MOTOR ABILITIES OF CHILDREN WITH CHILDHOOD APRAXIA OF SPEECH

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Abstract: *Previous studies on fine and gross motor skills of children with childhood apraxia of speech (CAS) have reported inconclusive results. In this study, we investigate the motor abilities of children with CAS by focusing on three distinct motor factors: control during movement, fine motor skills/handwriting, and general coordination.*

Participants included 25 children with CAS and 20 age-matched typically developing (TD) children between the ages of 5 and 7 years. Motor abilities were evaluated using a parent questionnaire - the Croatian version of The Developmental Coordination Disorder Questionnaire (DCDQ-HR).

Compared to age-matched TD children, those with CAS showed significantly poorer overall motor ability based on the DCDQ-HR, as well as on all three motor factors: control during movement, fine motor skills/handwriting, and general coordination. Even though their results were worse than TD children, they were still within the range that indicates normal motor abilities. Among the three motor factors considered, children with CAS exhibited significant problems with fine motor skills/handwriting.

Children with CAS may not be categorised as children with motor deficits, but they exhibit poor overall motor abilities, especially fine motor skills, compared to TD children. This study supports the premise that co-occurring language impairment is an important variable to consider when discussing motor abilities in CAS.

Keywords: *childhood apraxia of speech; motor abilities; fine motor skills; motor comorbidity; developmental coordination disorder*

INTRODUCTION

Childhood apraxia of speech (CAS) is a childhood motor speech disorder characterised by poor planning and/or programming of speech sound sequences, in which the precision and consistency of movements underlying speech are impaired, in the absence of neuromuscular deficits (American Speech-Language-Hearing Association [ASHA], 2007). Although the nature of the underlying deficit was traditionally thought to be motoric (Ozanne, 2010), there is controversy in the field as to whether CAS should be classified as a "syndrome" (i.e., a symptom complex that includes speech and language difficulties) or solely as a motor-speech disorder (Stein et al., 2020).

Despite the lack of agreement about the specific features of CAS, it is known that children with CAS exhibit an array of symptoms such as inconsistent errors, vowel distortions, voicing errors, difficulty with transitionary movement, articulatory groping, increased difficulty with multisyllabic words, slow speech rates (diadohokinetic rates), reduced phonetic inventory, and prosodic disturbances (ASHA, 2007; Grigos, Moss & Lu, 2015; Iuzzini-Seigel & Murray, 2017). However, not all features of CAS are purely speech-related behaviours: for instance, Ozanne (2010) reported non-speech-related CAS features such as problems with feeding, gross/fine motor incoordination, and body dyspraxia/body awareness in space, while Davis and Velleman (2000) found gross and fine motor delays, clumsiness, and volitional oral motor skills as characteristics co-occurring with CAS. Although it is not surprising that children with CAS are at higher risk for language problems and deficiencies in fine and gross motor skills (Iuzzini-Seigel, 2019), there is little knowledge about the extent of motor difficulties and the presence of possible global motor deficits. Given that speech output involves motor programming, one might expect motor deficits to be most pronounced in children with impairments

in speech production (Bishop, 2002), such as children with CAS, due to their poor planning and/or programming of speech. This statement is only partially true because data on the motor abilities of children with CAS are limited and inconclusive.

Motor characteristics in children with CAS

Motor abilities are broadly divided into gross motor and fine motor skills. Gross motor skills involve large muscle movements such as running and jumping, while fine motor skills involve the use of smaller muscles (Gonzalez, Alvarez & Nelson, 2019). Bradford and Dodd (1994) examined the motor performance of four groups of participants with speech-impairments (delayed articulation skills and/or delayed phonology, deviant consistent phonology, inconsistent deviant speech, and developmental verbal dyspraxia [former term for CAS]) on subtests from the Bruininks-Oseretsky Test of Motor Proficiency. The authors found that children diagnosed with CAS showed difficulties on fine motor subtests (upper limb speed and dexterity, visual-motor integration), potentially reflecting deficits at the level of incorporating sensory information into a plan of action, as well as at the level of co-ordinating speed and dexterity of intricate movements. Unlike children with CAS, children with inconsistent deviant speech were able to complete untimed motor tasks, however, their performance was significantly poor than controls on tasks that required speed and dexterity of fine motor movements.

Tükel, Björelius, Henningsson, McAllister and Eliasson (2015) raised the question of a core global motor deficit in CAS because of the overlap between manual motor planning and coordination problems in children with developmental coordination disorder (DCD) and those with CAS. DCD is a neuro-developmental disorder characterised by diminished fine and/or gross motor coordination that affects approximately 5–6 % of school-aged children (American Psychiatric Association, 2013). Tükel et al. (2015) also used the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) to examine overall body motor proficiency and manual motor ability. The group median performances in manual and overall body motor function were at the low end of the normal range, indicating normal motor abilities. However, there was a high incidence of co-occurring motor difficulties on an individual level. Many children with CAS had difficulties in up to seven of the eight motor functions when using –1 standard deviation (SD) as the cut-off, which is a common cut-off score for identifying the risk of DCD (Tükel et al., 2015). Unlike other studies, Tükel et al. (2015) used the presence of receptive language disorder as an exclusion criterion for children with CAS, which, according to Iuzzini-Siegel (2019), is an important variable to consider.

Following this premise, Iuzzini-Siegel (2019) investigated fine and gross motor skills between groups of children based on language performance (children with comorbid speech sound disorder and language impairments - SSD + LI; children with childhood apraxia of speech and comorbid language impairment - CAS + LI; children with only speech sound disorders - SSD-only; children with only childhood apraxia of speech - CAS-only; children with typical language abilities - TD). Compared to the TD group, the CAS + LI group had significantly poor performance on the manual dexterity, balance and aiming, and catching components. With respect to movement tasks, there were no statistically significant differences for the CAS-only and SSD + LI groups relative to other groups. Even though these results have to be interpreted carefully because of the small sample, these findings represent preliminary evidence that there may be a clinically meaningful difference in the motor abilities of subgroups of children with CAS (Iuzzini-Siegel, 2019). Some studies have also shown that children with developmental speech and language disorders have significantly poorer results on the Movement Assessment Battery for Children than children with speech disorders and children with both speech and language disorders (Visscher, Houwen, Scherder, Moolenaar & Hartman, 2007).

In their recent study, Iuzzini-Seigel, Moorer, and Tamplain (2022) examined the co-occurrence of DCD in children with CAS. Their preliminary results indicate that the potential for undiagnosed co-occurrence of DCD in children with CAS is high and clinically significant. However, four out

of seven participants with CAS had concurrent developmental language disorder (DLD) and all met the criteria for DCD, whereas only two out of three participants who had CAS-only met DCD criteria. These findings are similar to the study by Duchow et al. (2019), in which 49% of participants with suspected CAS were at risk for DCD based on DCDQ responses compared to 9% of children in the general Canadian population; however, this study did not directly assess participants for speech and language abilities.

Additionally, the presence of a receptive language disorder such as DLD must be considered, since children with DLD also show deficits in fine/gross motor skills (Sack, Dollaghan & Goffman, 2022). As a group, they perform worse than their typically developing peers in manual dexterity and balance-related tasks and they find it more difficult to organise sequentially patterned items, as evidenced by their weaker performance on nonverbal serial reaction time tasks (Sack et al., 2022). In addition, movement difficulties observed in children with DLD are very similar to those observed in children with DCD (Hill, 2001), such as difficulties with oral motor coordination (e.g., closing the lips to blow soap bubbles or blowing out birthday candles (Harris, Mickelson & Zwicker 2015). For this reason, when discussing the motor skills of children with various speech and language disorders, language skills should also be considered.

Furthermore, there are strong theoretical reasons to believe that the underlying mechanism of both CAS and DCD may be shared. This co-occurrence of motor and language problems can be explained by the spatial similarity/overlap of neural substrates (Visscher et al., 2010) or by the procedural learning deficit hypothesis (Nicolson & Fawcett, 2007). The procedural learning system is the mechanism by which patterns are learned without being explicitly taught: through multiple repetitions, these patterns are stored in the procedural memory system and a person begins to perform them automatically (Iuzzini-Siegel, 2019). Maassen (2002) indicated that perceptual motor learning plays a role in many children with CAS, while Iuzzini-Siegel's (2021) research showed that children with CAS performed differently from their peers on procedural learning tasks compared to children with other speech sound disorders (without CAS) and typically developing children. In addition, children with CAS who exhibited these procedural learning patterns also tend to have concurrent language and motor deficits. These findings are consistent with other research showing that children with CAS have a more generalised motor sequencing disorder (Bradford & Dodd, 1996; Dewey, Roy, Square-Storer & Hayden, 1988; Nijland, 2003) and implicit learning deficits (Iuzzini-Seigel, 2021; Bombonato et al., 2022). In addition, children with DCD also show a tendency toward poorer motor learning (retention and transfer) in repeated sections, suggesting that they have difficulties associated with implicit motor learning conditions (Jarus et al., 2015). This confirms the complexity of both populations and is a reason for further investigation into these possibly co-occurring deficits.

Aim of the study

The purpose of this study was to investigate the motor abilities of children with CAS (taking their language abilities into consideration) and to test for differences, if any, in three distinct motor factors: control during movement, fine motor skills/handwriting, and general coordination. We hypothesised that children with CAS would show poor performance on The Developmental Coordination Disorder Questionnaire – DCDQ-HR (Sangster Jokić, Knežević, Wilson, in preparation), as well as on all three motor factors individually.

METHODS

Participants

This study included 25 children with CAS and 20 age-matched typically developing children (TD). Exclusion criteria for participants were: presence of neurological or physical cause of the speech sound disorder (e.g., cleft palate), motor impairment, cognitive impairment, hearing impairment, and inadequate receptive language skills. All children had normal or corrected vision and normal hearing (based on the results of neonatal screening). Only children with results within the normal range on Raven's Colour Progressive

Matrices Test (CPM, Raven, 1999) and the Test for Reception of Grammar (TROG-2:HR; Bishop, Kuvač Kraljević et al., 2014) were included in the study (SR ≥85). All children were monolingual speakers of Croatian.

Participants included 33 males (CAS = 21, TD = 12) and 12 females (CAS = 4, TD = 8), ranging in age from 64 to 91 months (*M* = 77 months, *SD* = 6.7). All children with CAS received speech and language therapy for at least one year at the time of the study, but none of them had ever received occupational or physical therapy.

Participants completed a series of tasks representing different levels of the speech production process as part of a larger research study (Doctoral research project entitled *Phonological abilities of children with Childhood Apraxia of Speech*). Children with CAS were referred by a speech and language pathologist (SLP). All participants with CAS had a previous CAS diagnosis or were suspected of having CAS. For the purpose of this study, the diagnostic classification for CAS was based on the presence of the three criteria stated in ASHA (2007) (1) inconsistent consonant and vowel errors, (2) difficulty forming articulatory transitions between sounds and syllables, and (3) prosodic errors. A researcher and one experienced SPL determined the diagnostic classification for CAS based on Grigos, Moss, and Lu (2015). Children diagnosed with CAS showed these features in more than one speech context and within at least three different words (or sounds/syllables in the sequencing task): inconsistent errors that were defined as consonant and vowel errors based on the differences in repeated productions of the same word (e.g., /svjetiljka/ Eng. /lamp/ produced as /sletika/, /sletilka/, /sletitka/ by the same speaker); difficulties in articulatory transitions that were characterised by poor coarticulation, especially when it included phonemes that were present in the child's repertoire (e.g., difficulty in combining the consonant /s/ with different vowels, even though /s/ and the vowels can be produced correctly in other contexts); and prosodic errors that were identified as incorrect lexical and/or phrasal stress. In addition to the three core features, children with CAS exhibited at least four of the following features throughout different tasks: metathesis (e.g., production of /poklopac/ Eng. /lid/ as /klopopac/), vowel errors (e.g., production of /poklopac/ as /paklopac/), voicing errors (e.g., voiceless sound is replaced by a voiced sound), phoneme distortions, articulatory groping (e.g.., visual struggle accompanying phoneme production), reduced phonetic inventory, and poorer expressive vs receptive language skills.

Instruments

To test the cognitive abilities of participants, Raven's Coloured Progressive Matrices (CPM, Raven, 1999) were used, which are considered to be appropriate for testing general cognitive abilities from ages 5 to 11 years. This test measures the ability to make perceptive and logical conclusions, as well as offers insight into perceptual, problem-solving, and learning abilities. The test consists of 12 tasks grouped into three sets (36 in total). In each task, the participant is presented with a coloured drawing in which an area has been left blank. The participant must select the image that best fills the white/blank frame of the main drawing. The test was administered by a psychologist.

The Test for Reception of Grammar (TROG-2:HR; Bishop, Kuvač Kraljević et al., 2014) was used for assessing receptive language of Croatian grammar with respect to inflexion, functional words, and word order. The TROG-2 consists of 80 items made up of sentences of varying complexity that are ordered from lower to higher complexity. The participant must select one of four images that corresponds to the sentence presented in the item. This test was administered by an SLP.

Motor abilities were tested using the Croatian version of The Developmental Coordination Disorder Questionnaire (DCDQ-HR; Sangster Jokić, Knežević & Wilson, in preparation). DCDQ (Wilson, Kaplan, Crawford & Roberts, 2007) is a questionnaire developed to identify subtle motor problems in children aged 5-15 years. Caregivers assess their child's coordination in comparison with other children of the same age on a 5-point Likert scale. This questionnaire represents a

standardised method for measuring a child's coordination in daily functional activities. It contains 15 items that examine: control during movement (1. throws the ball, 2. catches the ball, 3. hits ball/birdie, 4. jumps over, 5. runs, 6. plans activity), fine motor and handwriting skills (7. writing fast, 8. writing legibly, 9. effort and pressure, 10. cuts), and general coordination (11. likes sports, 12. learning new skills, 13. quick and competent, 14. "bull in the shop", 15. does not fatigue).

The Cronbach's alpha coefficient for the total test was measured to be 0.88. The DCDQ was also significantly correlated with the total impairment score of the Movement Assessment Battery for Children - Movement ABC ($r = - 0.59$, $p < 0.0001$) (Wilson, Kaplan, Crawford, Campbell & Dewey, 2000). If the child scored less than 47 on the DCDQ (for children from 5;00 to 7;11), that was considered as an indication of DCD or suspect DCD. The maximum score on DCDQ is 75.

Procedure

Th is study was approved by the Ethical Review Board of the Faculty of Education and Rehabilitation Sciences [602-04/20-42/5; 251-74/20-01/2]. The caregivers of all the participants provided written informed consent for the child's participation in the study.

Statistical analysis

Data was analysed using SPSS 24 (IBM, Armonk, NY). After applying the test for normality (Shapiro-Wilk Test was used due to the small sample), nonparametric Mann-Whitney U test was used to determine whether there were differences between children with CAS and TD children in general coordination, control during movement, fine motor and handwriting skills, and in the total DCDQ score (i.e., overall motor skills). Variables: control during movement, fine motor and handwriting skills, and general coordination were normally distributed in children with CAS, so one-way repeated measure analysis of variance (ANOVA) test was used to determine whether there was a difference between sub-scores on DCDQ-HR in children with CAS. All children were controlled for receptive language abilities on TROG-2:HR test (CAS, *M*=91.3; TD, *M*=104.1) and cognitive abilities on Raven's Coloured Progressive Matrices (CAS, *M*=76.6; TD, *M*=89.1).

RESULTS

To understand the motor abilities of children with CAS, we compared their overall DCDQ-HR scores to that of the TD children. Based on the Mann-Whitney *U* test, it can be concluded that TD children had significantly better DCDQ-HR

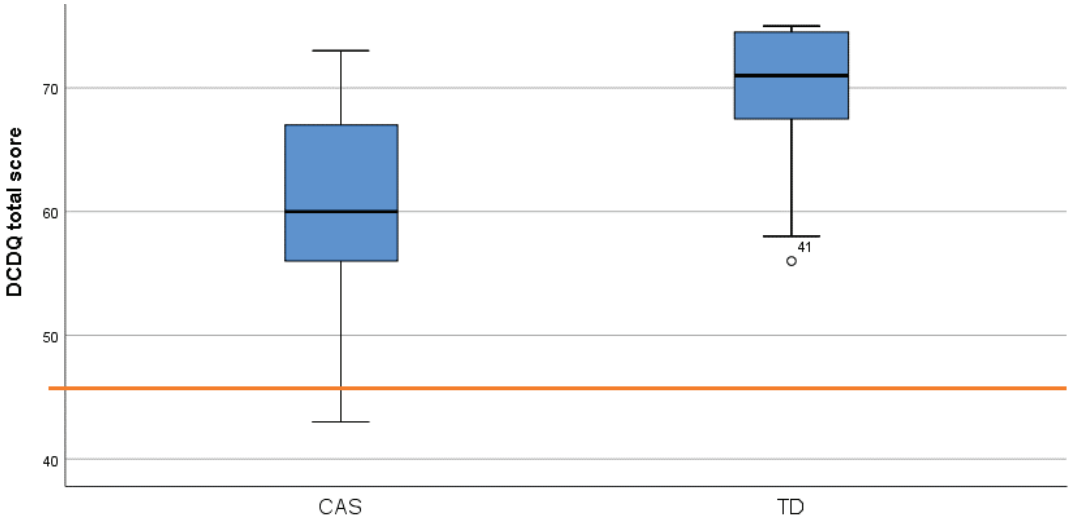

Figure 1. *DCDQ-HR mean total scores for CAS and TD children*

scores than children with CAS (U = 82.00, p = 0.000), as seen in Figure 1 (the orange line represents a score below 47, indicating suspected DCD). The mean total score for TD children was 69.60 (SD = 5.6), while children CAS had a mean total score of 59.64 (SD = 8.7).

After calculating DCDQ-HR scores for the three different motor factors (control during movement, fine motor skills/handwriting, general coordination), new variables were constructed based on the average result for each item in each factor, since there were different numbers of questions corresponding to each motor factor (see *Instruments*). These average subscores were used for further analysis. The highest score on each item was 5, representing the best motor performance on that specific item (i.e., the higher the score, the better the motor abilities). To test whether there were differences between TD and CAS children on three different motor factors, the groups were compared on three subscores of DCDQ-HR. Mann-Whitney U test results showed that there were significant differences between the two groups with respect to all three motor factors. TD children had significantly better results on control during movement (Z(-3.199), p = 0.001); fine motor (Z(-3.717), p = 0.000); and general coordination (Z(-3.653), p = 0.000). Mean scores on each motor factor are visible in Table 1.

Furthermore, a repeated measures ANOVA (sphericity assumed) determined that mean scores on different motor abilities differed significantly in children with CAS ($F(2, 86) = 9.750$, $p < 0.05$), confirming the main effect of motor abilities. Post hoc analysis (paired samples t-test) showed that children with CAS performed significantly better on motor tasks involving control during movement than those related to fine motor skills ($t(24) = 3.770$, $p < 0.05$); Cohen's D was 0.75, indicating medium to large effect sizes. Children with CAS were also better in general coordination when compared to fine motor skills ($t(24) = -2.553$, $p < 0.05$); Cohen's D was 0.51, indicating a medium effect size. There was no significant difference between scores on motor tasks involving control during movement and general coordination. In contrast, paired samples Wilcoxon test confirmed that TD children showed similar performances on all three motor factors ($p > 0.05$), indicating a balanced motor profile.

DISCUSSION

In the present study, the motor abilities of children with CAS were assessed using the Developmental Coordination Disorder Questionnaire (DCDQ-HR). Children with CAS were expected to show poorer performance on the DCDQ-HR compared to typically developing children. The presented data supported this hypothesis: children with CAS had significantly lower overall scores on DCDQ-HR than age-matched TD children. In addition, when tested for differences in three different motor factors (control during movement, fine motor skills/handwriting, and general coordination), TD children had significantly better scores on each of the motor factors. Although children with CAS did have poorer results, their mean score was within the expected range (above 47) for children from 5 to 7 years. Only three children with CAS scored below 47, indicating suspected DCD. In the present study, only 12% of children with CAS were at risk for DCD based on DCDQ-HR responses, compared to 49% in the study conducted by Duchow et al. (2019).

Unlike in Gretz (2013) where approximately 50% of children with CAS were shown to have a history of physical and/or occupational therapy, or in Iuzzini-Seigel et al. (2022) where 57% of

Table 1. *Mean DCDQ-HR scores for CAS and TD children with respect to three distinct motor factors*

	Control during movement Mean (SD)	Fine motor and handwriting skills Mean (SD)	General coordination Mean (SD)
CAS	4.18 (0.59)	3.60 (0.80)	4.03 (0.74)
TD	4.71 (0.35)	4.53 (0.55)	4.75 (0.35)

Note: CAS – children with childhood apraxia of speech; TD - typically developing children; SD - standard deviation

CAS children had previously undergone physical or occupational therapy, none of the children with CAS in the present study had received occupational therapy or physiotherapy. Our results are very similar to the results presented by Tükel et al. (2015), in which children with CAS were at the lower end of the normal range, indicating normal motor abilities. Furthermore, our results are consistent with the results of the study by Iuzzini-Siegel (2019), in which the CAS-only group (after reclassification based on language abilities) showed no significant difference in movement tasks relative to other groups. As noted by Iuzzini-Siegel (2019), we can understand the fine and gross impairments of children with CAS (with and without language impairments) better, after controlling for language ability, as well as history of physical and occupational therapy. That may be one of the reasons for previous inconclusive findings on the motor abilities of children with CAS. The present study controlled for the above-mentioned factors and included a narrower age range. Our findings support Iuzzini-Siegel's hypothesis that there may be a clinically meaningful difference in motor abilities among subgroups of children with CAS (Iuzzini-Siegel, 2019), i.e., depending on the definition of CAS (with or without language impairment). This was also confirmed by their recent study (Iuzzini-Seigel et al., 2022), in which children with CAS and concurrent DLD (CAS + DLD) represent a subgroup that tends to perform differently and more poorly on motor tasks than children who have only CAS.

Furthermore, research on motor abilities in children with CAS has shown that they have fine motor impairments in timed tasks that could relate to their inability to incorporate sensory information into a plan of action (Bradford & Dodd, 1994). The results of Newmeyer et al. (2007) indicate an association between abnormal oral-motor imitation and abnormal visual-motor integration skills, suggesting an underlying abnormality in the planning and processing of motor movements that affect both speech and fine motor functioning in children with speech-sound disorders and developmental dyspraxia. Furthermore, some studies have shown poor gross motor abilities and balance (Powell & Bishop, 1992), while Iuzzini-Siegel (2019) has demonstrated poor aiming and catching skills in addition to poor balance in children with CAS.

Our study also confirmed that children with CAS perform poorly on both fine and gross motor tasks, but the question of whether there is a main effect on the motor abilities remained. The results of the present study reveal that children with CAS indeed performed significantly worse on fine motor/handwriting items (writing fast, writing legibly, effort and pressure, cuts) compared to control during movement items (throws the ball, catches the ball, hits ball/birdie, jumps over, runs, plans activity) and general coordination items (likes sports, learning new skills, quick and competent, "bull in the shop", does not fatigue). These results contrast those put forth by Iuzzini-Siegel (2019), in which there were no differences in fine motor tasks (manual dexterity). However, our results may be comparable to the study by Tükel et al. (2015), which found that despite the weak correlation, the co-occurrence of speech/non-speech and manual-motor difficulties was common at the individual level.

Several studies have confirmed the relationship between speech and fine motor skills. For example, Choi, Leech, Tager-Flusberg, and Nelson (2018) have shown that a high level of fine motor skills at 6 months of age predicts higher expressive language performance at 36 months of age, or that oral language performance at 4 years of age is significantly positively correlated with fine motor skills (Rhemtulla & Tucker-Drob, 2011). If we know that children with CAS are characterised by poor planning and/or programming of speech movements, and that similar procedural knowledge and motor sequencing are needed for using the appropriate effort or tension when writing or drawing, cutting shapes, or colouring in a coordinated way, these co-occurring motor deficits could be reflecting poor procedural learning abilities. Similar to Newmeyer et al. (2007), our results suggest a common neurophysiological link between the planning of speech and fine motor movements. Although children with CAS exhibit delayed rather than deviant motor abilities com-

pared to TD children, the assessment and treatment of fine motor skills should be considered by a speech and language pathologist because children with CAS may have greater difficulties with new motor sequencing tasks, such as skilled hand movements needed for handwriting. In addition, handwriting is an example of the overlap in occupational therapy and speech and language pathology, and knowledge of the broader implications of fine motor difficulties for both professions. This is very important because recognising fine motor difficulties in preschool children could help ensure timely interventions for these children, who otherwise risk becoming disillusioned with the educational system after a number of years of failure as they struggle with their poor writing speed and legibility (O'Hare, 2004). Although these results support the idea of assessing fine motor functioning in children with CAS, further research is needed to determine and understand these underlying mechanisms in children with CAS.

Limitations

One of the limitations of the present study was the small sample that included only children with CAS and did not included children with other speech sound disorders or language impairments. Our study, however, provides a more comprehensive view of the motor abilities of children with CAS without additional language impairments. Furthermore, this study did not use standardised tests to examine overall motor ability such as the Bruininks-Oseretsky Test of Motor Proficiency, or Movement Assessment Battery for Children. Future studies should include parent reports such as DCDQ-HR, as well as validated tests for motor abilities to derive more comprehensive motor profiles. In collaboration with physical and occupational therapists, future studies should carefully test different aspects of fine and gross motor skills concerning speech planning and speech output to better understand the overall complexity of motor function in children with symptoms and/or diagnosis of CAS. More attention should be given to differentiating children with different speech, language, or both speech and language disorders to provide them with optimal assessment and intervention.

CONCLUSION

This study demonstrated that children with CAS have poorer motor abilities than TD children with respect to different motor aspects (fine motor skills, control during movement, general coordination), but their results are still within the range that indicates normal motor abilities. When comparing the three distinct motor aspects, children with CAS showed poorest performance in fine motor and handwriting skills. These results could indicate a common underlying mechanism or a link between the planning of speech and fine motor movements. Furthermore, these results suggest that children with only CAS (i.e., without concurrent DLD) are more likely to have delayed rather than deviant motor abilities, in contrast to children with CAS and concurrent DLD who met criteria for a DCD diagnosis in the study by Iuzzini-Siegel et al. (2022), suggesting that language may be an important variable when considering motor abilities in children with CAS. Although motor abilities alone may not be severe enough for a DCD diagnosis in children with CAS, motor abilities - particularly fine motor skills and handwriting - should be considered and assessed when working with children with CAS.

Considering that speech and language pathologists are among the primary professionals to come into contact with children (Michaud and Committee on Children with Disabilities, 2004), they play an important role in the early identification of children who may need physical and occupational therapy to ensure the best outcomes for clients and to help reduce or prevent physical and mental health problems (Iuzzini-Siegel et al., 2022).

REFERENCES

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of mental disorders (5th ed.)*. Washington: American Psychiatric Association.

American Speech-Language-Hearing Association. (2007). *Childhood apraxia of speech* [Technical report]. http://www.asha. org/policy

Bishop D. V. (2002). Motor immaturity and specific speech and language impairment: evidence for a common genetic basis. *American journal of medical genetics*, *114*(1), 56–63. https://doi.org/10.1002/ajmg.1630

Bishop, D. V. M., Kuvač Kraljević, J., Hržica, G., Kovačević, M. & Kologranić Belić, L. (2014). *Test for reception of grammar, Second Edition (TROG-2:HR)*. Jastrebarsko: Naklada Slap.

Bombonato, C., Casalini, C., Pecini, C., Angelucci, G., Vicari, S., Podda, I., Cipriani, P., Chilosi, A. M., & Menghini, D. (2022). Implicit learning in children with Childhood Apraxia of Speech. *Research in developmental disabilities*, *122*, 104170. https://doi.org/10.1016/j.ridd.2021.104170

Bradford, A. & Dodd, B. (1994). Do all speech-disordered children have motor deficits? *Clinical Linguistics & Phonetics*, *10*(2), 77–101. https://doi.org/10.3109/02699209608985164

Choi, B., Leech, K. A., Tager-Flusberg, H., and Nelson, C. A. (2018). Development of fine motor skills is associated with expressive language outcomes in infants at high and low risk for autism spectrum disorder. *J. Neurodev. Disord. 10*, 1–11.https://doi.org/10.1186/s11689-018-9231-3

Davis, B. L., & Velleman, S. L. (2000). Differential Diagnosis and Treatment of Developmental Apraxia of Speech in Infants and Toddlers. *Infant-toddler intervention: The transdisciplinary Journal*, *10*(3), 177-92.

Dewey, D., Roy, E. A., Square-Storer, P. A., & Hayden, D. (1988). Limb and oral praxic abilities of children with verbal sequencing deficits. *Developmental medicine and child neurology*, *30*(6), 743–751. https://doi.org/10.1111/j.1469-8749.1988.tb14636.x

Duchow, H., Lindsay, A., Roth, K., Schell, S., Allen, D., & Boliek, C. A. (2019). The co-occurrence of possible developmental coordination disorder and suspected childhood apraxia of speech. *Canadian Journal of Speech-Language Pathology and Audiology*, *93*(2), 81-93.

Gonzalez, S. L., Alvarez, V., & Nelson, E. L. (2019). Do Gross and Fine Motor Skills Differentially Contribute to Language Outcomes? A Systematic Review. *Frontiers in psychology*, *10*, 2670. https://doi.org/10.3389/fpsyg.2019.02670

Gretz, S. (2013). Current trends in CAS from the "street." Panel presentation at the Childhood Apraxia of Speech Research Symposium, Atlanta, GA

Grigos, M. I., Moss, A. & Lu, Y. (2015). Oral Articulatory Control in Childhood Apraxia of Speech. *Journal of Speech, Language, and Hearing Research*, *58*(4), 1103–1118. https://doi.org/10.1044/2015_jslhr-s-13-0221

Harris, S. R., Mickelson, E., & Zwicker, J. G. (2015). Diagnosis and management of developmental coordination disorder. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*, *187*(9), 659–665. https://doi.org/10.1503/cmaj.140994

Hill E. L. (2001). Non-specific nature of specific language impairment: a review of the literature with regard to concomitant motor impairments. *International journal of language & communication disorders*, *36*(2), 149–171. https://doi.org/10.1080/13682820010019874

Iuzzini-Seigel J. (2021). Procedural Learning, Grammar, and Motor Skills in Children With Childhood Apraxia of Speech, Speech Sound Disorder, and Typically Developing Speech. *Journal of speech, language, and hearing research : JSLHR*, *64*(4), 1081–1103. https://doi.org/10.1044/2020_JSLHR-20-00581

Iuzzini-Seigel, J. & Murray, E. (2017). Speech Assessment in Children With Childhood Apraxia of Speech. *Perspectives of the ASHA Special Interest Groups*, *2*(2), 47–60. https://doi.org/10.1044/persp2.sig2.47

Iuzzini-Seigel, J. (2019). Motor Performance in Children With Childhood Apraxia of Speech and Speech Sound Disorders. *Journal of Speech, Language, and Hearing Research*, *62*(9), 3220–3233. https://doi.org/10.1044/2019_jslhr-s-18-0380

Iuzzini-Seigel, J., Moorer, L., & Tamplain, P. (2022). An Investigation of Developmental Coordination Disorder Characteristics in Children With Childhood Apraxia of Speech. *Language, speech, and hearing services in schools*, 1–16. Advance online publication. https://doi.org/10.1044/2022_LSHSS-21-00163

Jarus, T., Ghanouni, P., Abel, R. L., Fomenoff, S. L., Lundberg, J., Davidson, S., Caswell, S., Bickerton, L., & Zwicker, J. G. (2015). Effect of internal versus external focus of attention on implicit motor learning in children with developmental coordination disorder. *Research in developmental disabilities*, *37*, 119–126. https://doi.org/10.1016/j.ridd.2014.11.009

Maassen B. (2002). Issues contrasting adult acquired versus developmental apraxia of speech. *Seminars in speech and language*, *23*(4), 257–266. https://doi.org/10.1055/s-2002-35804

Michaud, L. J., & American Academy of Pediatrics Committee on Children With Disabilities (2004). Prescribing therapy services for children with motor disabilities. *Pediatrics*, *113*(6), 1836–1838. https://doi.org/10.1542/peds.113.6.1836

Newmeyer, A. J., Grether, S., Grasha, C., White, J., Akers, R., Aylward, C., Ishikawa, K., & Degrauw, T. (2007). Fine motor function and oral-motor imitation skills in preschool-age children with speech-sound disorders. *Clinical pediatrics*, *46*(7), 604–611. https://doi.org/10.1177/0009922807299545

Nicolson, R. I., & Fawcett, A. J. (2007). Procedural learning difficulties: reuniting the developmental disorders?. *Trends in neurosciences*, *30*(4), 135–141. https://doi.org/10.1016/j.tins.2007.02.003

Nijland L. (2003). *Developmental apraxia of speech: deficits in phonetic planning and motor programming* (Doctoral dissertation).

O'Hare, A. (2004). Hands up for handwriting. *Developmental Medicine & Child Neurology, 46*(10), 651-651. https://doi.org/10.1017/S0012162204001094

Ozanne, A. (2005). Childhood apraxia of speech. In B. Dodd (Ed.), *Differential diagnosis and treatment of children with speech disorder Second Edition* (2nd ed., pp. 71–82). London: Whurr

Powell, R. P., & Bishop, D. V. (1992). Clumsiness and perceptual problems in children with specific language impairment. *Developmental medicine and child neurology*, *34*(9), 755–765. https://doi.org/10.1111/j.1469-8749.1992.tb11514.x

Raven, J. C. (1999). *Kolorirane progresivne matrice - CPM*. Jastrebarsko: Naklada Slap.

Rhemtulla, M., & Tucker-Drob, E. M. (2011). Correlated longitudinal changes across linguistic, achievement, and psychomotor domains in early childhood: evidence for a global dimension of development. *Developmental science*, *14*(5), 1245–1254. https://doi.org/10.1111/j.1467-7687.2011.01071.x

Sack, L., Dollaghan, C., & Goffman, L. (2022). Contributions of early motor deficits in predicting language outcomes among preschoolers with developmental language disorder. International journal of speech-language pathology, 24(4), 362–374. https://doi.org/10.1080/17549507.2021.1998629

Sangster Jokić, C., Knežević D., & Wilson, B. N. (2020). *Validacija mjernog instrumenta za rano prepoznavanje razvojnog poremećaja koordinacije: Ispitivanje psihometrijskih svojstava hrvatske inačice Upitnika za procjenu koordinacije (DCDQ-HR).* Katedra za radnu terapiju; Zdravstveno veleučilište Zagreb

Stein, C. M., Benchek, P., Miller, G., Hall, N. B., Menon, D., Freebairn, L., Tag, J., Vick, J., Taylor, H. G., Lewis, B. A. & Iyengar, S. K. (2020). Feature-driven classification reveals potential comorbid subtypes within childhood apraxia of speech. *BMC Pediatrics*, *20*(1), 519. https://doi.org/10.1186/s12887-020-02421-1

Tükel, Ş., Björelius, H., Henningsson, G., McAllister, A. & Eliasson, A. C. (2015). Motor functions and adaptive behaviour in children with childhood apraxia of speech. *International Journal of Speech-Language Pathology*, *17*(5), 470–480. https://doi.org/10.3109/17549507.2015.1010578

Visscher, C., Houwen, S., Moolenaar, B., Lyons, J., Scherder, E. J. A. & Hartman, E. (2010). Motor proficiency of 6- to 9-year-old children with speech and language problems. *Developmental Medicine & Child Neurology*, *52*(11), e254–e258. https://doi.org/10.1111/j.1469-8749.2010.03774.x

Visscher, C., Houwen, S., Scherder, E. J. A., Moolenaar, B. & Hartman, E. (2007). Motor Profile of Children With Developmental Speech and Language Disorders. *Pediatrics*, *120*(1), e158–e163. https://doi.org/10.1542/peds.2006-2462

Wilson, B. N., Kaplan, B. J., Crawford, S. G., & Roberts, G. (2007). The developmental coordination disorder questionnaire 2007 (DCDQ'07). *Administrative manual for the DCDQ107 with psychometric properties*, 267-272.

Wilson, B. N., Kaplan, B. J., Crawford, S. G., Campbell, A., & Dewey, D. (2000). Reliability and validity of a parent questionnaire on childhood motor skills. *The American journal of occupational therapy: official publication of the American Occupational Therapy Association*, *54*(5), 484–493. https://doi.org/10.5014/ajot.54.5.484