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Variables That Influence Articulation Accuracy in Children with Down Syndrome and Specific Language Disorder: Similarities and Differences

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Abstract

Research about speech sound disorders (SSD) in children with Down syndrome (DS) and children with specific language impairment (SLI) suggests similar linguistic profiles with weakness in phonology skills. The question is if these similarities are superficial or share deficits in levels and underlying skills to its speech disorders: phonological memory (PM), coordination motor skills, and articulatory muscular system. Our research involved 24 children divided into four groups: SLI, DS, and two groups of typical development. SLI group presented a mild-moderate speech disorder and DS group moderate-severe. Following skills were evaluated: nonverbal intelligence, PM, and oral motor coordination (oral-DDK). The Iowa Oral Performance Instrument (IOPI) was used for the measurement of physiological variables (strength and endurance of tongue and lips). Percentage of consonants correct (PCC) was found. Phonological memory, motor coordination, and physiological variables are factors associated with SSD in teenagers with DS. However, SSD in children with SLI only are associated to phonological memory. Motor coordination and physiological variables are not involved in their SSD of mild and moderate-severe levels. We have objectively measured the strength and endurance of tongue and lips. This may have clinical implications. It is necessary to assess objectively all the variables affecting articulatory accuracy to design intervention programs in SSD.

Keywords: speech sound disorder, specific language impairment, Down syndrome, oral-diadochokinetic, tongue strength

1. Introduction

Research about speech sound disorders in children with Down syndrome (DS) and children with specific language impairment (SLI) suggests similar linguistic profiles with weakness in phonology skills [1, 2]. The question is if these similarities are superficial or share deficits in different levels and underlying skills to their speech disorders.

The widespread problem of language disorder in children with SLI, according to some researchers, can be explained by the deficit in speech processing skills (perceptual skills, phonological memory, praxis, or motor programming), which hinders the phonological development, vocabulary learning, morphosyntactic processing, and production of words [3, 4]. It is the main handicap that may be interfering with articulatory accuracy, revealing a slowing of the typical development which can also present different evolutionary patterns with idiosyncratic itineraries. Van der Lely [5] proposed that the phonological deficit could attend with other grammatical alterations (morphological, syntactic), although it does not mean a causal relationship between them, although they can act in a reciprocal manner. Other studies suggest that not all children with SLI presented a phonological deficit [6, 7].

On the other hand, various factors that affect speech and development of the language of people with DS have been described in the literature. In addition to cognitive deficit that is the main factor, hearing loss, anatomical alterations, and failures in speech processing, among others, have an effect on speech. However, it is difficult to determine the influence needed for each factor, also can vary from one person to another, but it is known that difficulties in speech are not highly correlated with language or cognition, which may indicate that these problems are rooted in other factors [8]. The speech of children with DS often presents inconsistent errors, both developmental and devious, which reduce the intelligibility producing negative effects on social and labor activities [9–13]. This issue requires several levels of analysis.

1.1. Phonological short-term memory

The first level of study is focused toward phonological short-term memory (PM) which plays a crucial role in the segmentation of speech and further construction of accurate phonological representations, which will have implications in speech and in development of other areas of language (e.g. vocabulary) in the acquisition of phonological awareness and literacy development [14–16].

Traditionally, this cognitive function has been evaluated with pseudo-words repetition tasks (PWR), but it is debated whether it is really a unique and reliable measure of phonological memory [6], since, in addition, its execution is influenced by input processing, phonological awareness, and vocabulary skills and motor programs [17]. Recent research notes that high variability in speech errors is associated with low scores in RPW tasks [18].

Numerous studies conclude that children with SLI have low performance in these tasks in comparison with children of same chronological age and, in some cases, their own linguistic age, which is interpreted as a deficit in PM that seems to persist through time [16, 19–21]. This limitation may influence the quantity and / or quality of stored phonological information which, in turn, can affect language development [16, 22].

Although difficulties may be due to linguistic skills usually reduced, poor performance can be found even in children with SLI that have reached levels close to normal language, suggesting it is a good phenotypic marker of SLI in ages ranging from 4 to 6 years [23–26]. The reason for this age range is because in preschool the PM seems to be more related to oral language ability. However, after 6 years of age, this ability can be more tied to development of literacy [27, 28].

The evidence shows that alterations in memory have their greatest effect with longer stimulus [29–31]. In addition, some studies have found that phonological complexity and lexical and sublexical phonological awareness mediate on accuracy of repetitions [17, 20, 32].

An alternative explanation for the low yields obtained in PWR tasks is that children with SLI have a deficit in phonological processing beyond a specific limitation in memory, at the stage of coding, storage, or retrieval of phonological stimuli [3, 15, 33]. Consequently, representation of any pseudo-word will be low in quality, increasing difficulties with the length of stimuli.

On the other hand, research has exposed that the deficit in the PM is also one of the characteristics of people with DS and therefore presented a speech widely variable [34–36]. The findings of some studies suggest that it is a specific deficit for verbal information, since they do not seem to show poor performance on tests of visuospatial short-term memory, and is not caused, mainly, by hearing loss or speech production difficulties [37–40].

Effect of stimulus length has also been found in the population with DS, even when performance is compared to children matched in linguistic age [34, 37]. Other works have not observed this effect so clearly [36, 38], but we have to think about some limitations that could be masking the results: in one of the studies, only stimuli of one or two syllables were compared, and on the other, the control group was of preschool age, where it is common to find it hard to repeat pseudo-words of four syllables. Moreover, some researchers have found that the lexical effects influence either the population with DS and preschoolers with typical development, both of them benefiting from the linguistic knowledge. The difference is that people with DS need to lean more on the lexical knowledge, even though it does not mean that they benefit to a greater extent than the control group.

1.2. Coordination motor skills

Oral motor skills are another factor that could explain the articulatory accuracy difficulties, since there are evidences which connect neuromotor maturation with phonological development [41]. One way that has been suggested to evaluate it is oral-diadochokinetic rates tasks (oral-DDK) that measure the speed with which a subject is capable of producing, repeatedly and with precision, sequences of nonsense syllables that are alternating movements of articulators' different organs [42–44].

The majority of studies on motor coordination skills assessed through oral-DDK tasks have included children with verbal dyspraxia. In this condition, it is characteristic to find a deficit which is reflected in low yields obtained in oral-DDK (reduced rates, sequencing and precision errors), both compared to children with typical development [45, 46] and children with speech and language disorders [45]. Other works have studied children with phonological and articulation disorders, noting difficulties in sequencing and accuracy of sounds during the repetition of syllabic scripts (e.g. replacement of /k/ for /t/), but not in fluency and

intelligibility [41, 47, 48]. Finally, a study compared children with SLI with two control groups matched for chronological age and linguistic age, wherein the SLI group always showed poor performance, suggesting it is a marker of SLI in combination with others [49].

Most of the researches, conducted on people with DS, have found decreased rates with higher accuracy errors, less consistency of production, and a greater number of attempts when oral-DDK tasks are carried out [50–52]. McCann and Wrench [53] observed similar rates to those obtained in children with typical development, although productions were more inaccurate. This suggests that motor speech disorder is not only the difficulty in execution (dysarthria) but also the difficulty in planning or programming of spatial-temporal parameters in sequences of movement (dyspraxia).

1.3. Articulatory muscular system

The effector organs of articulation are dependent on muscle function. Research on aspects such as endurance and strength of lips and tongue in children with speech disorders is scarce, mainly, due to doubts about reliability of measurements of performance in children and lack of comparative data in children with typical development.

Potter and Short [54] examined tongue strength in 150 children and teenagers (between 3 and 16 years of age), no history of speech disorders, using Iowa Oral Pressure Instrument (IOPI). In their study they concluded that strength of tongue increases with age and in men is slightly higher than women between 14 and 16 years of age.

Some works do not find alterations in children with phonological disorder, but find them in children with verbal dyspraxia, concluding that oral performance variable is a differentiator between these two groups [55, 56]. There is no reason to think about a possible disturbance in this level of speech production in children with SLI, as it is suggested by the data provided in this research.

Differences in anatomy and physiology of the organs of people with DS (hypotonia, reduced range of motion, etc.) are well-known factors that could be the basis of reduced intelligibility [52, 57–59]. However, there are no clear conclusions about its impact on the specific speech difficulties [8]. Thus, some authors point out that these differences do not explain the entire speech disorder [2, 60].

In our research, we have analyzed variables related to articulatory accuracy in the population with SLI and DS: phonological processing skills, motor coordination, and physiological variables, using Medical IOPI device that allows obtaining objective measures of the strength and endurance of lips and tongue.

2. Method

2.1. Participants

The sample was 24 participants divided into four groups: (1) six children with SLI matched in chronological age ($p = 0.29$) and nonverbal intelligence with a control group of six children

with typical development (Typical Development Control 2); (2), six teenagers with DS matched in chronological age with another control group of six subjects with typical development (Typical Development Control 1) ($p = 0.87$). This decision was taken because the research includes the variables of physiological and motor coordination which are related to age-dependent maturation factors.

SLI group presented a severity level of mild-moderate speech disorder (percentage of consonants correct, PCC = 0.80) and DS group moderate-severe (PCC = 0.65), compared to their controls groups that reached the highest articulatory accuracy. Groups' characteristics are described in **Table 1**.

It was established as common inclusion criteria that participants had Spanish as their first language and they used it at school. The control groups were matched in chronological age to two study groups and they had no history of language disorders or learning disabilities.

2.2. Instruments

To assess PM, a PWR task was used [61]. It consists of repeating two lists of 40 pseudo-words with high-frequency and low-frequency syllables. Each list contained four groups of 10 pseudo-words for two, three, four, and five syllables. Each pseudo-word was equal to another pseudo-word of the other list in number of syllables, syllabic structure, accentuation pattern, and order in which syllables were placed with their different structures.

Oral-DDK: they were used to assess oral motor coordination skills. They consist of issuing a number of nonsense syllables involving opposing movement patterns, accurately and quickly. One syllable ([pa], [ta], and [ka]), two syllables ([pata], [paka], [taka]), and three syllables ([pataka]) were used.

Oral performance measurement: Medical IOPI device (Iowa Oral Performance Instrument, model 2.3) has been used to objectively measure lingual and labial resistance (maximum pressure in kilopascals, kPa, time in seconds that a pressure equal to 50% of the maximum force can be sustained).

Pronunciation task: Stimuli AF125 composed by a set of 125 images designed to induce a representative sample of the Spanish phonological system and to find the percentage of correct consonants (PCC) was used with the *Ánfora* software [62–64]. It contains a comprehensive repertoire of syllabic types in Spanish, repeated at least four times, with words of syllabic

	N	Age (months)		Age range (months)		IQ nonverbal		PCC		
		M	SD	Min.	Max.	M	SD	M	SD	S.SD ¹
SLI	6	72	13.06	52	86	109.17	12.64	0.80	0.13	MM
CG 2	6	68	4.85	60	73	103.67	13.79	1	0.01	–
DS	6	173	23.2	135	208	65	0	0.65	0.20	MS
CG 1	6	170.33	13.64	148	184	102.17	13.18	1	0	–

Notes: M, media; SD, standard deviation; PCC, percentage of consonants correct; S.SD, severity speech disorder; MM, mild-moderate; MS, moderate-severe. ¹Shriberg y Kwiatkowski, 1982.

Table 1. Participants.

structures common in the language. All language phonemes appear at least three times in each position and in the most common phonetic environments.

Raven's progressive matrices test [65]: It is a nonverbal intelligence test applied to control this variable and perform the pairing of SLI group.

3. Procedures

All participants in this study have been subjected to all assessment protocol that was applied in three sessions of 30 minutes: in the first, PWR together with oral-DDK were applied; in the second session, AF125 pronunciation task and oral performance was measured with Medical IOPI device. Finally, Raven's progressive Matrices test was applied to obtain IQ.

The application of PWR task was divided into two parts because it is a fairly long task and requires sustained attention. Each pseudo-word was read by the evaluator twice, slowly, clearly, and respecting accentuation. The instruction given to child was: *I'll say a few words that mean nothing. You should pay attention because you will have to repeat them as I do.* The scoring method used was that of whole words, that is, each repeated item is evaluated as a whole and noted down as right or wrong production compared to the target, regardless of the number of phonological errors and without penalizing accentuation and/or articulation errors. Productions were recorded to listen to them carefully and to record the percentage of successful responses.

The measurement of oral-DDK consisted of two phases: First of all came the training, where the examiner showed a child how to do repetitions and they practiced together. After that, the child was able to produce oral-diadochokinetic without help, with precision and speed, until the evaluator indicated him to stop. The **order** given was: *Quiero que digas unos sonidos lo más rápido posible. Primero lo haré yo y luego tú. El primer sonido es...* (I want you to say sounds as soon as possible. I will do it first, then you. The first sound is...). If the Item was annulled after several attempts or stopped before the indication of the evaluator, is because the child could not make changes of articulation place. The Time-by-count method has been used to record the time each subject takes to produce 20 repetitions for each isolated syllable ([pa], [ta], and [ka]), 15 for two syllables([pata], [paká], [taka]), and finally, 10 repetitions for three syllables ([pataka]). The productions were recorded to count the number of syllables and to write down exact time using a wave's editor.

Oral performance measurement also had a first phase of training in which a child was acquainted with Medical IOPI device. Once the participants were prepared and their maximum tongue strengths were measured, in kPa, by placing the balloon on the top of the tongue and pressing it against the palate with the greatest possible strength for approximately 2 seconds. Then, orbicular muscle strength was measured by positioning the balloon of IOPI device on front side of the mouth, between teeth and lips, to exercise force. Finally, tongue endurance was assessed by quantifying time in seconds that each participant was able to maintain a pressure equal to 50% of its maximum value in tongue strength, placing the balloon in the same position as in the first measurement. Three measures of each valued appearance were taken at periods between

30 and 60 seconds, and the maximum value obtained was recorded. If a decreasing trend was observed in the values obtained in these three measurements, the rest time had to be increased.

AF125 pronunciation test was administered in a single application. This task is to present images under the general order: *Dime qué es esto o cómo se llama* (Tell me what this is or what this is called). If the child did not respond, the examiner had to tell him the right word and he would ask him later. The evaluation continued during two more items, and then the examiner was retreated to retrieve the words that the child had not acted upon. If this was not possible after the third attempt, this word had to be ruled out of the sample. Productions were transcribed to software *Ánfora*. If the pronunciation was distorted, but it was intelligible, it was noted. If the pronunciation was distorted, but it was intelligible, it was noted. If the pronunciation was unintelligible, the option “nonparsable” appeared marked in the program. From the analysis of speaking sample, software *Ánfora* calculated the percentage of consonants correct (PCC = consonants pronounced error-free/total sample consonants). It means consonant pronounced error-free and in correct position. Values are included between 1, perfect pronunciation, and 0.

Finally, Raven test-scale Color was applied (series A, Ab, and B) to children from 4 to 10 years of age. General scaling, series A, B, C, D, and E, was applied to older participants.

4. Results

Two objectives of comparison have been raised: SLI group and CG2 (younger); SD group and CG1 (older). To find the differences between the study groups, the data was analyzed through Mann-Whitney U contrasts for independent samples. In addition, the range test with Wilcoxon sign for related samples was applied to check differences in the PWR task between high-frequency and low-frequency syllables.

Homoscedasticity condition is met in most of the variables examined in the study group SLI-CG2 (tongue strength, $p=0.31$; lips strength, $p=0.76$; tongue endurance, $p=0.94$; repetitions [ta], $p=0.08$; repetitions [ka], $p=0.14$; repetitions [taka], $p=0.28$; repetitions [pataka], $p=0.18$; PWR with high-frequency syllables, $p=0.11$), and also in the DS-CG1 group (IQ, $p=0.84$; tongue strength, $p=0.62$; lips strength, $p=0.82$; tongue endurance, $p=0.68$; repetitions [pa], $p=0.89$; repetitions [ta], $p=0.28$; repetitions [ka], $p=0.47$; repetitions [pata], $p=0.94$; repetitions [paka], $p=0.70$; repetitions [taka], $p=0.69$; repetitions [pataka], $p=0.85$; PWR with high-frequency syllables, $p=0.45$; PWR with low-frequency syllables, $p=0.22$).

In objective 1, averages obtained in oral performance variable are similar between the two groups, except in the force of tongue where scores are more distant (**Figure 1**). Results of the comparative analysis (**Table 2**) prove absence of significant differences in the measures taken. This indicates that participants with SLI do not present alterations in peripheral component of speech, at least in the three studied variables.

In oral motor coordination variable, SLI children tend to spend more time in oral-DDK, both repeat isolated syllables as in two and three syllables (**Table 2** and **Figure 2**). Results also reflect a progressive times increase as repetitions require more number of opposing movements of

	SLI		CG 2		U	Z	p	r
	M	SD	M	SD				
High-frequency syllables	60.98	11.71	96.59	2.78	0	-2.90	0.02*	0.83
Low-frequency syllables	46.25	16.18	88.75	5.42	0	-2.89	0.02*	0.83

Notes: Oral-DDK, oral-diadochokinetic tasks; PWR pseudowords repetition. * p < 0.05.

Table 2. Values and statisticians to Objective 1 (Differences between SLI group and control group).

lips and tongue in both groups. Statistical analysis (**Table 2**) shows that differences are not significant; therefore, pronunciation errors cannot be explained by an affectation of general motor coordination.

Finally, you can see in **Figure 3** that the averages obtained by the SLI group in RPW task are lower than that of the control group. The contrast of hypotheses (**Table 2**) shows significant differences ($p = 0.02$) with a large effect size ($r = 0.83$) in both lists: They obtained lower percentages in low-frequency syllables. This significant difference is more pronounced in SLI group ($p = 0.02$; $r = 0.63$). The data suggest that deficits in PM justify an important part of pronunciation errors.

During the Objective 2, the SD group reached an average score in oral performances lower than the control scores of the control group (**Figure 4**). Mann-Whitney U (**Table 3**) confirms that the differences are statistically significant in tongue ($p = 0.00$) and lips ($p = 0.04$) strenght.

Average times obtained by the SD group were greater than the CG1 in oral-DDK tasks (**Figure 5**); statistical analysis (**Table 3**) shows significant differences in all repetitions with

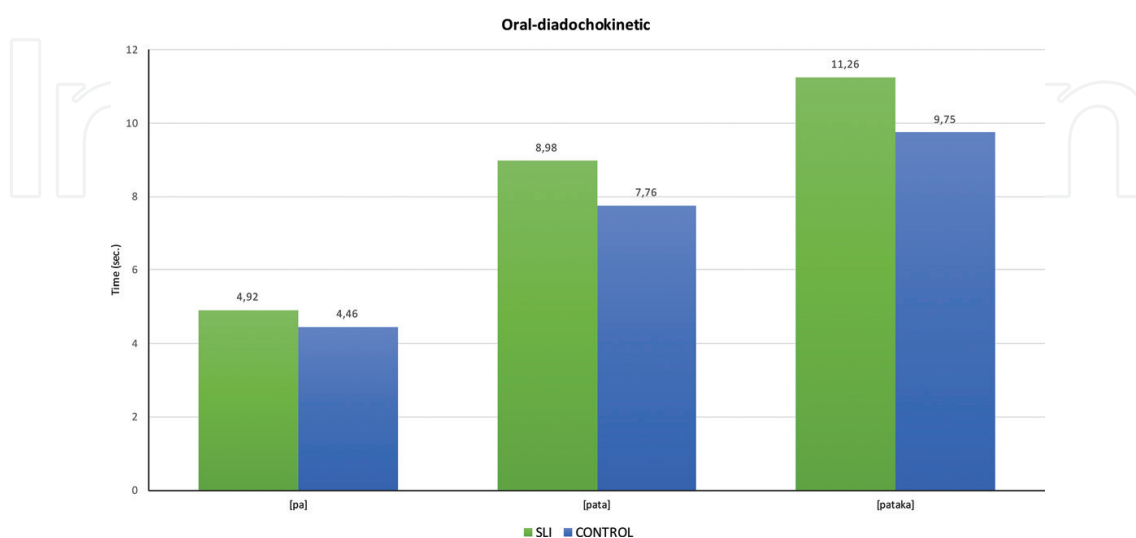


Figure 2. Mean scores in oral-diadochokinetic tasks (SLI group vs control).

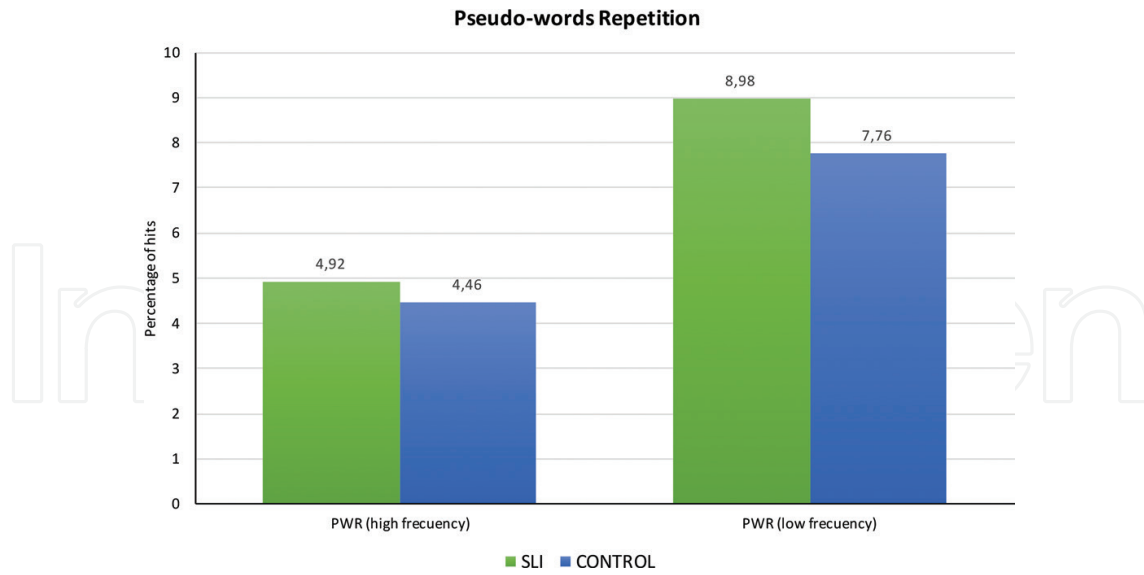


Figure 3. Percentage of hits in repetition pseudo-words task (PWR) (SLI group vs control).

elevated effect sizes. This suggests that motor maturation is not expected for age and can be a variable that is interfering in the articulatory accuracy.

Finally, success rate of the SD group in PWR does not exceed 50% compared to almost 100% of the CG1 group (Figure 6): Comparative analysis (Table 3) tested hypothesis of difference in our list of high-frequency and low-frequency syllables with large effect sizes. Wilcoxon test was applied in the same way as it was applied in the objective 1, obtaining significant differences ($p = 0.04$) with high effect size ($r = 0.58$). Success rate in PWR with high-frequency syllables was significantly higher than with the low-frequency syllables list. Therefore, deficits in PM constitute another factor that interferes with correct pronunciation in the SD group.

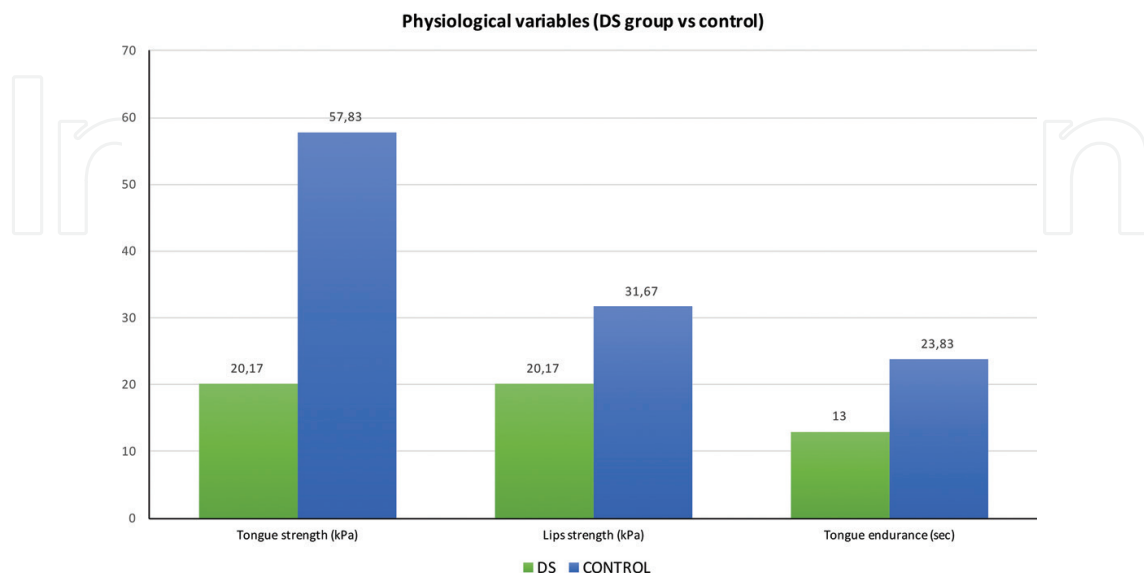


Figure 4. Mean scores in physiological variables (Down syndrome group vs control).

	SD		CG 1		U	Z	p	r
	M	SD	M	SD				
Tongue strength (kPa)	20.17	10.34	57.83	11.91	0.00	-2.88	0.00*	0.83
Lip strength (kPa)	20.17	9.60	31.67	4.27	5.50	-2.00	0.04*	0.58
Tongue endurance (seg)	13.00	8.10	23.83	6.68	5.50	-2.00	0.04*	0.58
Oral-DDK tasks (seg)								
[pa]	4.71	1.63	2.77	0.33	2.00	-2.56	0.01*	0.74
[ta]	6.00	1.44	2.84	0.39	1.00	-2.72	0.00*	0.79
[ka]	6.67	1.35	3.18	0.32	0.00	-2.72	0.00*	0.79
[pata]	13.10	10.43	4.15	0.54	1.00	-2.55	0.01*	0.74
[paka]	12.86	9.36	4.76	0.80	1.00	-2.55	0.01*	0.74
[taka]	9.78	1.46	4.59	0.75	0.00	-2.32	0.02*	0.67
[pataka]	16.47	7.08	5.28	0.95	0.00	-2.55	0.01*	0.74
PWR (%)								
High-frequency syllables	49.24	16.43	99.24	1.86	0.00	-2.98	0.00*	0.86
Low-frequency syllables	40.42	13.55	96.67	3.03	0.00	-2.89	0.00*	0.84

Notes: Oral-DDK, oral-diadochokinetic tasks; PWR pseudowords repetition. * p < 0.05.

Table 3. Values and statisticians to Objective 2 (Differences between SD group and control group).

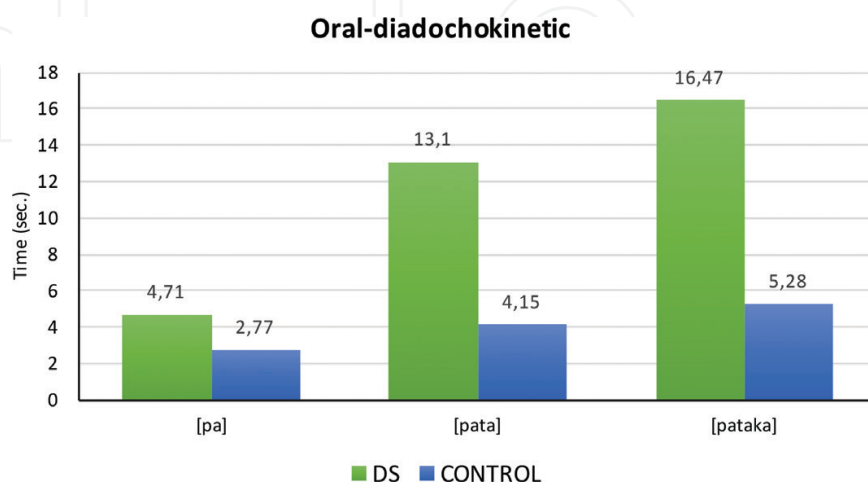


Figure 5. Mean scores in oral-diadochokinetic tasks (Down syndrome group vs control).

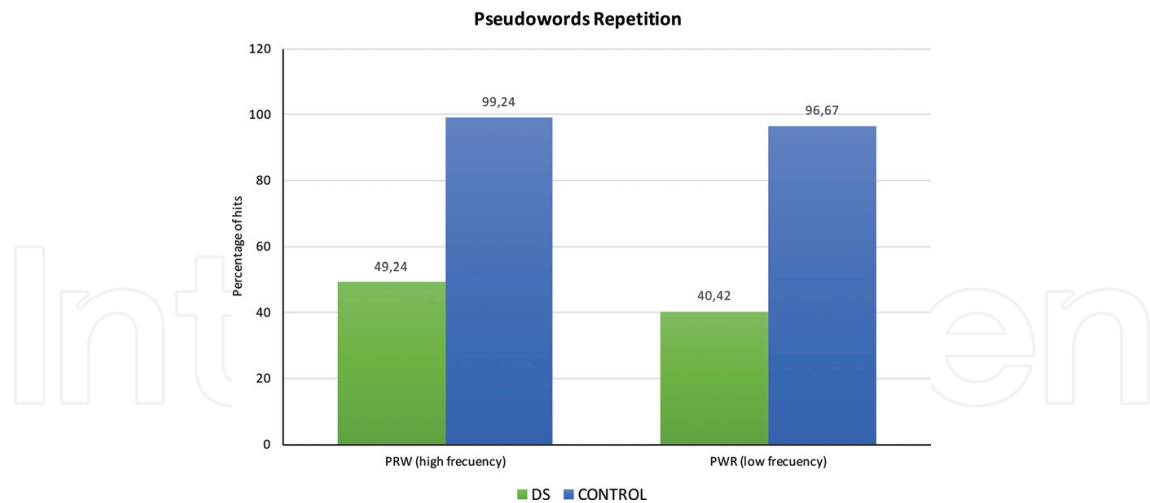


Figure 6. Percentage of hits in repetition pseudo-words task (RPW) (Down syndrome group vs control).

5. Discussion

Results confirm the existence of phonological short-term memory deficit with effects of use frequency, according to investigations conducted with SLI children [16, 19–21] and DS [34–38]. These results indicate that PM test cannot be used as a single measure of phonological short-term memory, because other levels of speech processing and phonological awareness are also involved; therefore, it is difficult to determine direct influences on articulatory accuracy as well as design tasks that only evaluate phonological memory.

The groups studied are not affected alike in PM test. This raises the question of whether it is a matter of severity, because it seems that poor performance has repercussions on the level of speech disorder severity or, on the contrary, there are qualitative differences in speech processing or even other variables that influence phonological memory, for example vocabulary size [66], perhaps because it influences the constant improvement of phonological categories. It would also be interesting to examine whether the limitation in the phonological memory occurs due to issues of quantity and/or quality of the information stored.

Literature found about neuromotor maturation in SLI population is sparse. We have recorded oral-diadochokinetic rates similar to typical development group, although with difficulties in sequencing and precision of sounds, as other works of articulation or phonological disorders [41, 47]. Buiza et al. [49] proposed that low yields obtained in this variable is a good marker of SLI, but our results do not allow to support this idea because although SLI children execution is qualitatively different from typical development children, oral-diadochokinetic rates are similar. However, measures and analyses used in our study are different, therefore comparisons should be made with caution. More conclusive data have been obtained in children with verbal dyspraxia in which motor coordination skills deficit is primary [45, 46].

Publications aimed at this level in people with Down syndrome come to similar results: reduced oral-diadochokinetic rates with more attempts, less consistency of production, and

more sequencing errors [50–52]. Data confirm that there is a difficulty in motor programming and sequencing of speech which could explain low scores in articulatory precision. This agrees with the contribution by Wertzner et al. [41] that found an interrelation between neuromotor maturation and phonological development.

Finally, we have not found involvement of peripheral variable in participants with SLI, which confirms an aspect apparently clear among professionals, but that does not translate into clinical practice. Intervention programs, that have an impact on this level of production, are still applied [67] when there is insufficient evidence supporting its use to produce effects in speech [68].

Data concerning population with DS are consistent with previous research [52, 57–59]: there are significant differences in values of oral performance, but it is discussed to what extent it interferes in articulatory accuracy [8]. Studies with different experimental designs and other kind of analysis are required to determine this with certainty.

In summary, in children with SLI, deficits in phonological short-term memory could explain many of the articulatory accuracy errors, since significant differences were not found in other analyzed variables. It would be necessary to clarify the type of specific difficulties in speech processing to design specific psycholinguistic intervention programs for each child. That is the only variable that differs with respect to control group, it suggests that PWR task could be a useful language disorders screening measure, as proposed by other authors [69]. In subjects with DS, articulatory difficulties are not explained by a specific involvement, since there have been significant differences in all analyzed variables. As a result, intervention programs that are designed should address all levels, not only linguistic but also physiological and motor coordination. However, in both populations it is difficult to determine how much each variable affects the pronunciation.

6. Conclusions

While in children with DS seems that the phonological memory, the motor coordination, and the physiological variables could be factors associated with articulatory difficulties, in children with SLI would be involved the first of them. We cannot ensure that variables behave the same way in children with severe speech disorders, since our participants ranged between mild and moderate levels.

These findings have implications in clinical practice. In children with SLI, nonspeech oral motor treatments are not justified to improve speech disorder, because it is clear that there is no involvement at this level, and scientific evidence does not support its use as standard treatment. We suggest the need to clearly evaluate where the difficulties are in the speech processing level and to design programs that affect specific deficits of each person.

On the other hand, children with DS seem to need a broader treatment, that is, treatment not only for speech deficits but also for oral motor and coordination skills. But, before intervening in this last aspect, clinicians must determine if physiological deficiencies are sufficient to interfere with speech and find scientific support for programs that work in this level, so it is recommended to follow principles of practice based on evidence.

Intervention programs cannot be designed depending on the severity of the articulatory disorder because the same symptoms may be due to alterations in different levels of processing. It is necessary to further research in these two population groups to define processes, mechanisms, and skills underlying speech disorders.

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