent consonants correct (PCC; a measure of speech production accuracy and severity) following intervention in 5- to 8-year-old children with SSD. The child-level factors included age, pretest speech error severity (PCC), and language ability, whereas the therapy-level factors were the total number of minutes in therapy, total number of (group) therapy sessions, average number of therapy sessions per week, and number of individual therapy sessions. From the list of variables, only pretest PCC severity measure (child-level), total number of (group) therapy sessions and the number of individual sessions received (therapy-level) predicted gains following intervention. Interestingly, only pretest PCC severity and total number of (group) therapy sessions were positively related to outcomes (i.e., more severe at pretest and more group therapy sessions yielded larger gains in treatment). On the other hand, the number of individual therapy sessions was negatively associated with treatment gains (i.e., children receiving more individual sessions demonstrated less treatment gains). The authors attribute this group therapy advantage over individual therapy to the former mimicking learning environments and peer interactions typically present in the classroom and thus providing a more naturalistic environment for practicing speech skills.

Importantly, these above studies are limited to predicting outcomes at an impairment level (changes in severity; number/type of errors; Farquharson et al., 2020; Preston et al., 2013; Tyler et al., 2003). As such, these impairment level measures do not take into account the whole child and how they use speech from a broader social perspective to interact with their environment (Cunningham et al., 2017; Kearney et al., 2015). The World Health Organization's (WHO's) International Classification of Functioning, Disability and Health–Children and Youth (ICF-CY) version (WHO, 2007) recommends the measurement of health-related outcomes not only at impairment level (body structure and function) but also their functional impact in terms of changes in children's activities and participation (e.g., Does the child talk while playing? Does the child ask for things and join in conversations? Does the child participate in group activities? Cunningham et al., 2017; Morgan et al., 2017; Thomas-Stonell, Washington et al., 2013). Several functional communication (participation-level) measures have been recommended by researchers (Cunningham et al., 2017; Kearney et al., 2015; Thomas-Stonell et al., 2010). These include the American Speech-Language-Hearing Association Pre-Kindergarten National Outcome Measure System, Therapy Outcome Measures, and Focus on the Outcomes of Communication Under Six (FOCUS; Kearney et al., 2015; Thomas-Stonell et al., 2010; Thomas-Stonell, Oddson, et al., 2013). Of these measures, FOCUS has been specifically recommended given its sensitivity to measure treatment-related change across all of the ICF-CY levels (WHO, 2007) and the availability of published data on its validity and reliability (Thomas-Stonell, Oddson, et al., 2013; Thomas-Stonell, Washington, et al., 2013). The original validation study on the FOCUS states that "The results show that the FOCUS is able to measure changes in communicative competence after an average of 9 hours of speech–language therapy" in children with expressive language and articulation/phonological disorders (Thomas-Stonell, Oddson, et al., 2013, p. 551). This is also in line with a recent review paper that reported significant changes in FOCUS scores with interventions that were between 9 and 12 weeks in duration (Cunningham et al., 2021). Additionally, data derived from several pilot studies have shown that this duration (approximately 8–12 weeks) is sufficient to result in positive changes in functional/social communication scores in both late talkers and children with motor speech issues (Cunningham et al., 2019; Dale & Hayden, 2013; McLeod et al., 2017; Pennington et al., 2013).

Furthermore, the above studies have only been conducted on children with concomitant speech and language impairments and not with other subtypes of SSD (Farquharson et al., 2020). One of the SSD classification systems categorizes SSD based on behavioral phenotypes into speech delay, speech errors (/s/ and /r/ articulation errors), and motor speech disorders (Shriberg et al., 2010, 2019). Motor speech disorders can be further subdivided into speech motor delay, childhood apraxia of speech (CAS), childhood dysarthria, and CAS with concurrent childhood dysarthria (Farquharson et al., 2020; Shriberg et al., 2010; Shriberg & Strand, 2018). While the subtypes CAS and childhood dysarthria may be familiar to the reader, the term *speech motor delay* is a recent addition to the SSD classification system and was formerly referred to as motor speech disorder-not otherwise specified (Shriberg et al., 2019; Shriberg & Wren, 2019) or SSD with motor speech involvement (Namasivayam et al., 2019). Children with speech motor delay present with difficulties in speech motor control and coordination that is not consistent with children with CAS or dysarthria (Shriberg et al., 2019; Shriberg & Wren, 2019; Vick et al., 2014; see the Clinician Diagnosis section for more information).

Of these categories, children with motor speech disorders are at a greater risk for persistent speech difficulties as they are resistant to traditional articulation and phonological intervention approaches (Cassar et al., 2022; Namasivayam et al., 2019; Shriberg et al., 2012). Children with motor speech disorders are likely to experience short- and long-term difficulties in literacy/academic, social, and emotional domains. These may negatively impact their choice of occupation and employment prospects in adulthood (Cassar et al., 2022; Felsenfeld et al., 1994; Raitano et al., 2004), which makes early identification and intervention critical (Cassar et al., 2022; Morgan et al., 2017; Namasivayam et al., 2019; Wren et al., 2016). Thus, this population warrants an independent investigation of predictors of successful treatment outcomes.

In this study, we investigate the following research question: What child-level and intervention-level factors predict functional communication outcomes (as indexed by change in FOCUS scores) in children with idiopathic motor speech disorders (primarily CAS and speech motor delay populations)?

Method

All methods were carried out in accordance with relevant guidelines and regulations as approved by the institutional Research Ethics Board at the University of Toronto (Protocol 25981). Additional approvals were obtained from participating clinical sites as required. All SLPs, clinicians, and participants/caregivers provided written informed consent prior to the start of the study. All children gave verbal assent to participation in the study.

Participants and Setting

A total of 85 preschool-age children with moderate–severe SSD with motor speech difficulties were recruited from preschool speech and language programs from across the province of Ontario, Canada. In this sample, 65 (76.5%) were male and their mean age was 43 months (*SD* = 7.2, range: 30–62). These children were part of a large-scale outcomes research project (Namasivayam et al., 2018, 2019; Namasivayam, Pukonen, Goshulak, et al., 2015; Namasivayam, Pukonen, Hard, et al., 2015) funded by the Ministry of Children and Youth Services (province of Ontario, Canada).

Participants spoke English as the primary language at home, displayed age-appropriate play and social skills, and had hearing, vision, and receptive language within normal limits. These were assessed by standardized clinical eligibility/intake forms, parental reports, and clinical observation by an SLP as part of the Ontario preschool speech and language program's referral process. Participants presented with moderate–severe SSD (PCC range from 2.7% to 64.9%; with the exception of one participant who scored at 80.8%, n = 76). They also met a minimum of four of 12 "red flags" for motor speech involvement (Namasivayam et al., 2013). These 12 items were (1) using limited variety of speech motor movements/using jaw as primary articulator, (2) variable speech productions, (3) limited vowels and vowel distortions, (4) limited consonants and consonant distortions, (5) limited syllable and word shapes, (6) child demonstrates patterns of atypical errors (e.g., backing, initial consonant deletion), (7) atypical intonation, (8) inappropriate pitch/rate/loudness, and (9–12) difficulty maintaining sound and syllable integrity with increasing length and complexity evidenced by (a) increased variability of errors, (b) groping, (c) fatigue, and (d) decreased intelligibility.

The exclusion criteria were (a) presence of autism spectrum disorders, (b) signs and symptoms suggesting global motor (e.g., cerebral palsy, body tone abnormalities) or orofacial structural/resonance issues (e.g., cleft palate), (c) presence of significant drooling/feeding impairments, and (d) childhood dysarthria. The complex care needs of children with cerebral palsy/childhood dysarthria typically require a multidisciplinary rehabilitation approach that may include nonspeech communication methods (such as gestures, vocalizations, and the use of alternative and augmentative communication devices). Thus, this population was excluded to maintain treatment integrity to a strictly speech-based intervention. A licensed SLP performed all screening procedures and verified inclusion/exclusion criteria as reported in Namasivayam et al. (2019) and Namasivayam, Pukonen, Goshulak, et al. (2015). Participant characteristics are presented in Table 1.

Experimental Design

We utilized a pre–post design with stratified randomization to investigate predictors of intervention outcomes based on age, sex, clinician diagnosis/disorder subtype, severity, dose parameters, and home practice. Outcome assessments were carried out by a licensed speech-language pathologist (blind to the study purpose, time point, or population) both before and after the 10-week intervention period. These assessments were typically administered over two or three sessions spanning 1–2 weeks, thus totaling a 12- to 14-week study period. In this study, we examined the effects of two variations in service delivery (high-dose frequency: 2 times per week for 10 weeks; low-dose frequency: once per week for 10 weeks). Participants were not randomly assigned to high/low-dose frequency groups given the dispersion of participants over a wide geographical area, agency funding availability (some

Table 1. Participant demographics (n = 85).

Variable	Frequency (%) or *M* (*SD*)
Child-level factors	
Age (months); range	43.0 (7.2); 30–62
Sex*	
Male	65 (76.4)
Female	20 (23.6)
Clinician diagnosis*	
CAS	37 (43.5)
Speech motor delay	48 (56.5)
Speech severity	
GFTA-2 standard score[a]; range	63.1 (12.6); 40–106
PCC[b,*]	
Severe	64 (84.2)
Less severe	12 (15.8)
Speech intelligibility – CSIM[c]; range	26.4 (10.8); 6–52
KSPT diagnostic rating scale[d]; range	2.0 (0.8); 0–5
Intervention-level factors	
Dose frequency*	
High dose (2×/week × 10 weeks)	48 (56.4)
Low dose (1×/week × 10 weeks)	36 (43.6)
Home practice (min); range	461.4 (459.4); 0–2897.5
Outcome[e]	
FOCUS pre-intervention score; range	193.2 (45.8); 114–298
FOCUS postintervention score; range	221.0 (50.7); 111–336

Note. n = number of participants; CAS = childhood apraxia of speech; GFTA-2 = Goldman-Fristoe Test of Articulation–Second Edition; PCC = percent consonants correct; CSIM = Children's Speech Intelligibility Measure; KSPT = Kaufman Speech Praxis Test; FOCUS = Focus on the Outcomes of Communication Under Six.

[a]Missing four values. [b]Missing nine values. [c]Missing 19 values. [d]Missing four values. [e]Missing five values.

*Categorical variables are in frequencies and percentages.

clinics only received public funding for 10 sessions per child), and clinician-level factors such as variability in clinician training and amount of previous experience in working with children with motor speech issues. Thus, we used a stratified randomization approach to allocate approximately 50% of clinicians to the lower intensity paradigm and the remaining clinicians to the higher intensity paradigm and then adjusted for agency-level funding where necessary. This was carried out to prevent the assignment of more (or less) experienced clinicians to one group and biasing treatment outcomes (Namasivayam et al., 2019; Namasivayam, Pukonen, Hard, et al., 2015).

Intervention Approach

Motor Speech Treatment Protocol (MSTP; see Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015; Namasivayam, Pukonen, Hard, et al., 2015) is a motor speech intervention that integrates principles of development of speech motor control, along with hierarchical, temporal, and multisensory cueing strategies. MSTP utilizes general principles of motor learning and engages caregivers in the intervention to facilitate transfer and generalization (Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015; Namasivayam, Pukonen, Hard, et al., 2015). Based on a child's level of speech motor control (e.g., mandibular, labio-facial, lingual; Hayden et al., 2020; Namasivayam et al., 2020), specific speech movement goals are identified. For each of these movement goals, appropriate sounds, syllables, and word shapes are chosen. These are then embedded into functional vocabulary and phrases. For example, if a child is unable to round the lips during speech, the intervention goal would be to increase lip rounding/control. Speech sounds that use this movement are vowels like /u/ and /o/ and some consonants such as /w/. These are then combined with consonants /g, h, n/ and sounds that are already in the child's phonetic/phonemic inventory to form consonant–vowel (CV), vowel–consonant (VC), and consonant–vowel–consonant (CVC). Sample vocabulary can include “go,” “who,” “no,” “boot,” and “nose,” and phrases such as “go home” and “oh no.” The linguistic and motor complexity of target words and phrases is increased both within and over the course of the intervention. The clinician may vary the time delay between their production and the child’s response (temporal cueing; Strand et al., 2020), modify rate of speech, and provide multisensory cues (auditory, visual, and somatosensory) as required (Hayden et al., 2020; Strand et al., 2020). The session structure is planned such that the practice conditions facilitate acquisition, retention, and generalization of speech motor movements (Maas et al., 2008). For example, opportunities are created for both massed and distributed/variable practice so that new speech motor patterns can be acquired and generalized (Maas et al., 2008). During practice, knowledge of results (overall success of the production, e.g., “that was great, you did that correctly”) and knowledge of performance (how the movement was made, e.g., “use your rounded lips”) feedback is provided to improve the quality of productions.

All therapy sessions follow a general structure. Sessions start with a review of successes and challenges during home practice to determine the child’s readiness for progression in goal. Following this, a highly structured activity is chosen to provide opportunities for massed practice of the new speech motor targets and vocabulary. The next three to four activities incorporate repetitive storybooks, games, and/or crafts to provide distributed practice in a naturalistic context. In MSTP, caregivers are active participants in the intervention and are present throughout the session. They guide the selection of treatment goals and vocabulary and receive training on observing and identifying their child’s difficulties. The last 15 min of the session are dedicated to providing caregiver training. The caregivers practice intervention strategies with their child and receive feedback to facilitate home practice and the child’s speech development outside of the clinic.

Clinicians and Intervention Training

A total of 28 licensed SLPs provided the MSTP intervention (Namasivayam et al., 2019; Namasivayam, Pukonen, Hard, et al., 2015). Clinicians underwent approximately 50 hr of specialized training (two multiday workshops, guided observations, case study feedback, and online/offline learning tools) in the assessment and treatment of developmental motor speech disorders. All clinicians passed a video-based competency test prior to the start of the study. The cutoff test score for participating in this study was set at 80%. All clinicians met this criterion (M = 88.5%, SD = 12.8%; for further details on clinician training, see the works of Namasivayam et al. [2019] and Namasivayam, Pukonen, Goshulak, et al. [2015]).

Intervention Integrity and Fidelity

Intervention integrity refers to whether an intervention was delivered as planned (Kaderavek & Justice, 2010). The quality and quantity of intervention administered relate to internal validity and impact intervention gains (van Otterloo et al., 2006). Quality of intervention delivered was monitored via a review of three session plans (beginning/mid/end of treatment block); a clinical progress report outlining goals, successes, and challenges; one video recording of an intervention session; three quality of parent–child interaction observation scale ratings corresponding to video recordings (Namasivayam et al., 2018); and lastly weekly parental log forms. The parent–child interaction observation scale is a 5-point scale (Namasivayam et al., 2018; van Otterloo et al., 2006) that monitors various aspects of child-centered (child’s focus, enthusiasm, and responsiveness to parent) and parent-centered interactions (parent’s observational skills, application of strategies, ability to provide appropriate feedback). The weekly parental logs were used to monitor the frequency and intensity (in minutes) of home practice. Quantity of intervention administered met ≥ 80% of the recommended intervention practice schedule (i.e., lower intensity = 8/10 and higher intensity = 16/20 sessions) with treatment sessions averaging 45 min.

A fidelity checklist was used to assess the clinician’s competence and adherence to protocol, and treatment differentiation in this study. Competence assessed the quality or skillfulness of the clinician in delivering the intervention. The competence section contained questions relating to choice of goals, appropriateness of syllable/word shapes selected, and the clinician’s ability to adapt in real time to changing child behaviors. The section was scored by an experienced speech-language pathologist with expertise in motor speech disorders in children. Adherence refers to the use of prescribed intervention techniques such as session structure, intervention dosage, practice schedule, and providing feedback. These key elements have been recognized as necessary for successful outcomes in motor speech interventions (Maas et al., 2008). Five independent SLPs were trained for 6 hr on scoring the fidelity checklist until they scored 100% on three practice video recordings. Following this, these SLPs scored three session plans along with one video recording (usually midpoint of intervention period) for each participant. Finally, treatment differentiation was assessed as a binary yes/no response in the weekly parental log and checked whether the child received other non-MSTP interventions during the study period. One participant was removed from further analysis as they received non–MSTP-based intervention. The average fidelity score in this study was 85.4% (SD = 8.9).

Intervention-Level Factors

This study examined the effects of two intervention-level factors that are known to affect clinical outcomes in children.

Intervention Dose Frequency

Several studies and systematic reviews have suggested that intervention with higher dose frequencies yields better outcomes relative to lower dose frequencies (Allen, 2013; Kaipa & Peterson, 2016; Murray et al., 2014; Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015). However, optimal treatment intensity is specific to an intervention approach and the population it is applied to. Children with CAS demonstrate better outcomes with higher than lower dose frequency, whereas this benefit is not as evident for other populations like children with speech motor delay (Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015). We examined the effects of two variations in service delivery (high-dose frequency: 2 times per week for 10 weeks; low-dose frequency: 1 time per week for 10 weeks) in predicting functional communication gains in children with CAS and speech motor delay. In this study, intervention dose was defined as the number of target-related production attempts by the child, calculated using video recordings of the intervention sessions. From each 45-min session, a child's production attempts were calculated from three randomly selected 5-min windows, which were then multiplied by the total number of windows (e.g., 45 min divided by 5 min = nine windows) for each session. Our pilot analysis indicated no statistically significant difference in dose calculations between this random sampling procedure versus measurements based on full 45-min therapy sessions (Namasivayam et al., 2019). Within a session, dose measurements did not statistically differ between the two dose frequency groups, $t(12) = 1.45$, $p = .17$; lower dose frequency group ($M = 116.1$, $SD = 30.9$); higher dose frequency group ($M = 161.8$, $SD = 77.3$).

Home Practice

Home practice is often an integral component of speech intervention to facilitate maintenance and generalization of skills by increasing the dose of target productions (Namasivayam et al., 2018). The quality and quantity of home practice delivered during pediatric interventions are typically assessed using daily/weekly logs maintained by caregivers and/or from videos of in-home interactions (Günther & Hautvast, 2010; Namasivayam et al., 2018; van Otterloo et al., 2006). In some reading interventions that are fully home based, these factors may account for up to 43% of the outcome variance in children (van Otterloo et al., 2006). With regard to articulation interventions for children with SSD, increasing home practice frequency and the number of practice minutes resulted in better articulation outcomes and less variance in treatment success (Günther & Hautvast, 2010). In this study, we examined whether the amount of home practice (in minutes) based on weekly parental logs predicted functional communication outcomes in children with motor speech disorders.

The weekly parental logs collected information regarding the person providing the home activity (to ensure the person who was getting trained was the person delivering the intervention at home), goals and activities for that week's home practice, frequency of home practice (1, 2, 3 or more times a week), average duration of home practice session (in minutes), challenges and successes in completing the home practice, and if the child received any other treatment (from another clinician/center) other than the MSTP. To help reinforce the child's learning, the home practice activities were determined by the clinician based on treatment goals and caregiver feedback on challenges and the support needed.

Child-Level Factors

Age in Months

The study included children in the age range 30–62 months ($Mdn = 41.0$, $M = 43.0$ months) who were in preschool speech and language programs in the province of Ontario. An important factor in determining clinical service delivery models (e.g., group vs. individual therapy, parent training, treatment dosage, inclusion of home practice) is whether success for a given intervention is dependent on the age of the child. In a recent study, it was found that for children with concomitant speech and language impairments (Farquharson et al., 2020), age was not a determining factor in speech production accuracy outcomes. In this study, we explore whether age has an impact on functional communication gains.

Sex

Participants were 85 preschool-age children consisting of 65 boys and 20 girls (ratio 3.25:1.0). The higher association between the male sex and SSD is consistent with the literature on preschool/school age children in North America and data from prevalence studies conducted internationally (Shriberg et al., 2019; Wren et al., 2016). We sought to explore the impact of sex on functional outcomes in children with motor speech disorders, since this has not been studied previously.

Clinician Diagnosis

Of the 85 children who participated in this study, 37 (43.5%; boys = 28, girls = 9) had features of CAS (Namasivayam, Pukonen, Goshulak, et al., 2015) and the remaining 48 (56.5%; boys = 37, girls = 11) clinically presented with features of speech motor delay (Namasivayam et al., 2019). In line with contemporary practice, a clinical consensus/expert opinion based on a published checklist of behavioral characteristics was used to distinguish CAS from speech motor delay (Iuzzini-Seigel et al., 2017; Namasivayam, Pukonen, Goshulak, et al., 2015). An SLP (not providing assessment or treatment; SLP 1) with expertise in developmental motor speech disorders screened all participants using a behavioral checklist specific to CAS (Iuzzini-Seigel et al., 2017; Namasivayam, Pukonen, Goshulak et al., 2015) based on video/audio recordings from speech assessments containing syllable-, word- and phrase-level repetition and sequencing tasks, word-level picture naming task, and perceptually from a spontaneous speech sample, where available. For a positive CAS classification, at least seven of 12 features must be present.

Speech motor delay categorization was based on observable features associated with this population and by the exclusion of CAS and childhood dysarthria (Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015; Namasivayam, Pukonen, Hard, et al., 2015). The existence of such population within motor speech disorders that does not fit CAS or childhood dysarthria has been pointed out in a recent study on motor speech phenotypes in children with epilepsy (Allison et al., 2023). These children demonstrate moderate–profound speech production errors with the phenotype characterized by delay in the development of speech-related neuromotor precision, stability, and control (Namasivayam et al., 2020; Shriberg et al., 2019; Shriberg & Wren, 2019). Clinically, these children present with limited control of the degree of jaw height (jaw grading) and increased duration for midvowels (e.g., [ɪ], [ɛ]; Shriberg & Wren, 2019), decreased articulatory stability (e.g., lateral jaw sliding), excessive jaw movement range, decreased lip rounding and retraction, limited independence of lingual movements from the mandible, undifferentiated lingual gestures, imprecise vowels and consonants (sound distortions), increased epenthesis errors, and decreased intelligibility in connected speech (Namasivayam et al., 2013, 2020; Namasivayam, Huynh, Granata, et al., 2021; Namasivayam, Pukonen, Hard, et al., 2015; Vick et al., 2014).

Although we have used the term *speech motor delay* in this study, we urge the reader to excise caution when using this label. Standardized assessments, specificity, and sensitivity for specific behavioral and physiological markers for the differential diagnosis and identification of this population have not yet been published at this time and speech motor delay in this study was identified based on exclusion of other subtypes (CAS and DYS) and not on the presence of markers for this population (Shriberg et al., 2019; Shriberg & Wren, 2019; Vick et al., 2014).

To establish reliability of screening procedures, a second clinician (SLP 2; blind to the child's assessment and diagnostic information, including the CAS classification by SLP 1) reviewed videos of therapy sessions and cross-verified the presence of CAS characteristics on the checklist. Reliability between SLP 1 and SLP 2 was fair to good (Cohen's kappa = .669; Fleiss et al., 2013) based on a random sample of 26 children (30% of data).

Speech Severity

The study assessed speech severity using the following four predictor variables. These speech severity measures were administered and scored by licensed SLPs before and after intervention.

Goldman-Fristoe Test of Articulation–Second Edition (GFTA-2). Word-level speech articulation severity was assessed using the Sounds-in-Word subtest of the GFTA-2. GFTA-2 is a standardized and norm-referenced test with published validity and reliability data for individuals between 2 and 21 years of age (Goldman & Fristoe, 2000). GFTA-2 internal consistency coefficient α ranges between .85 and .98, test–retest reliability* = 98%, and interrater reliability* 90%–93% (* = as percent agreement on presence of error; Goldman & Fristoe, 2000). A child's production of English consonants in three word positions (initial, medial, and final) is tested using a picture-naming task with 34 pictures and 53 target words (61 consonants and 16 consonant clusters tested). Raw scores (min 0 to max 77) are calculated by summing the phoneme errors (errors in place of articulation, manner of production, and voicing) across all three word positions. The GFTA-2 manual provides tables to convert raw scores to standard scores for males/females across different age groups and ranges from 40 to 137. Standard scores use an equal interval scale and hence can be used to track intervention-related progress across time, where higher standard score after treatment implies fewer errors and a better outcome.

PCC. The PCC (Shriberg et al., 1997; Shriberg & Kwiatkowski, 1982) metric measures phonetic accuracy as a percentage of consonants correctly produced out of the total number of consonants intended in a speech sample. PCC has high reliability (intrajudge r = .97; point-by-point interrater agreement = 83%; Shriberg et al., 1997; Shriberg & Kwiatkowski, 1982) and criterion validity and correlates well with other measures of speech severity such as speech intelligibility (Namasivayam, Huynh, Granata, et al., 2021). PCC was calculated from the 34-item picture-naming task as mentioned above for GFTA-2. There are a total of 151 consonantal production opportunities in the GFTA-2 in different word (initial, medial, and final) positions. PCC was calculated as follows: (151 − child's errors)/total consonants in GFTA-2 (151) × 100. The percent scores (range: 0–100) are converted to severity levels (mild > 85%, mild–moderate

65%–85%, moderate–severe 50%–64%, and severe < 50%), and higher scores represent better outcomes in treatment (Shriberg et al., 1997).

Children's Speech Intelligibility Measure (CSIM). The CSIM is a standardized test with established validity and reliability (average test–retest reliability across age bands r = .85; average intrarater reliability across age bands r = .84; average interrater reliability r = .8; internal consistency coefficient α ranging from .85 to .90) to evaluate children's speech intelligibility at word level (Wilcox & Morris, 1999). Children imitated the clinician's model of 50 single words randomly chosen from one of 200 fifty-word lists. The list of words used at each assessment time was unique to ensure no stimulus item was repeated. The children's productions were audio-recorded (Zoom digital recorders; resolution 16 bit/sample at 44.1 kHz), edited to remove verbal instructions and extraneous noise, and then saved as .wav files. Each .wav sound file was played back at 70 dB SPL (sound pressure level) via a headphone amplifier system (PreSonus HP60; Sony MDR-XD1 headphones) to a group of three naive listeners who were then required to identify the word the child produced from a set of 12 phonetically similar words. The final CSIM score was the average score across all three listeners derived from the percentage of words correctly circled (Namasivayam, Pukonen, Goshulak, et al., 2015; Wilcox & Morris, 1999). A total of 171 listeners (M_{age} = 24.7 years; SD = 5.7; women = 120; men = 51) with little to no exposure to children with SSD were recruited from the University of Toronto. Listeners passed a hearing screening at 25 dB HL and only heard the same child or the same word list once to avoid practice effects. Raw scores (0–50) from words correctly identified were converted to percentage scores.

Kaufman Speech Praxis Test (KSPT) diagnostic rating scale. Apart from measuring speech severity based on phonetic accuracy (e.g., PCC), the degree of motor speech difficulty exhibited by the child was assessed using the KSPT diagnostic rating scale (Kaufman, 1995). The KSPT is a standardized and norm-referenced test that assesses how a child can maintain phoneme integrity when syllabic length and complexity are increased (i.e., breakdown in speech production with increasing speech complexity). All items in KSPT are elicited via direct imitation. The KSPT contains four subtests with increasing levels of difficulty.

Subtest 1 examines oral movements (tongue protrusion, lateralization, lip spread, etc.). Subtest 2 examines speech production at the simple phonemic and syllabic level, specifically the production of vowels, diphthongs, and early-acquired consonants (i.e., unmarked phonemes) in isolation and in simple monosyllabic and bisyllabic shapes (CV/VCV/CVC/CVCV; e.g., "do," "man," "top," "happy," "tuna"). Subtest 3 examines production of speech at the complex phonemic and syllabic level. Items at this level are middle- to late-acquired consonants (e.g., /s/, /z/, /l/; marked phonemes) produced in isolation and at word initial and final positions in CVC structures (e.g., "lake," "run," "mouth"). Subtest 3 also examines blends (CCVC structures; "snack," "speak," etc.), tongue anterior–posterior movements in CVC (e.g., "duck," "dig"), complex bisyllables and polysyllables (e.g., "wagon," "television"), and whether or not a child can maintain clarity when moving from monosyllabic to bisyllabic to polysyllabic word levels. Subtest 4 examines whether errors increase in spontaneous speech due to increased length and complexity.

The results obtained from these fours subtests guide the completion of the KSPT diagnostic rating scale, which encompasses a continuum of motor speech deficits from 0 to 6 (in 0.5 increments), where 0 = *oral–motor apraxia*, 1 = *verbal apraxia* (executive), 2 = *verbal apraxia* (secondary planning–severe), 3 = *verbal apraxia* (secondary planning–moderate), 4 = *verbal apraxia* (secondary planning–mild), 5 = *articulation disorder*, and 6 = *normal/typically developing*. There is a list of criteria for each point on the rating scale where a score of 0 characterizes a child who is mostly nonverbal and has difficulty initiating volitional oral movements (oral–motor apraxia); 1 is verbal apraxia characterized by oral groping, vowel distortions, inconsistent speech, sound preference patterns, and difficulty in maintaining stable and accurate phoneme production even with early-acquired sounds (e.g., /p/, /b/, /m/, /t/) in simple monosyllabic and bisyllabic words. Points 2, 3, and 4 on the continuum correspond to severe, moderate, and mild speech difficulties in the child, respectively. A score of 2 on the continuum would be characterized by excessive deletions, additions, phoneme replacements, and inconsistent productions with increased length and complexity (bisyllabic and polysyllabic items with late-acquired consonants are more difficult). A score of 3 indicates excessive replacements (instead of deletions), selective omissions of certain phoneme classes, relatively consistent error patterns, and increased difficulty with increasing length and complexity of utterance. A score of 4 reflects presence of consistent phoneme replacements/substitutions, no deletions, and minimal vulnerability to increased length and complexity of utterance. A score of 5 corresponds to articulation issues specific to lisps (lateral/frontal) and inaccurate productions of sibilants (e.g., /s/, /z/) and liquids (e.g., /r/ and /l/). Finally, a score of 6 (Normal) indicates typical developmental (age expected) phoneme errors and dialectal variations (Kaufman, 1995). KSPT has published validity and reliability data (test–retest reliability r = .87; internal consistency coefficient α across subtests = .84–.97; interrater reliability intraclass correlation coefficient [ICC] = .94

for the KSPT test and .98 for diagnostic rating scale; Kaufman, 1995).

Outcome Measure

Changes in functional communication were measured by the parent version of FOCUS (Thomas-Stonell et al., 2010). Aligned with the ICF-CY framework (WHO, 2007), FOCUS is a valid and reliable outcome measure designed to capture the impact of intervention on communicative participation in preschool-age children (Thomas-Stonell, Oddson, et al., 2013). As pointed out in the introduction section, the FOCUS can measure changes in communicative competence after an average of 9 hr of intervention (Cunningham et al., 2021; Thomas-Stonell, Oddson, et al., 2013). FOCUS has high internal consistency (Cronbach's a = .96), high test–retest reliability (r > .95), and acceptable interrater reliability (ICC = .70; 95% CI [.24, .91]), and correlates well with health-related quality-of-life measures such as Pediatric Quality of Life Inventory (Oddson, et al., 2013; Thomas-Stonell et al., 2010; Thomas-Stonell, Oddson, et al., 2013; Thomas-Stonell, Washington, et al., 2013). Caregivers scored 50 items on a 7-point rating scale (maximum of 350 points) both before (pre) and after (post) treatment. A pre–post treatment change score ≥ 16 points is considered a minimal clinically important difference (MCID) in FOCUS scores (Namasivayam, Pukonen, Goshulak, et al., 2015; Thomas-Stonell, Washington, et al., 2013).

Data Reliability

Transcription reliability (for assessments such as GFTA-2, KSPT, PCC) was estimated using a point-by-point agreement index across 40%–50% of the data set by five licensed SLPs who were blind to the study purpose, time point, or population. The average interrater reliability (percent agreement) was 83.8%.

Statistical Analysis

We described the sample characteristics using mean and standard deviation for continuous variables, and frequency and percentage for categorical variables (see Table 1). We examined bivariate associations between the MCID outcome of noticeable change in therapy and child- and intervention-level factors using the t test or Wilcoxon two-sample tests for continuous variables, and chi-square or Fisher's exact tests for categorical variables. Because of missing data, and high correlation between clinician diagnosis, KSPT scores, and PCC severity, we decided to fit three separate multivariable logistic regression models (for these three variables as predictors) for the MCID outcome of noticeable change in therapy (yes vs. no). Thus, all models included dose frequency (total sessions: 2 times per week for 10 weeks vs. once per week for 10 weeks), child's age (in months), sex (male vs. female), and home practice duration (in hours) as covariates, but Model 1 additionally included clinician diagnosis (speech motor delay vs. CAS), Model 2 included KSPT rating scale score, and Model 3 included PCC severity measure (severe < 50% PCC vs. less severe ≥ 50% PCC).

We estimated adjusted odds ratios and 95% confidence intervals (CIs), and the area under the curve. Area-under-the-curve value of .5 suggests no discrimination between groups, .7 to .8 is considered acceptable, .8 to .9 is considered excellent, and > .9 is considered outstanding (Mandrekar, 2010). Variables with missing data (CSIM) and those that demonstrated high correlation (GFTA-2 standard score) with other variables (PCC scores) were removed from subsequent analyses. For PCC, there were insufficient participants in subcategories (n: Mild–Moderate = 1; Moderate–Severe = 11; Severe = 64); hence, this variable was dichotomized as Severe (< 50% PCC) versus Less Severe (≥ 50% PCC). All analyses were performed using SAS 14.3 (SAS Institute Inc.). Statistical significance was defined if two-tailed p values were ≤ .05.

Results

Participant characteristics including missing data for all pre-intervention variables are presented in Table 1. The participants were on average 3.5 years old with a 3.25(male):1(female) sex ratio. Approximately 44% of children in the current sample were diagnosed with CAS and the remaining children as having speech motor delay. Eighty-four percent of children in this study had severe SSD scoring less than 50% on the PCC metric. Overall, 52 of 80 participants (n = 5 missing data on outcome measure) demonstrated noticeable change in the FOCUS outcome measure (i.e., MCID ≥ 16 points). Table 2 represents results from bivariate analysis.

Although the KSPT diagnostic rating scale, dose frequency, and other variables (e.g., age, sex, and home practice) did not reach statistical significance, they were still retained for the multivariate analyses owing to evidence and clinical importance given to them in the literature regarding their potential contributions to communication outcomes (Farquharson et al., 2020; To et al., 2022; Wren et al., 2016). Additional chi-square testing, $\chi^2(1, 76) = 3.23$, $p = .07$, revealed that a score of 2.5 on the KSPT scale was of clinical interest. A score of ≥ 2.5 on the KSPT scale resulted in 78.3% of children demonstrating noticeable change versus only 56.6% of those below this value demonstrating positive noticeable outcomes.

Table 2. Bivariate analysis for child and intervention factors by minimal clinically important difference.

Factor	Noticeable change	No success	*p*
Age in months, *M* (*SD*)	42.8 (6.8)	42.8 (7.6)	.95
Male sex, *n* (%)*	41 (78.9)	19 (67.9)	.28
CAS clinician diagnosis, *n* (%)*	22 (42.3)	14 (50.0)	.51
GFTA-2 standard score, *M* (*SD*)	63.8 (12.4)	61.0 (11.2)	.34
Severe PCC*, *n* (%)	41 (82.0)	20 (90.9)	.48
Speech intelligibility – CSIM, *M* (*SD*)	27.1 (10.7)	22.7 (9.4)	.13
KSPT diagnostic rating scale, *M* (*SD*)	2.1 (0.7)	1.7 (0.7)	.06
KSPT ≥ 2.5, *n* (%)	18 (37.5)	5 (17.9)	.07
High-dose frequency*, *n* (%)	34 (65.4)	13 (46.4)	.10
Home practice in minutes			
M (*SD*)	510.0 (513.1)	397.5 (361.8)	.49
Mdn (IQR)	365.0 (199.3–650.0)	328.8 (215.0–423.8)	

Note. *n* = number of participants; CAS = childhood apraxia of speech; GFTA-2 = Goldman-Fristoe Test of Articulation–Second Edition; PCC = percent consonants correct; CSIM = Children's Speech Intelligibility Measure; KSPT = Kaufman Speech Praxis Test; IQR = interquartile range.
*Categorical variables are in frequencies and percentages.

The point biserial correlations between clinician diagnosis and KSPT scores, and clinician diagnosis and PCC were .61 ($n = 81$) and .57 ($n = 76$), respectively. The Pearson correlation between KSPT scores and PCC was .59 ($n = 72$). Results for the multivariable logistic regression are shown in Table 3. Model 2 is considered the best model with an area under the curve of .72, indicating moderate ability to discriminate between noticeable change in therapy and no success. The KSPT diagnostic rating scale emerged as a significant predictor of noticeable change in functional communication outcomes in children. For every additional point in the KSPT diagnostic scale, the odds of noticeable change in therapy increased by 2.5 times.

Furthermore, with high-dose intervention, the odds of noticeable change in therapy increased by 2.4 times

Table 3. Multivariable logistic regression models for the association of noticeable change in therapy (minimal clinically important difference outcome), diagnosis, and disorder severity.

Child and intervention level factors	Model 1		Model 2		Model 3	
	***OR* [95% CI]**	***p***	***OR* [95% CI]**	***p***	***OR* [95% CI]**	***p***
Clinician diagnosis						
SMD vs. CAS	1.54 [0.58, 4.24]	.406	—	—	—	—
Disorder severity						
KSPT diagnostic rating scale	—	—	2.51 [1.18, 5.32]	.016	—	—
PCC (severe vs. less severe)	—	—	—	—	0.45 [0.08, 2.46]	.360
Age (for every 6 months increase)	1.03 [0.66, 1.61]	.892	1.00 [0.64, 1.55]	.995	1.01 [0.63, 1.62]	.974
Male vs. female	2.53 [0.81, 7.93]	.111	2.02 [0.61, 6.67]	.248	2.34 [0.62, 8.79]	.208
Number of sessions (20 vs. < 20)	2.67 [0.96, 7.37]	.058	2.44 [0.84, 7.09]	.100	2.56 [0.85, 7.74]	.095
Home practice duration (for every additional hour)	1.05 [0.97, 1.14]	.202	1.07 [0.99, 1.16]	.107	1.06 [0.96, 1.17]	.230
Area under the curve	0.66	—	0.72	—	0.64	—

Note. *OR* = odds ratio; CI = confidence interval; SMD = speech motor delay; CAS = childhood apraxia of speech; KSPT = Kaufman Speech Praxis Test; PCC = percent consonants correct; "—" = not tested in the model.

(Model 2), but this estimate had high variability (wide 95% CI) and was not statistically significant. With regard to home practice, for every additional hour, the odds of noticeable change increased by 7% (1.07; 95% CI [0.99, 1.16]; see Table 3). For males, the odds of noticeable change in therapy were 2.02 times higher than for females. In general, although these variables were not statistically significant (except for KSPT rating scale), all variables were positively associated with noticeable change in therapy. In the Discussion section, we will only be discussing those outcomes that were significant ($p < .05$) or those that are deemed clinically relevant (dose frequency and home practice amount), as indicated above.

Discussion

We investigated the following research question: What child-level and intervention-level factors predict functional communication outcomes (FOCUS scores) in children with idiopathic motor speech disorders? We explored seven child-level (age, sex, clinician diagnosis, articulation test standard scores, PCC, speech intelligibility, and KSPT diagnostic rating scale) and two intervention-level factors (dose frequency and minutes of home practice), which were then narrowed down to three predictor variables (KSPT diagnostic rating scale, PCC severity, clinician diagnosis of CAS vs. speech motor delay) and four covariates (age, sex, dose frequency, and home practice in hours) in the final multivariate analysis. Overall, 52 participants (65%) demonstrated noticeable change in FOCUS outcome measure (i.e., MCID ≥ 16 points), whereas the remaining 28 did not.

In the multivariate analysis, the KSPT diagnostic rating scale emerged as a significant predictor of noticeable change in functional communication outcomes in children. For every additional point in the KSPT diagnostic scale, the odds of noticeable change in therapy increased by 2.5 times. Furthermore, in this study, children with noticeable change in treatment generally had a pretreatment KSPT rating of 2.5 (or greater), whereas children with less than a rating of 2.5 had less successful outcomes in functional communication. On the KSPT scale, errors in late-acquired consonants and complex syllable structures (CVCVC, CVCVCV, CCVC) generally correspond to a rating of 2, whereas errors in early-acquired consonants and simpler syllable structures (CV, CVC, CVCV) correspond to a rating of 1.

These results may be interpreted from a coordination dynamics perspective as elaborated in the articulatory phonology (AP) model as applied to SSD (Namasivayam et al., 2020). Articulatory gesture-based approaches such as the AP model can account for increasing errors with increasing complexity. For example, biological systems (e.g., moving two fingers, limbs, or lips) prefer stable in-phase coordination patterns as opposed to less stable antiphase patterns. In CV syllable production, consonants are linked to vowels in-phase, whereas two consonants in CC clusters or in a VC sequence in a syllable are linked antiphase. This is also why (according to AP) there is a dominance of a CV syllable structure during speech development (e.g., during babbling), as well as across languages (Goldstein et al., 2006; Namasivayam et al., 2020). Conversely, the increased complexity of the antiphase syllable structures requires more effortful learning and practice, and hence, are acquired later during child development (Namasivayam et al., 2020).

The coordination dynamics perspective also explains complexity at a phoneme level. Early-acquired consonants (e.g., /p/, /b/, /t/; Subtest 2 items on the KSPT) require fewer vocal tract constrictions to be coordinated in comparison to late-acquired consonants (/r/, /l/, /s/, /tʃ/; Subtest 3 items on the KSPT) that require coordination between multiple vocal tract constrictions. For example, the /r/ sound entails coproduction of up to five vocal tract constrictions/gestures (i.e., tongue tip elevation, tongue root retraction, tongue mid lowering, tongue body bracing, and lip protrusion; Preston et al., 2020) in contrast to the /p/ sound requiring only the coordination between the lips and the jaw. The complex coordination pattern for /r/ demands a high level of speech motor skill and, thus, is mastered by older children between 4 and 7 years of age (Namasivayam et al., 2020).

Thus, the KSPT findings suggest an impact of speech motor complexity on functional outcomes. Based on these findings, we speculate that children at or above a KSPT rating of 2.5 might be able to effect a larger system-wide change and consequentially show better functional outcomes because they are beginning to master more complex speech motor patterns (Namasivayam et al., 2020). Manipulating task or stimulus complexity to differentially diagnose motor speech disorders in children is not new (Iuzzini-Seigel et al., 2017; Namasivayam, Huynh, Bali, et al., 2021). However, envisioning task complexity as a potential tool to predict functional communication success is an innovative approach, in our view.

Additionally, the intervention-level variables dose frequency and home practice are of clinical importance. Choosing an intervention dose must be optimized for speech motor skill learning. Too high of a dose results in overlearning (continuing practice after skill mastery), whereas too low of a dose results in underlearning (practice termination before criterion performance has occurred). In the former case, time and resources are wasted as performance has reached a ceiling value, and in the latter case learning has not occurred (Kaipa & Peterson, 2016). Thus, determining optimal intervention dose is critical for clinical cost–benefit efficiency. In this study, with the high-dose intervention (2 times per week), the odds of noticeable change in therapy increased by 2.4 times, relative to lower dose (1 time per week). This is a clinically relevant effect even though it is not statistically significant. This result is also in line with the general finding that higher dose frequencies (e.g., 2 times per week) yield better functional outcomes relative to lower dose frequencies (e.g., 1 time per week; Allen, 2013; Murray et al., 2014; Namasivayam et al., 2019; Namasivayam, Pukonen, Goshulak, et al., 2015). Given the wide 95% CI (see Table 3; values between 0.84 and 7.09) found for this variable, the magnitude of this effect is somewhat uncertain, and future studies with larger sample sizes may provide more definitive answers.

With regard to the amount of home practice, this variable was not a significant predictor of functional outcomes in this study but was a variable of clinical interest. This variable had a narrow 95% CI [0.99, 1.16] around the odds ratio point estimate of 1.07 (see Table 3). Thus, for every additional hour of home practice, the odds of noticeable change increase by 7%. This finding is of clinical importance and supports the need for monitoring quality and quantity of home practice delivered during pediatric motor speech interventions, for example, via daily/weekly logs maintained by caregivers (Günther & Hautvast, 2010; Namasivayam et al., 2018; van Otterloo et al., 2006). These results support earlier studies (Günther & Hautvast, 2010) on children with articulation errors who demonstrated benefits in speech articulation outcomes and a reduction in outcome variance as a function of home practice compliance.

Clinical Implications

The current motor speech care pathway for children > 36 months of age in the province of Ontario is based on severity metrics that are related to PCC and GFTA scores (percentile cutoffs). In this care pathway, children between the 8th and the 16th percentiles and those that are ≤ 7th percentile are recommended to receive speech motor intervention for 1 time per week or 2–3 times per week, respectively (Pukonen et al., 2013). The results from this study suggest that a speech motor complexity-based measure at pretreatment significantly predicts functional outcomes in children with idiopathic motor speech disorders, much better than PCC or GFTA-2 scores. Thus, it would be worthy to explore the possibility of developing and validating a screening checklist based on speech motor complexity to triage children for intervention from waitlist and/or for determining service delivery variables (i.e., intervention dosage). Given that current waitlists for receiving assessment and/or intervention services for preschool/school age children in Ontario may run into several months (Mahoney, 2017), having such a screening checklist along with weighing in of other risk factors (Rvachew & Rafaat, 2014) would have a significant cost–benefit impact. This strategy would necessitate a sense of urgency to provide assessment and intervention services to those children who fail screening of early-acquired consonants and simpler syllable structures, regardless of child's age and/or sex, as the latter two did not predict functional outcomes in this study. Overall, these data indicate that children with more severe apraxia (< 2.5 on the KSPT scale) demonstrate decreased functional outcomes and support the contemporary best clinical practice guidelines of increasing intervention dosage for those with severe forms of this disorder (American Speech-Language-Hearing Association, 2007; Murray et al., 2014; Rvachew & Rafaat, 2014). Additionally, intervention dose and home practice play an important role in producing noticeable change in functional outcomes for children with idiopathic motor speech disorders.

Limitations

There are several limitations in this study: (a) Studies conducting predictive analysis typically involve large sample sizes (N = several hundreds to thousands), and although we conducted a multicenter study and were able to recruit $N = 85$ participants, it was clinically and logistically not feasible to recruit a larger sample size for disorders such as motor speech disorders that have low prevalence and incidence (Shriberg et al., 2019). Variables such as dose frequency, home practice, and speech intelligibility may have been affected by sample size (and missing data) issues in this study. Although we deemed dose frequency and home practice as clinically relevant, they are not statistically significant, and hence, caution is warranted when interpreting these results.

(b) Furthermore, we did not examine other child-level (motivation, focus) or therapist-level factors (job satisfaction, caseload size, etc.) in this study, and these factors have been reported to influence service delivery decisions and quality of services delivered (Farquharson et al., 2020; Günther & Hautvast, 2010; Tyler et al., 2003). (c) Maintenance of treatment gains over time (e.g., 4–6 months postintervention) is an important factor in determining intervention effectiveness for children with motor speech disorders (Murray et al., 2015). We only assessed functional outcomes immediately posttherapy, which although ecologically valid, fail to address whether these predictor variables are related to these outcomes over extended periods of time. (d) Finally, future large-scale studies are required for this population to identify whether a different intervention type or manipulations of dose frequency and/or a longer intervention duration (> 10 weeks) might yield increased magnitude of functional outcomes and improved success rates in therapy.

Conclusions

This is the first study to examine the effects of child- and intervention-level factors on functional communication outcomes in children with idiopathic motor speech disorders. The findings indicate that the KSPT diagnostic rating scale significantly predicted noticeable change in functional communication outcomes in these children, while two other variables (dose frequency and home practice) were clinically relevant. Dose frequency improved the odds of noticeable functional change in therapy, but the CI estimate was variable and further large-scale studies are warranted. The impact of amount of home practice on functional outcomes in children resulted in a small but important clinical effect. Overall, the findings suggest that a rating scale based on the speech motor complexity approach might have potential for further development as a screening tool to triage children for intervention from waitlist and/or to determine service delivery variables for children with idiopathic motor speech disorders.

Author Contributions

Aravind K. Namasivayam: Conceptualization (Lead), Data curation (Lead), Methodology (Lead), Project administration (Lead), Validation (Lead), Visualization (Lead), Writing – original draft (Lead), Writing – review & editing (Equal). **Hyunji Shin:** Visualization (Supporting), Writing – original draft (Supporting), Writing – review & editing (Lead). **Rosane Nisenbaum:** Data curation (Supporting), Formal analysis (Lead), Writing – review & editing (Supporting). **Margit Pukonen:** Funding acquisition (Lead), Project administration (Equal), Resources (Lead), Visualization (Supporting), Writing – review & editing (Supporting). **Pascal van Lieshout:** Methodology (Supporting), Project administration (Supporting), Resources (Lead), Visualization (Supporting), Writing – review & editing (Equal).

Protection of Humans and Animals in Research/Informed Consent of Patients/ Ethics Approval and Consent to Participate

All methods were carried out in accordance with relevant guidelines and regulations as approved by the Institutional Research Ethics Board at the University of Toronto (Protocol 25981). Additional approvals were obtained from participating clinical sites as required. All SLPs, clinicians, and participants/caregivers provided written informed consent prior to the start of the study. All children gave verbal assent to participation in the study.

Data Availability Statement

The datasets generated and/or analyzed during this study are not publicly available due to ethical restrictions. De-identified data are however available from the corresponding author upon reasonable request and with approval from the Research Ethics Board at the University of Toronto.

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