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Original Article

Diadochokinetic Rate in Typically Developing Young Adults Aged 18 to 25 Years Who Are Spanish Speakers from Chile

Ilich Cancino-Barros [a, b, *], Luis Martínez [b], Reynaldo Zambra-Vidal [b], Felisa Quitral-Quezada [b], Fanny Becerra-Becerra [b] and Ramón D. Castillo [a]

[a] *Centro de Investigación en Ciencias Cognitivas, Facultad de Psicología, Universidad de Talca, Chile.*
[b] *Departamento de Ciencias de la Fonoaudiología, Facultad de Ciencias de la Salud, Universidad de Talca, Chile.*

ABSTRACT

Diadochokinesia is the ability to perform repeated and alternating movements quickly. In speech evaluation, the diadochokinetic (DDK) rate is used to assess the dexterity and integrity of motor control. Although studies on DDK rate exist for Chilean Spanish speakers, data on young adults remain limited. This study aimed to describe and establish preliminary normative data for DDK rate among Chilean Spanish-speaking young adults, with a sample of 250 typically developing individuals aged 18 to 25 years. Participants were instructed to repeat the syllable [pa] into a microphone as quickly as possible for 8 seconds. Speech was recorded using Motor Speech Profile software, and five parameters were analyzed: DDKavp, DDKavr, DDKcvp, DDKjit, and DDKcvi. The distribution of scores for these parameters in the sample did not fit a normal distribution; therefore, norms were established based on quartiles. Additionally, Spearman correlation analysis indicated that the parameters DDKcvp and DDKjit tended to decrease with age within the 18-25 years range. These findings hold potential for research and clinical applications, as they enable comparisons with populations of different ages and with clinical groups.

Keywords:
Diadochokinesia; Speech; Typical Adult; Normative Data

Tasa de diadococinesia en adultos jóvenes típicos entre 18 y 25 años hablantes de español de Chile

RESUMEN

La diadococinesia es la capacidad para ejecutar movimientos repetidos y alternados de manera rápida. En el ámbito del habla, la tasa de diadococinesia (TDDK) se utiliza para evaluar la destreza e integridad del control motor. Aunque existen estudios sobre la TDDK en hablantes de español chileno, no existen valores normativos en adultos jóvenes. Nuestro estudio tuvo como objetivo describir y establecer datos normativos preliminares de la TDDK. Para ello se midió la TDDK de 250 adultos jóvenes típicos de entre 18 y 25 años, hablantes de español de Chile. Para medir la TDDK, los participantes tuvieron que repetir la sílaba [pa] lo más rápido posible frente al micrófono, durante 8 segundos. Para el registro del habla se utilizó el software Motor Speech Profile. Se analizaron cinco parámetros: DDKavp, DDKavr, DDkcvp, DDkjit y DDKcvi. En la muestra estudiada, la distribución de puntajes de estos parámetros no se ajustó a la distribución normal; motivo por el cual se procedió a establecer normas por cuartiles. Además, se calculó la correlación de Spearman de estos parámetros con la edad y se observó que los parámetros DDKcvp y DDKjit tienden a disminuir entre los 18 y los 25 años. Se espera que estos hallazgos sean útiles para fines de investigación y clínicos, ya que basados en estos parámetros se podrán realizar comparaciones con poblaciones de otras edades y personas pertenecientes a grupos clínicos.

Palabras clave:
Diadococinesia; Habla; Adulto típico; Datos Normativos

**Corresponding Author: Ramón D. Castillo*
Email: racastillo@utalca.cl

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INTRODUCTION

Speech is a complex motor process that is susceptible to the effects of various disorders, especially those of neurological origin (Duffy, 2020). A useful method for assessing the integrity of speech in clinical practice is the diadochokinetic rate (DDK) (Kent et al., 1987; Stackhouse, 2000). DDK rate, also known as the rate of alternating movements, evaluates the ability to perform rapid and repetitive articulatory movements by producing isolated syllables, traditionally using the sequence [pa], [t̪a], and [ka] (Duffy, 2020; Kent et al., 1987; Pierce et al., 2013). This measure helps determine the speed and regularity of movements of specific speech organs such as the jaw, lips, and tongue, providing essential information for assessing oral motor control (Duffy, 2020; Fletcher, 1972; Pierce et al., 2013).

Normative values for the DDK rate have been established for typically developing children and adults across various countries and languages. For pediatric populations, Stackhouse (2000) reported normative data for English-speaking children aged 3 to 5 years, Yaruss & Logan (2002) for American children aged 3 to 7 years, and Prathanee et al. (2003) for Thai children aged 6 to 13 years. As for adults, Pierce et al. (2013) measured DDK rates in Australian older adults aged 65 and above, Yang et al. (2011) in Taiwanese adults aged 23 to 75 years, and Padovani et al. (2009) in Brazilian adults aged 30 to 94 years. Notably, normative values differ between these studies, likely due to speech characteristics specific to each linguistic context. However, these results are not entirely comparable due to differences in the types of stimuli used, such as silent oral movements, monosyllables, syllable sequences, or words. Additionally, these studies employed diverse analysis methodologies, including video observation, audio recordings, and various computational programs. Despite this, cross-linguistic studies with standardized methodologies have also shown significant differences in DDK rate values across languages (Camargo-Mendoza et al., 2023; Icht & Ben-David, 2014).

The above highlights the importance of establishing country-specific normative DDK rate values, as these offer a reference point for comparison with local clinical populations. This is particularly significant since deviations from typical DDK rate performance may indicate speech disorders (Alshahwan et al., 2020). It has been observed that DDK rate performance is impaired in people with dysarthria, resulting from conditions such as stroke (Kent et al., 1999; Ozawa et al., 2001; Ziegler, 2002), Friedreich's disease (Gentil, 1990; Ziegler & Wessel, 1996), ALS (Kent et al., 1991; Nishio & Niimi, 2000; Rong, 2020; Samlan & Weismer, 1995), multiple sclerosis (Hartelius & Lillvik, 2003; Tjaden & Watling, 2003), Parkinson's disease, traumatic brain injury (Wang et al., 2004; Ziegler, 2002), and cerebellar or spinocerebellar atrophy or degeneration (Ozawa et al., 2001; Wang et al., 2008; Ziegler, 2002; Ziegler & Wessel, 1996). Furthermore, poor DDK rate performance has been observed in individuals with apraxia of speech (Ziegler, 2002), disfluency (Juste et al., 2012), and hearing loss (Seifpanahi et al., 2008). Having normative DDK rate values across the lifespan would also make it possible to observe how DDK rate emerges and varies in different age groups, both in populations with and without speech difficulties.

Because of the unique phonatory and articulatory characteristics of Chilean Spanish, a specific and detailed evaluation is required for the diadochokinetic rate (DDK rate). There are currently some normative studies on the DDK rate for people with typical development throughout their lifespan. For instance, Velásquez (2008) assessed 67 typically developing children aged 6 to 9 years 11 months, while Vergara (2008) examined 98 children aged between 10 and 13 years 11 months. Another study by Badilla-Díaz et al. (2022) assessed the diadochokinetic performance of 46 first-grade students, correlating it with socioeconomic status. Additionally, Pérez et al. (2015) established normative values for diadochokinetic performance in adults aged between 18 and 61 years, comparing these values with normative data from English speakers (Deliyski & Gress, 1997). It is noteworthy that the aforementioned studies on Chilean populations by Velásquez (2008), Vergara (2008), Badilla-Díaz et al. (2022), and Pérez et al. (2015) determined normative values for five parameters provided by the Motor Speech Profile (MSP) software from Kay Elemetrics Corp., using the syllable [pa] as a stimulus (see Table 1). This is particularly relevant since an objective and reliable evaluation of the DDK rate requires acoustic analysis with specialized computational software. Such analyses allow for the quantification of aspects like mean duration, formant structure, pauses, syllable count, temporal variability, and energy variability (Wang et al., 2008).

To our knowledge, there is only one study on the DDK rate in the adult Chilean population that uses specialized computational software (Pérez et al., 2015). This study provides normative values for a relatively broad age range (18 to 61 years). However, evidence suggests that the DDK rate varies with age, emphasizing the need for normative values tailored to more specific age groups. Furthermore, given that normative DDK rate data in other languages are not transferable, it is critical to conduct normative studies assessing DDK rate in subjects at more specific stages of the life cycle. Such studies would yield more precise values that could be used in clinical and academic settings. One of the least studied age groups is young adults. For this reason, it has been proposed to characterize the DDK rate in typically developing adults aged 18 to 25 years who are Chilean Spanish speakers.

Table 1. Mean and Standard Deviation (SD) for the parameters provided by the MSP software in children aged 6–7 years, 6–9 years, and 10–13 years, as well as adults aged 18–61 years.

Diadochokinetic Parameter	Children Between 6 and 7 years from Low Socioeconomic Status (Badilla et al., 2022)		Children Between 6 and 7 years from Upper-Middle Socioeconomic Status (Badilla et al., 2022)		Children Between 6 and 9 years (Velásquez, 2008)		Children Between 10 and 13 years (Vergara, 2008)		Adults between 18 and 61 years (Pérez et al., 2015)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DDKavp (ms)	226.71	29.98	227.23	24.38	255.61	106.20	243.62	122.01	263.36	66.15
DDKavr (/s)	4.48	0.57	4.45	0.47	4.36	1.14	4.76	1.37	4.00	1.01
DDKcvp (%)	32.03	14.62	19.05	11.57	33.31	27.13	35.00	21.92	5.48	1.66
DDKjit (%)	4.24	1.87	2.89	1.56	9.78	10.91	11.16	15.09	1.78	0.66
DDKcvi (%)	4.06	1.3	3.79	1.33	2.85	1.62	2.18	1.24	1.84	0.75

Present Study

This study aims to describe and establish preliminary normative values for the diadochokinetic (DDK) rate in typically developing young adults aged 18 to 25 years 11 months who are Chilean Spanish speakers. Studying the DDK rate in this population will help develop guidelines for future research on Chilean individuals in other age groups. Additionally, the results may serve as a reference point for assessing young adults with motor speech disorders.

METHOD

Participants

A probabilistic sample was used, consisting of students from various disciplines and academic levels at Universidad de Talca. A representative sample of 250 men and women aged 18 to 25 years, from diverse socioeconomic backgrounds, was selected. The inclusion criteria covered regular students of this university within the specified age range. The exclusion criteria were as follows: 1) being a Speech-Language Therapy student (to avoid procedural bias); 2) having a neurological diagnosis affecting motor abilities, such as dysarthria or apraxia of speech; 3) presenting any anatomical or functional speech impairments; 4) having any hearing impairments.

Materials and Procedure

The assessment took place in the Voice and Phonetics Laboratory of the Speech-Language Therapy school at Universidad de Talca. Researchers were provided with an individual folder for each participant, containing the data obtained during the evaluation. Before DDK rate measurement, each participant read and signed an informed consent form approved by the Scientific Ethics Committee of Universidad de Talca (File No. 17/2023). Subsequently, each participant underwent a clinical interview, an anatomical-functional speech assessment, and an audiological assessment, which included otoscopy (Riester 2060 pen-scope 2.7 volt otoscope) and otoacoustic emissions assessment (Madsen AccuScreen PRO).

The DDK rate analysis was carried out using the Motor Speech Profile software model 5141 (Kay Elemetrics Corp.) on an HP computer with Windows XP Professional and a unidirectional cardioid microphone, SHURE SM-48. To measure diadochokinesis, participants were instructed to repeat the syllable [pa] as quickly as possible in front of the microphone, positioned ten centimeters from their mouth. The task had an 8-second duration and the participants were prompted to start and stop the syllable production.

Table 2. Diadochokinetic parameters, descriptors, and meaning of what they measure.

DDK Parameters (Measurement Unit)	Descriptor	Meaning
DDKavp (ms)	Average diadochokinetic period	The average time between produced syllables.
DDKavr (/s)	Average diadochokinetic rate	It represents the number of syllables produced per second. Inversely proportional to DDKavp.
DDKcvp (%)	Coefficient of variation of the diadochokinetic period	It measures the degree of rate variation during the production.
DDKjit (%)	Disturbance of the diadochokinetic period (jitter)	It measures the degree of cycle-to-cycle variation during production.
DDKcvi (%)	Coefficient of variation of the diadochokinetic peak intensity	It measures the degree of intensity variation at the peak of each produced syllable.

Analysis Plan

SPSS software was used for the statistical analysis of these parameters, and the mean, standard deviation, and standard error, as well as the quartiles, were estimated. A Kolmogorov-Smirnov test was performed to assess whether the cumulative distribution of each diadochokinesis parameter was normal. This test is crucial for determining the type of norms to be applied. If the score distributions are normal, the norms can be established using mean and standard deviation. If the scores do not conform to a normal distribution, it is recommended to use norms based on the quartiles. Finally, Spearman's correlation between age and each of the parameters was calculated. These analyses enabled a detailed characterization of the variability and characteristics of diadochokinesis in the sample across the 5 parameters provided by the MSP (see Table 2).

RESULTS

Table 3 presents the mean and standard deviation values corresponding to each of the diadochokinesis parameters evaluated. The fourth column represents the maximum absolute difference between the cumulative score distribution for each of the 5 parameters and the cumulative normal distribution. The fifth column represents the significance of this maximum difference. If the cumulative score distributions align with the cumulative normal distribution, the *p*-values should be greater than 0.05. By examining the *p*-values, it is evident that none of the parameters follow a normal distribution ($p < 0.05$). This can be visually corroborated by examining the histograms in Figure 1, where none of the parameters exhibit the shape of a normal distribution.

Table 3. Mean, Standard Deviation, Kolmogorov-Smirnov Maximum Absolute Difference, Significance, Spearman Correlation, Minimum Value, Values Associated with the 25th, 50th, and 75th Percentiles, and Maximum Value by Diadochokinetic Parameters.

DDK Parameter (Measurement Unit)	Mean	SD	K-S	p	r	Min	P25	P50	P75	Max
DDKavp (ms)	218.55	122.11	0.29	0.00	-0.111	124.31	160.97	174.14	213.31	972.14
DDKavr (/s)	5.48	3.45	0.30	0.00	0.105	1.03	4.66	5.74	6.22	54.90
DDKcvp (%)	33.24	29.83	0.16	0.00	-0.165**	3.06	7.67	21.57	49.38	129.92
DDKjit (%)	8.80	15.22	0.29	0.00	-0.171**	0.52	1.56	2.75	8.60	97.49
DDKcvi (%)	2.51	1.55	0.21	0.00	0.006	0.65	1.57	1.97	3.00	9.03

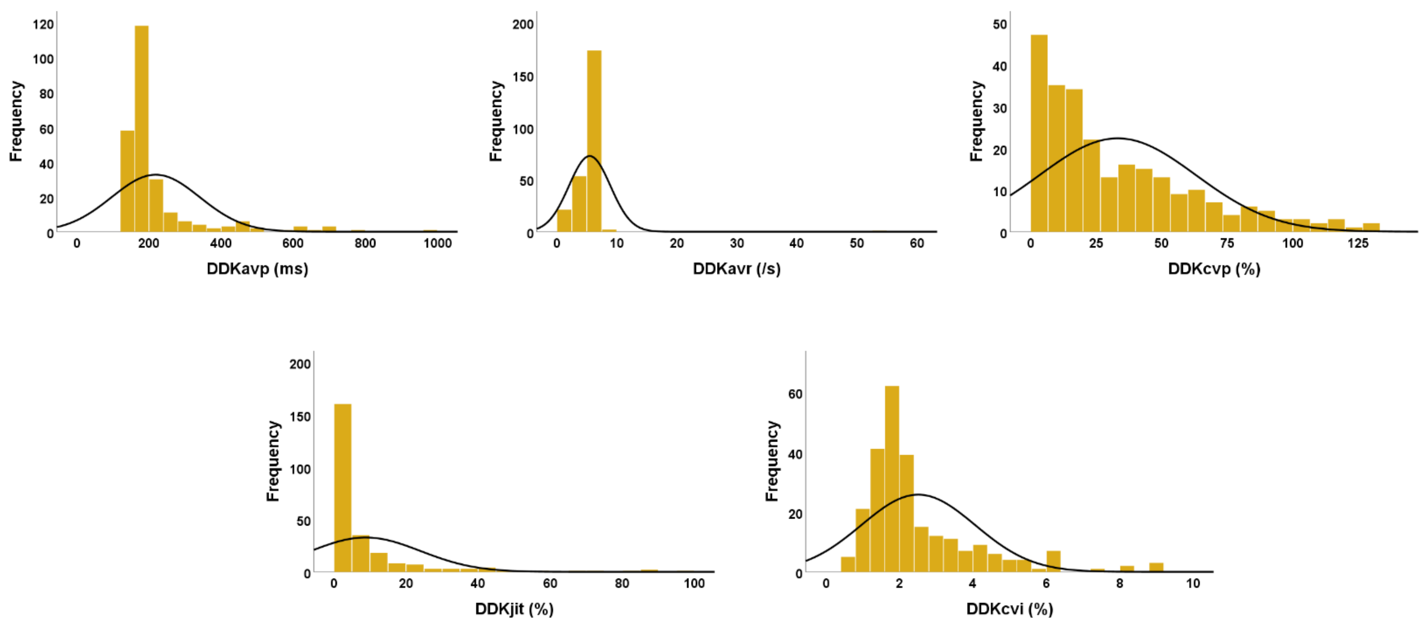

Figure 1. Histogram of diadochokinetic parameters.

The sixth column details the Spearman correlation of each diadochokinesis parameter with the chronological age of the subjects. It can be observed that for two parameters (DDKcvp and DDKjit), there is a significant negative correlation with age ($p < 0.01$). This indicates that as age increases, the parameter decreases. For the other parameters, this correlation is not significant, meaning it is not different from zero.

Table 4. Mean, Standard deviation, Student's *t*-Test, and Significance by DDK parameter.

Diadochokinetic Parameters	(Pérez et al., 2015)		Current Study		Student's *t-Test*	
	M	SD	M	SD	$t_{(287)}$	p
DDKavp (ms)	263.36	66.15	218.55	122.11	2.24	0.03
DDKavr (/s)	4.00	1.01	5.48	3.45	-2.66	0.01
DDKcvp (%)	5.48	1.66	33.24	29.83	-5.80	0.00
DDKjit (%)	1.78	0.66	8.80	15.22	-2.88	0.00
DDKcvi (%)	1.84	0.75	2.51	1.55	-2.65	0.01

Considering that none of the 5 parameters follows a normal distribution, we suggest using quartiles to characterize individuals' performance. Thus, the seventh column indicates the minimum value, and the remaining columns correspond to the values associated with the 25th, 50th, and 75th percentiles, as well as the maximum value. These values allow for the classification of a subject into the respective quartile based on what was obtained for a specific parameter.

Additionally, the normative data obtained in this study were compared to those found in Pérez et al. (2015), who used the MSP software in an adult population of Chilean Spanish speakers. When comparing the means using a Student's *t*-test for independent samples, significant differences were observed in all 5 parameters (DDKavp, DDKavr, DDKcvp, DDKjit, DDKcvi). Table 4 presents the mean and standard deviation of each DDK parameter evaluated. The sixth column shows the *t*-test value when comparing both studies, while the seventh column represents the significance of this maximum difference. For significant differences, *p*-values should be less than 0.05.

DISCUSSION

This study aimed to describe DDK rates in a sample of typically developing Spanish speakers from Chile, aged between 18 and 25 years. Means and standard deviations were calculated for the parameters DDKavp (average diadochokinesis period), DDKavr (average diadochokinesis rate), DDKcvp (coefficient of variation of the diadochokinesis period), DDKjit (diadochokinesis period disturbance), and DDKcvi (peak coefficient of variation of diadochokinesis). Since the data were not normally distributed, the parameters were characterized by quartiles. Additionally, the correlation between performance on each parameter and the participants' age was analyzed. It was found that only the parameters DDKcvp and DDKjit showed a negative correlation with age, meaning they decrease as age increases.

Significant differences were observed in each of the 5 parameters (DDKavp, DDKavr, DDKcvp, DDKjit, DDKcvi) when comparing our findings with the normative data obtained by Pérez et al., (2015) from a Chilean adult population. It is noteworthy that these authors also used the MSP software, and thus the same stimuli, instructions, and analysis method. The only differences were the sample size and age range (39 adults aged 18 to 61 years vs. 250 adults aged 18 to 25 years). Therefore, the differences observed between both studies could be attributed to the differences in age range between samples. However, further research is needed that considers additional variables to better understand the reasons behind these discrepancies. Pérez et al. (2015) also compared their results with another normative study, conducted with a sample of similar size and age range, but carried out with English-speaking participants from the United States (Deliyski & Gress, 1997). The analyses revealed significant differences in the parameters DDKavp, DDKavr, and DDKjit, likely due to the linguistic differences between studies. Taken together, these results suggest that both language and age should be considered when establishing normative values for the DDK rate.

Although it was not the aim of this research to contrast results with other age groups, we compared our findings with those of Velásquez (2008) and Vergara (2008), who also used the MSP software to assess children aged 6 to 9 years 11 months and 10 to 13 years 11 months, respectively. The study by Badilla et al. (2022) was not included in this comparison, as it incorporates socioeconomic status as a variable, which is not considered in the other studies. In Badilla's research, the mean values are similar to those of Velásquez (2008) and Vergara (2008); however, their standard deviations were notably smaller, indicating that the groups being compared were much more homogeneous. Regarding the comparative analysis, the mean and standard deviation of the 5 DDK rate parameters were used, with the following findings: DDKavp in our study had a total mean of 218.55 ms, with a standard deviation of 122.10. When compared to the average for children aged 10 to 13 years 11 months in Vergara (2008) (243.62 ms), and children aged 6 to 9 years 11 months in Velásquez, (2008) (255.61 ms), it was observed that this parameter tends to decrease with age. Regarding DDKavr, the total mean was 5.28 s, with a standard deviation of 1.42. When compared with the means for children aged 6 to 9 years 11 months (Velásquez, 2008) and children aged 10 to 13 years 11 months (Vergara, 2008), which were 4.36 s and 4.76 s, respectively, a significant increase was observed with age. Meanwhile, the three remaining parameters—DDKcvp, DDKjit, and DDKcvi—did not show any variation with age.

The fact that DDKavp tends to decrease as age increases indicates that the intervals between the consonant and the vowel are reduced, which is inversely proportional to DDKavr. This supports the idea that the DDK rate significantly increases during development. However, this finding needs to be complemented by further research that measures the DDK rate at various stages of the life cycle. It is worth noting that a previous study on Chilean adults aged 40 to 69 years did not find a correlation between the value of these parameters and age. However, the study was conducted exclusively with adults in a narrow age range and its measurement procedure was not based on a specialized program (Toledo et al., 2011).

As mentioned in the introduction, DDK rate assessment plays a significant clinical role, as it provides information on the integrity of the motor control of facial and oral muscles and their ability to perform rapid, alternating movements (Duffy, 2020). This is because normative values for the DDK rate are a precise and consistent indicator of potential neuromotor speech disorders (Alshahwan et al., 2020; Icht & Ben-David, 2014). It is for this reason that studies on people with Parkinson's disease, multiple sclerosis, and stroke, among others, consider disturbances in DDK rate to be a relevant sign in assessment processes (Godino-Llorente et al., 2017; Kashyap et al., 2018; Poellabauer et al., 2015; Rusz et al., 2018; Y. Wang et al., 2004; Zhang et al., 2018). Therefore, it is necessary to work with different clinical populations in Chile, as currently, there are only studies in children with cleft palate (Brisso, 2007) and phonological disorders (Orellana, 2008).

Furthermore, the DDK rate allows us to study and characterize speech considering variables such as sociocultural level and gender. For example, the study by Badilla et al. (2022) showed that first-grade children from a lower sociocultural level exhibit greater variability in DDK rate (DDKcvp) and a higher percentage of disruption (DDKjit) compared to children from an upper-middle sociocultural level. Regarding gender, the study conducted in Chile by Toledo et al. (2011) found significant differences between men and women in the repeated utterance of the syllable [pa]. However, it is evident that studies considering other variables are scarce, and thus integrating these variables into future research would be of great value.

As for the stimulus used to measure DDK rate, although [pa] is the most commonly used, it is also important to conduct studies that include other syllables like [t̪a] or [ka], as this would allow us to evaluate repetitive movements at other points of articulation (Duffy, 2020). It would also be relevant to consider laryngeal diadochokinesis with vowels like [a] and [i], which allows us to analyze the coordination of vocal fold movements and detect issues related to phonation (Canter, 1965; Kent et al., 2022). Additionally, an important complementary evaluation is the sequential motion rate (e.g., repeatedly producing [pa.ˈt̪a.ka]), which provides information about the coordination and precision of oral movements from one articulatory point to another (Duffy, 2020).

This study has some limitations. For example, variables such as gender, socioeconomic level, and origin were not considered in these analyses. The absence of these factors makes it impossible to generalize the results. As mentioned earlier, new studies need to thoroughly investigate the potential influences of these variables on the DDK rate in Chilean Spanish. Moreover, future research should include other stimuli such as the syllables [t̪a] and [ka], vowels, and the sequential motion rate, which would enrich the analysis of the DDK rate. It is also crucial to measure DDK rate in other populations, such as different age groups or people with motor speech disorders, in order to make relevant comparisons and determine the implications for speech-language therapy.

Finally, there are now freely accessible computational resources that make it possible to quantify diadochokinetic performance, such as the script developed and validated by Osses et al. (2023) for use with the software Praat (Boersma & Weenink, 2020). Therefore, future research must use the most objective and comparable tools possible, as acoustic analysis provides information about the sound characteristics of speech and how it may vary over the course of development (Wang et al., 2019; Wang et al., 2008).

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REFERENCES

Alshahwan, M. I., Cowell, P. E., & Whiteside, S. P. (2020). Diadochokinetic rate in Saudi and Bahraini Arabic speakers: Dialect and the influence of syllable type. *Saudi Journal of Biological Sciences*, *27*(1), 303–308. https://doi.org/10.1016/j.sjbs.2019.09.021

Badilla, C. B., Soto-Barba, J. P., León-Valdés, H. M., & Sáez-Carrillo, K. L. (2022). Comportamiento de los parámetros diadococinéticos orales en escolares de primero básico y su relación con el nivel sociocultural y el desempeño fonético-fonológico. *Revista Chilena de Fonoaudiología*, *21*(1), Article 1. https://doi.org/10.5354/0719-4692.2022.61275

Boersma, P., & Weenink, D. (2020). *Praat: Doing phonetics by computer* (Versión 6.1.16) [Software]. http://www.praat.org/

Brisso, V. (2007). *Tasa de diadococinesia en sujetos con fisura* [Universidad de Talca]. Repositorio académico institucional - Universidad de Talca

Camargo-Mendoza, M., Nöth, E., Mekyska, J., & Orozco-Arroyave, J. R. (2023). Oral-diadochokinesis rates for Spanish, German and Czech: Reference values for normotypical adults. *Revista de Investigación En Logopedia*, *13*(2), Article 2. https://doi.org/10.5209/rlog.85834

Canter, G. J. (1965). Speech Characteristics of Patients with Parkinson's Disease: III. Articulation, Diadochokinesis, and Over-All Speech Adequacy. *Journal of Speech and Hearing Disorders*, *30*(3), 217–224. https://doi.org/10.1044/jshd.3003.217

Deliyski, D., & Gress, C. (1997). *Characteristics of motor speech performance: Normative data*.

Duffy, J. R. (2020). *Motor Speech Disorders: Substrates, Differential Diagnosis, and Management* (4ª ed.). Elsevier Health Sciences.

Fletcher, S. G. (1972). Time-by-Count Measurement of Diadochokinetic Syllable Rate. *Journal of Speech and Hearing Research*, *15*(4), 763–770. https://doi.org/10.1044/jshr.1504.763

Gentil, M. (1990). Dysarthria in Friedreich disease. *Brain and Language*, *38*(3), 438–448. https://doi.org/10.1016/0093-934X(90)90126-2

Godino-Llorente, J. I., Shattuck-Hufnagel, S., Choi, J. Y., Moro-Velázquez, L., & Gómez-García, J. A. (2017). Towards the identification of Idiopathic Parkinson's Disease from the speech. New articulatory kinetic biomarkers. *PLOS ONE*, *12*(12), e0189583. https://doi.org/10.1371/journal.pone.0189583

Hartelius, L., & Lillvik, M. (2003). Lip and Tongue Function Differently Affected in Individuals with Multiple Sclerosis. *Folia Phoniatrica et Logopaedica*, *55*(1), 1–9. https://doi.org/10.1159/000068057

Icht, M., & Ben-David, B. M. (2014). Oral-diadochokinesis rates across languages: English and Hebrew norms. *Journal of Communication Disorders*, *48*, 27–37. https://doi.org/10.1016/j.jcomdis.2014.02.002

Juste, F. S., Rondon, S., Sassi, F. C., Ritto, A. P., Colalto, C. A., & de Andrade, C. R. F. (2012). Acoustic analyses of diadochokinesis in fluent and stuttering children. *Clinics*, *67*(5), 409–414. https://doi.org/10.6061/clinics/2012(05)01

Kashyap, B., Pathirana, P. N., Horne, M., Power, L., & Szmulewicz, D. (2018). Quantitative Assessment of Syllabic Timing Deficits in Ataxic Dysarthria. *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 425–428. https://doi.org/10.1109/EMBC.2018.8512311

Kent, R. D., Duffy, J., Kent, J. F., Vorperian, H. K., & Thomas, J. E. (1999). Quantification of motor speech abilities in stroke: Time-energy analyses of syllable and word repetition. *Journal of Medical Speech-Language Pathology*, *7*(2), 83–90.

Kent, R. D., Kent, J. F., & Rosenbek, J. C. (1987). Maximum Performance Tests of Speech Production. *Journal of Speech and Hearing Disorders*, *52*(4), 367–387. https://doi.org/10.1044/jshd.5204.367

Kent, R. D., Kim, Y., & Chen, L. (2022). Oral and Laryngeal Diadochokinesis Across the Life Span: A Scoping Review of Methods, Reference Data, and Clinical Applications. *Journal of Speech, Language, and Hearing Research*, *65*(2), 574–623. https://doi.org/10.1044/2021_JSLHR-21-00396

Kent, R. D., Sufit, R. L., Rosenbek, J. C., Kent, J. F., Weismer, G., Martin, R. E., & Brooks, B. R. (1991). Speech Deterioration in Amyotrophic Lateral Sclerosis. *Journal of Speech, Language, and Hearing Research*, *34*(6), 1269–1275. https://doi.org/10.1044/jshr.3406.1269

Nishio, M., & Niimi, S. (2000). Changes over time in dysarthric patients with amyotrophic lateral sclerosis (ALS): A study of changes in speaking rate and maximum repetition rate (MRR). *Clinical Linguistics & Phonetics*, *14*(7), 485–497. https://doi.org/10.1080/026992000750020323

Orellana, A. (2008). *Tasa de diadococinesia en niños con trastorno fonológico* [Tesis de Magíster]. Universidad de Talca.

Osses, D., Pérez, H. E., Román, D., & Quezada, C. (2023). Diseño, implementación y validación de un *script* de *Praat* para medir el rendimiento diadococinético. *Revista de Logopedia, Foniatría y Audiología*, *43*(2), 100288. https://doi.org/10.1016/j.rlfa.2022.01.004

Ozawa, Y., Shiromoto, O., Ishizaki, F., & Watamori, T. (2001). Symptomatic Differences in Decreased Alternating Motion Rates between Individuals with Spastic and with Ataxic Dysarthria: An Acoustic Analysis. *Folia Phoniatrica et Logopaedica*, *53*(2), 67–72. https://doi.org/10.1159/000052656

Padovani, M., Gielow, I., & Behlau, M. (2009). Phonarticulatory diadochokinesis in young and elderly individuals. *Arquivos de Neuro-Psiquiatria*, *67*, 58–61. https://doi.org/10.1590/S0004-282X2009000100015

Pérez, H., Fernández, R., & Oliva, C. (2015). Valores normativos para el programa de análisis acústico del habla Motor Speech Profile en hablantes de español de Chile. *Revista Chilena de Fonoaudiología*, *14*, 4–14. https://doi.org/10.5354/rcdf.v14i0.37608

Pierce, J. E., Cotton, S., & Perry, A. (2013). Alternating and sequential motion rates in older adults. *International Journal of Language & Communication Disorders*, *48*(3), 257–264. https://doi.org/10.1111/1460-6984.12001

Poellabauer, C., Yadav, N., Daudet, L., Schneider, S. L., Busso, C., & Flynn, P. J. (2015). Challenges in Concussion Detection Using Vocal Acoustic Biomarkers. *IEEE Access*, *3*, 1143–1160. IEEE Access. https://doi.org/10.1109/ACCESS.2015.2457392

Prathanee, B., Thanaviratananich, S., & Pongjanyakul, A. (2003). Oral diadochokinetic rates for normal Thai children. *International Journal of Language & Communication Disorders*, *38*(4), 417–428. https://doi.org/10.1080/1368282031000154042

Rong, P. (2020). Automated Acoustic Analysis of Oral Diadochokinesis to Assess Bulbar Motor Involvement in Amyotrophic Lateral Sclerosis. *Journal of Speech, Language, and Hearing Research*, *63*(1), 59–73. https://doi.org/10.1044/2019_JSLHR-19-00178

Rosen, K. M., Kent, R. D., & Duffy, J. R. (2005). Task-Based Profile of Vocal Intensity Decline in Parkinson's Disease. *Folia Phoniatrica et Logopaedica*, *57*(1), 28–37. https://doi.org/10.1159/000081959

Rusz, J., Benova, B., Ruzickova, H., Novotny, M., Tykalova, T., Hlavnicka, J., Uher, T., Vaneckova, M., Andelova, M., Novotna, K., Kadrnozkova, L., & Horakova, D. (2018). Characteristics of motor speech phenotypes in multiple sclerosis. *Multiple Sclerosis and Related Disorders*, *19*, 62–69. https://doi.org/10.1016/j.msard.2017.11.007

Samlan, R. A., & Weismer, G. (1995). The Relationship of Selected Perceptual Measures of Diadochokinesis to Speech Intelligibility in Dysarthric Speakers With Amyotrophic Lateral Sclerosis. *American Journal of Speech-Language Pathology*, *4*(2), 9–13. https://doi.org/10.1044/1058-0360.0402.09

Seifpanahi, S., Dadkhah, A., Dehqan, A., Bakhtiar, M., & Salmalian, T. (2008). Motor control of speaking rate and oral diadochokinesis in hearing-impaired Farsi speakers. *Logopedics Phoniatrics Vocology*, *33*(3), 153–159. https://doi.org/10.1080/14015430802045230

Stackhouse, P. W., Joy. (2000). Rate, accuracy and consistency: Diadochokinetic performance of young, normally developing children. *Clinical Linguistics & Phonetics*, *14*(4), 267–293. https://doi.org/10.1080/02699200050023985

Tjaden, K., & Watling, E. (2003). Characteristics of Diadochokinesis in Multiple Sclerosis and Parkinson's Disease. *Folia Phoniatrica et Logopaedica*, *55*(5), 241–259. https://doi.org/10.1159/000072155

Toledo, L., Bahamonde, C., González, J., Martínez, M., Muñoz, M., & Muñoz, D. (2011). Parámetros del habla en adultos normales chilenos. *Revista Chilena de Fonoaudiología*, *10*, 33–43. https://doi.org/10.5354/rcdf.v10i0.17350

Velásquez, C. (2008). *Tasa de diadococinesia en niños típicos hablantes de español, de entre 6 y 9 años, 11 meses de edad: Datos normativos* [Seminario de Licenciatura]. Universidad de Talca.

Vergara, C. F. (2008). *Tasa de diadococinesia en niños típicos hablantes de español de entre 10 años y 13 años 11 meses de edad: Datos normativos* [Seminario de Licenciatura, Universidad de Talca]. http://dspace.utalca.cl/bitstream/1950/5523/1/vergara_miranda.pdf

Wang, Y., Kent, R. D., Duffy, J. R., Thomas, J. E., & Weismer, G. (2004). Alternating motion rate as an index of speech motor disorder in traumatic brain injury. *Clinical Linguistics & Phonetics*, *18*(1), 57–84. https://doi.org/10.1080/02699200310001596160

Wang, Y. Y., Gao, K., Kloepper, A. M., Zhao, Y., Kuruvilla-Dugdale, M., Lever, T. E., & Bunyak, F. (2019). DeepDDK: A Deep Learning based Oral-Diadochokinesis Analysis Software. *2019 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI)*, 1–4. https://doi.org/10.1109/BHI.2019.8834506

Wang, Y.-T., Kent, R. D., Duffy, J. R., & Thomas, J. E. (2008). Analysis of Diadochokinesis in Ataxic Dysarthria Using the Motor Speech Profile Program™. *Folia Phoniatrica et Logopaedica*, *61*(1), 1–11. https://doi.org/10.1159/000184539

Yang, C.-C., Chung, Y.-M., Chi, L.-Y., Chen, H.-H., & Wang, Y.-T. (2011). Analysis of verbal diadochokinesis in normal speech using the diadochokinetic rate analysis program. *Journal of Dental Sciences*, *6*(4), 221–226. https://doi.org/10.1016/j.jds.2011.09.007

Yaruss, J. S., & Logan, K. J. (2002). Evaluating rate, accuracy, and fluency of young children's diadochokinetic productions: A preliminary investigation. *Journal of Fluency Disorders*, *27*(1), 65–85; quiz 85–86. https://doi.org/10.1016/s0094-730x(02)00112-2

Zhang, H., Wang, A., Li, D., & Xu, W. (2018). DeepVoice: A voiceprint-based mobile health framework for Parkinson's disease identification. *2018 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI)*, 214–217. https://doi.org/10.1109/BHI.2018.8333407

Ziegler, W. (2002). Task-Related Factors in Oral Motor Control: Speech and Oral Diadochokinesis in Dysarthria and Apraxia of Speech. *Brain and Language*, *80*(3), 556–575. https://doi.org/10.1006/brln.2001.2614

Ziegler, W., & Wessel, K. (1996). Speech timing in ataxic disorders. *Neurology*, *47*(1), 208–214. https://doi.org/10.1212/WNL.47.1.208