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Kinematic Characteristics of Speaking Rate in Individuals with Cerebral Palsy: A Preliminary Study

Ignatius S.B. Nip, Ph.D.
School of Speech, Language, and Hearing Sciences, San Diego State University

Abstract

Many individuals with cerebral palsy (CP) have a slower speaking rate compared with their typically developing peers. Previous studies examining age-related changes in speaking rate in typical development suggest that (1) cognitive and linguistic processing increases account for most of these changes, and (2) changes to linguistic task demands affect the articulatory strategies used to produce the target stimuli (e.g., truncating movements for tasks with fewer linguistic demands). The purpose of this study was to determine the relations between linguistic and physiologic factors in individuals with CP to better understand how the pathophysiology of CP affects speech production in these individuals. Four participants with CP and 38 age-matched peers were asked to complete a diadochokinetic (DDK) task, a vowel–consonant–vowel syllable repetition task, and a sentence repetition task. Speaking rate for the tasks and lower lip maximum movement speed, range of movement, and duration of the closing and opening gestures common to each task were measured. In general, participants with CP have reduced speaking rates compared with their typically developing peers despite increased movement speeds. In both groups, linguistic task effects were observed; higher linguistic demands resulted in slower speaking rates and higher movement speeds. Range of movement was greater for participants with CP than their typically developing peers and may have contributed to the observed decreased speaking rates in individuals with CP.

Keywords

cerebral palsy; dysarthria; speaking rate; kinematics

INTRODUCTION

Cerebral palsy (CP) is a group of nonprogressive disorders primarily characterized by chronic disturbances of movement and coordination caused by injury to the fetal or infant nervous system (Hustad, Gorton, & Lee, 2010). Approximately 76% of children with CP have speech or language difficulties (or both); one of the hallmark characteristics of dysarthria in this population is slowed speech, which can be used to identify communicative subgroups of children with CP (Hustad et al., 2010), Speaking rate is also commonly

Address Correspondence to Ignatius S.B. Nip, Ph.D., School of Speech, Language, and Hearing Sciences, San Diego State University, 5500 Campanile Dr., San Diego, CA 92182-1518, PHONE: (619) 594-2421, FAX: (619) 594-7109 inip@mail.sdsu.edu.

targeted to help improve intelligibility and comprehensibility (Pennington, Miller, Robson, & Steen, 2010).

One possible reason for the slowed speaking rate may be the underlying movement deficits associated with CP. Immature motor control results in poor force control (Barlow & Abbs, 1983), which may cause large articulatory displacements (Green & Nip, 2010) such as those observed in young children (Riely & Smith, 2003). In addition, individuals with CP have white matter injury to the corticobulbar tracts (Thomas et al., 2005), and the resultant reduction in myelination may reduce articulatory movement speed (Barlow, Finan, Bradford, & Andreatta, 1993; Müller & Hömberg, 1992). The increased oral excursions produced by individuals with CP may account for the slower rate of speech, especially if movement speed cannot be increased proportionally with displacements.

In typically developing children, speaking rate has been shown to be affected by linguistic task demands (Nip & Green, in press; Walker & Archibald, 2006) and cognitive processing (Haselager, Slis, & Rietveld, 1991). Potentially, the cognitive and language difficulties that many children with CP have may also contribute to their slower speaking rate. In typically developing children, speaking rate is largely dependent on cognitive and linguistic task demands (Nip & Green, in press); however, the interactions among speech motor performance, language, and cognition that affect speaking rate may differ for children with CP. Speaking rate, which includes both the time to articulate an utterance and its associated pauses (Nip & Green, in press), can become slower by increasing the frequency and duration of pauses, increasing the scale of articulatory gestures, or reducing the speed of the oral articulators (Campbell & Dollaghan, 1995), Understanding strategies that individuals with CP use to change speaking rate in response to linguistic demands may provide insight for interventions targeting speaking rate in this population.

The current investigation examines whether speaking rate and speech motor performance (maximum speed, range of movement, and duration) change with increasing linguistic task demands in individuals with CP and how these changes in speaking rate across speaking tasks compare with typically developing individuals.

METHODS

Four individuals with CP participated in the study These participants underwent intelligibility and language testing (CELF-4; Semel, Wiig, & Secord, 2003). Their speech characteristics were judged by three experienced speech-language pathologists (SLPs) (Table 1). A total of 38 typically developing age-matched peers with no history of speech, language, hearing, or neurologic disorders (shown in Table 2) also participated. An SLP screened these participants' speech skills informally and screened their language skills using the CELF-4 screening test (Semel, Wiig, & Secord, 2004). The participants below the age of 18 years passed a hearing screening at 20 dB, and the adult participants passed a hearing screening at 25 dB (American Speech-Language-Hearing Association, 1997).

Participants sat in front of an eight-camera optical motion capture system (Motion Analysis, Ltd.) to record lower lip movement. Fifteen reflective markers were placed on the face, including the lower lip and the jaw. A rigid head plate consisting of four reflective markers was placed on the forehead. The markers on the plate were later used to subtract head movement. Simultaneous digital video and audio were also recorded. Participants were asked to perform three speaking tasks that varied in linguistic content and articulatory demands: 10 repetitions of a diadochokinetic (DDK) task ("buh"), five repetitions of two syllables ("uhba"), and five repetitions of a sentence ("B**uy Bo**bby a puppy"). For the DDK task, participants were asked to produce as many repetitions as quickly and as clearly as they could in a single breath. Although a vast majority of participants were able to produce the requested number of repetitions, the participant with CP and the weakest language skills (9;6 M) was able to produce only three accurate repetitions of the sentence. All utterances were analyzed for pausing, operationally defined as silences of 100 ms or greater (Green, Beukelman, & Ball, 2004). All participants, except for the two youngest participants with CP, had no pauses in any of the speaking tasks. The youngest (6;11 F) participant with CP paused to take a breath after a few repetitions of the DDK task, and this task inspiratory pause was removed from analysis. The 9;6 M participant with CP paused during the sentence repetition task, likely because of his impaired language skills.

To evaluate the same movement across all tasks, the initial closing and opening gesture for each repetition was parsed in Cortex (Motion Analysis, Ltd.) using the jaw movement traces. Velocity zero crossings were used to determine the beginning and ending of the target articulatory gesture. Matlab algorithms were used to subtract head movement and to decouple lower lip movement from jaw movement. Lower lip peak speed, range of movement, and duration were then obtained for each repetition. Speaking rate was measured using acoustic analysis software (Adobe Audition 3.0) in syllables per second. The performance of the participants with CP was compared with the 90% confidence interval (CI) for speaking rate, maximum speed, range of movement, and duration of their age-matched peers.

RESULTS AND DISCUSSION

Figures 1 to 4 show the speaking rate, lower lip peak speed, range of movement, and duration of the closing and opening oral gesture for the participants. Overall, speakers with CP have slower speaking rates than their typically developing peers, particularly for tasks with greater linguistic demands (e.g., sentences). One surprising finding was that speakers with CP had maximum speeds that were the same or higher than their typically developing peers. One reason for this finding is that many of the participants demonstrated greater ranges of movement than their typically developing peers, similar to previous findings (Kent & Netsell, 1978); these increased oral excursions may reflect inefficient force control (Barlow & Abbs, 1983; Green & Nip, 2010).

Both speakers with CP and their typically developing peers had slower speaking rates for tasks requiring greater linguistic task demands (i.e., sentences) than those requiring less (i.e., DDK), supporting previous findings that demonstrate increased linguistic processing affects speaking rate (Nip & Green, in press; Walker & Archibald, 2006). In addition, the range of lower lip movement of speakers with CP generally increased with linguistic task demands, similar to typically developing peers; this trend appears to correspond with patterns of speaking rate across linguistic tasks. This finding may potentially reflect the use of hyperarticulation to convey the linguistic information (Lindblom, 1990).

In contrast, measures of speech motor performance did not consistently change with task demands in all participants. Peak speed increased with task demands for speakers with CP who had typical language skills, which was similar to their typically developing peers; speakers with CP who had language delays did not show the same pattern. Speakers with CP also increased the duration of oral closure and opening as linguistic task demands increased, which were not observed in their typically developing peers.

In summary, speaking rate is slower for individuals with CP and is affected by task demands. One potential reason for this decrease in speaking rate may be that individuals with CP have reduced force control. When attempting to convey greater linguistic information, speakers use a greater degree of hyperarticulation. The use of hyperarticulation may cause individuals with CP to produce much greater oral excursions. However, a greater number of participants with CP with similar types of dysarthria must be studied to determine if this pattern generalizes to this population. In addition, comparing the performance of individuals with CP to language-matched peers will help explicate the role of linguistic processing in regulating speaking rate.

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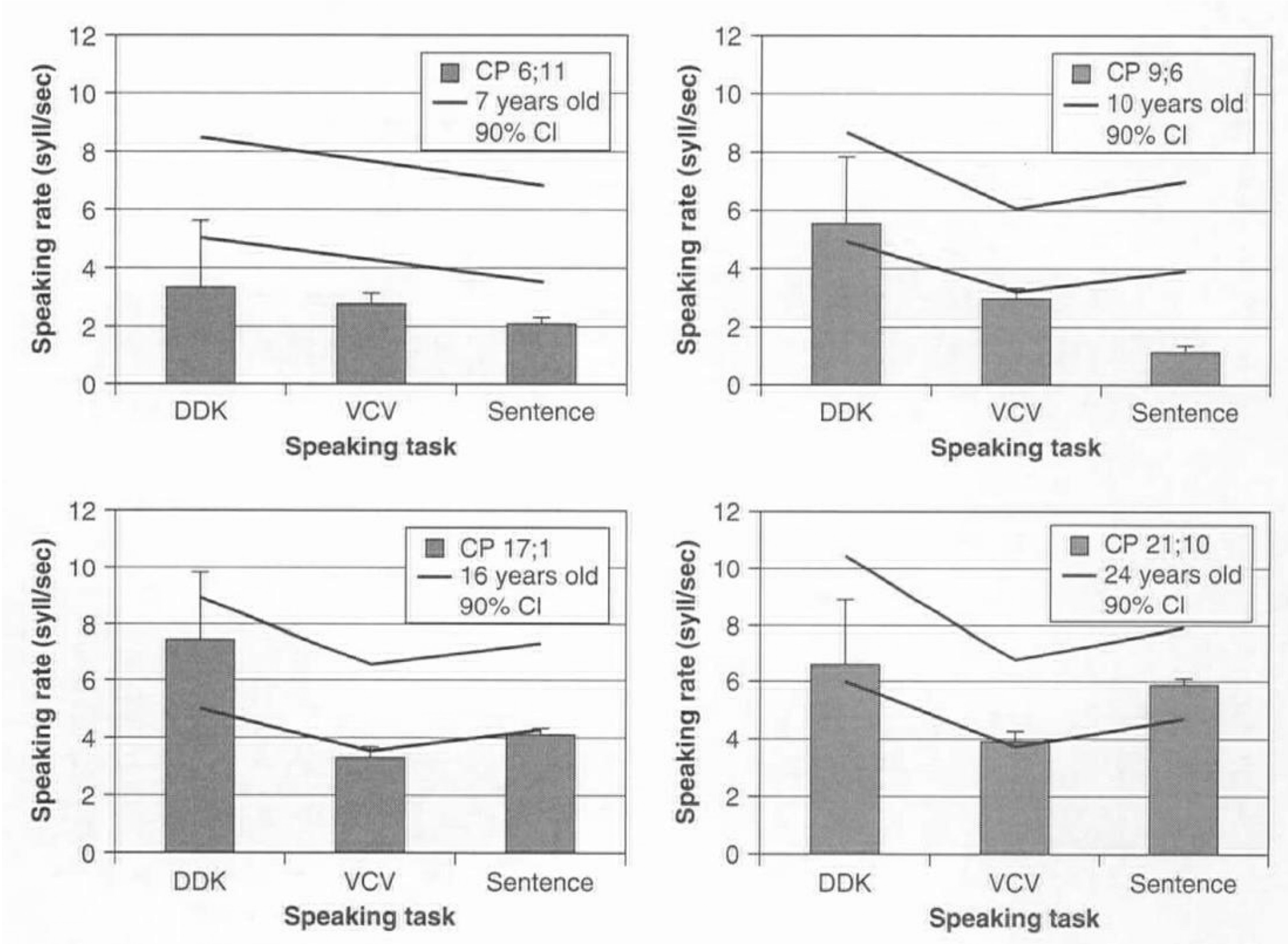

Figure 1.

Speaking rate of participants with cerebral palsy (CP) and 90% confidence interval (CI) of age-matched peers. DDK = diadochokinetic; VCV = vowel–consonant–vowel.

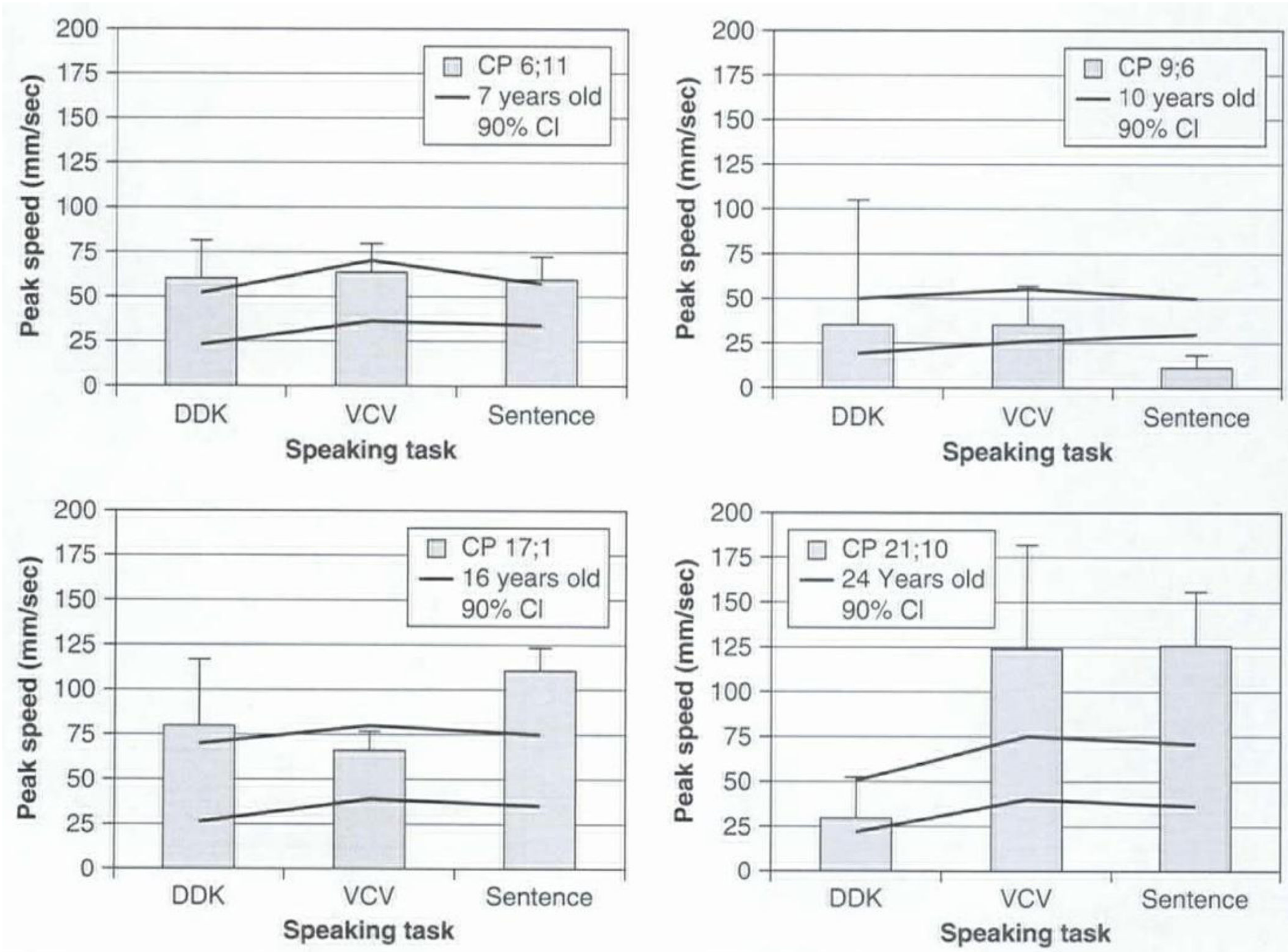

Figure 2.

Lower lip peak speed of participants with cerebral palsy (CP) and 90% confidence interval (CI) of age-matched peers. DDK = diadochokinetic; VCV = vowel–consonant–vowel.

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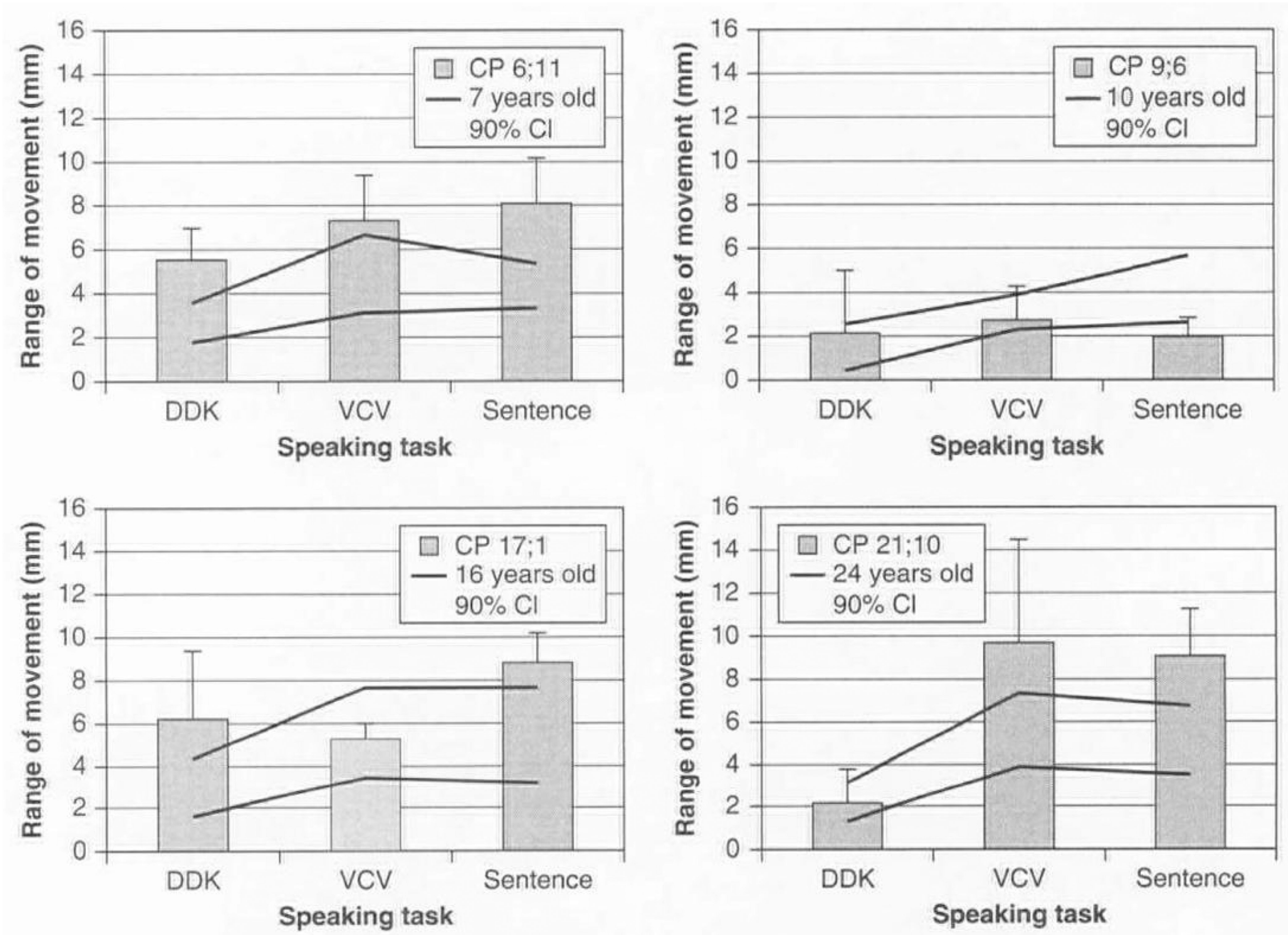

Figure 3.

Range of movements of participants with cerebral palsy (CP) and 90% confidence interval (CI) of age-matched peers. DDK = diadochokinetic; VCV = vowel–consonant–vowel.

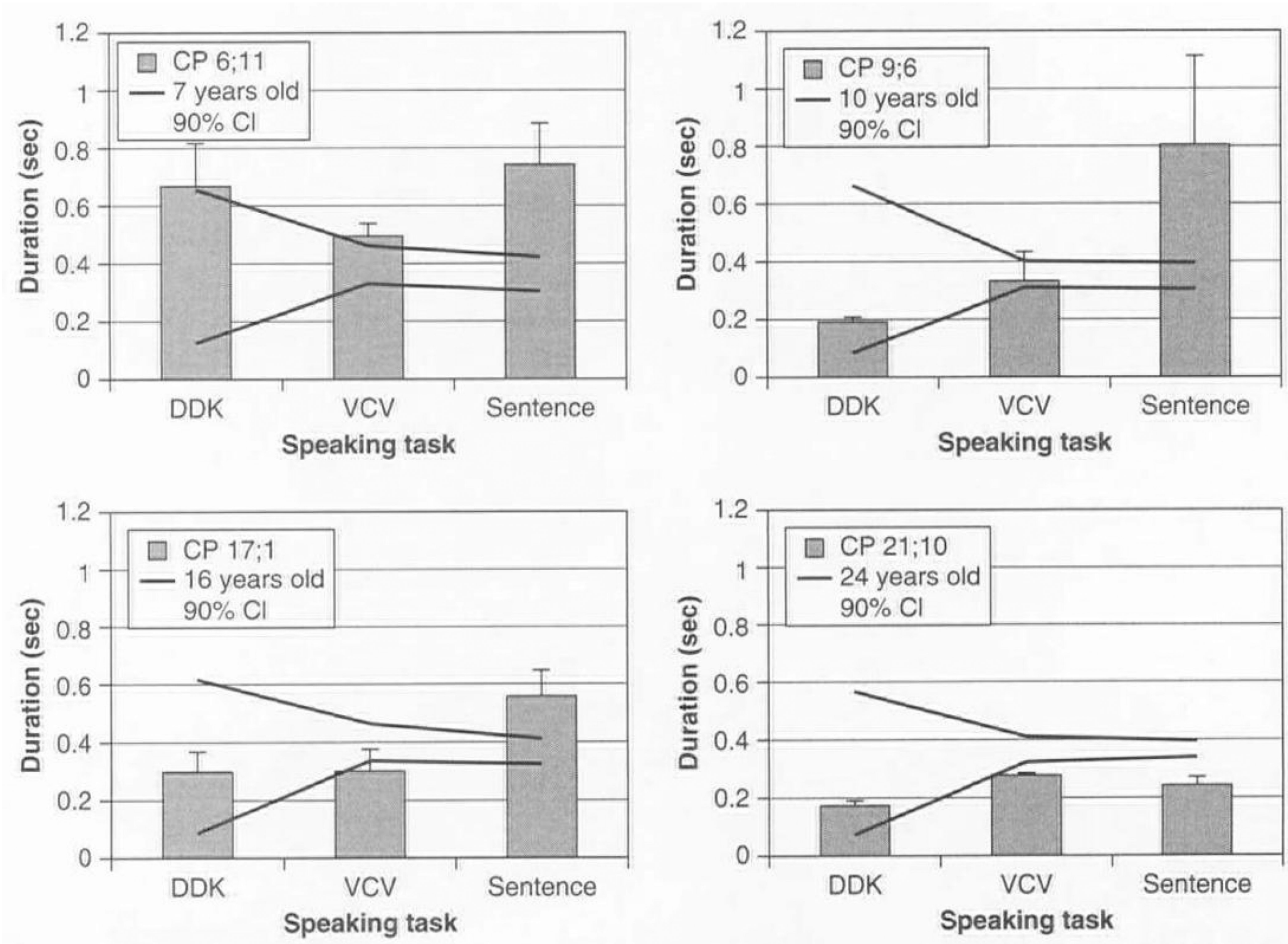

Figure 4.

Duration of closing and opening of participants with cerebral palsy (CP) and 90% confidence interval (CI) of age-matched peers, DDK = diadochokinetic; VCV = vowel–consonant–vowel.

TABLE 1

Speech and Language Characteristics of Participants with Cerebral Palsy

Participant Characteristics	Language Skills	Speech Characteristics
6;11F Spastic quadriplegia GMFCS level IV*	1st percentile (CELF-4) 39% intelligibility in speech sample	Mixed spastic-flaccid dysarthria – Slow rate of speech – Imprecise articulation – High pitch – Vowel distortions – Mild hypernasality
9;6M Spastic quadriplegia GMFCS Level I	<lst percentile (CELF-4) 6% single-word intelligibility (*TOCS+*†)	Spastic dysarthria – Imprecise articulation – Mild strained-strangled voice – Monopitch – Monoloud
17;1F Spastic hemiplegia GMFCS Level II	Language WNL (CELF-4) 86% sentence intelligibility (SIT‡)	Ataxtic dysarthria – Short breath groups – Vowel distortions – Monopitch – Imprecise articulation – Audible inspirations
21;10M Spastic quadriplegia GMFCS level V	Language WNL (CELF-4) 93%- sentence intelligibility (SIT)	Spastic dysarthria – Imprecise articulation – Increased pitch – Hypernasal – Strained-strangled vocal quality – Short breath groups – Vowel distortions – Weak pressure consonants

*Palisano, Rosenbaum, Bartiett, Livingston, 2008.

†Hodge & Daniels, 2007.

‡Yorkston, Beukelman, Hakel, & Dorsey, 2007.

CELF-4 = Clinical Evaluation of Language Fundamentals (4th ed); F = female; GMFCS = Gross Motor Functioning Classification Scale; M = male; SIT = Speech Intelligibility Test; WNL = within normal limits.

TABLE 2

Age-Matched Peers

Age Group	Sex	Mean Age (SD) in Years
7-year-olds	6F;5M	7.6 (0.29)
10-year-olds	5F;4M	10.4 (0.27)
16-year-olds	5F;4M	16.4 (0.32)
Young adults	4F;5M	23.9 (3.2)

F = female; M = male; SD = standard deviation.