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Sensitivity and specificity of the Percentage of Consonants Correct-Revised in the identification of speech sound disorder

Sensibilidade e especificidade da Porcentagem de Consoantes Corretas Revisada na identificação do transtorno fonológico

Keywords

Speech-language Pathology and Audiology
Diagnosis
Speech
Language
Sensitivity
Specificity

Descritores

Fonoaudiologia
Diagnóstico
Fala
Linguagem
Sensibilidade
Especificidade

ABSTRACT

Purpose: The purpose of the study was to determine the sensitivity and specificity, and to establish cutoff points for the severity index Percentage of Consonants Correct - Revised (PCC-R) in Brazilian Portuguese-speaking children with and without speech sound disorders. **Methods:** 72 children between 5:00 and 7:11 years old - 36 children without speech and language complaints and 36 children with speech sound disorders. The PCC-R was applied to the figure naming and word imitation tasks that are part of the ABFW Child Language Test. Results were statistically analyzed. The ROC curve was performed and sensitivity and specificity values of the index were verified. **Results:** The group of children without speech sound disorders presented greater PCC-R values in both tasks, regardless of the gender of the participants. The cutoff value observed for the picture naming task was 93.4%, with a sensitivity value of 0.89 and specificity of 0.94 (age independent). For the word imitation task, results were age-dependent: for age group $\leq 6:5$ years old, the cutoff value was 91.0% (sensitivity of 0.77 and specificity of 0.94) and for age group $> 6:5$ years-old, the cutoff value was 93.9% (sensitivity of 0.93 and specificity of 0.94). **Conclusion:** Given the high sensitivity and specificity of PCC-R, we can conclude that the index was effective in discriminating and identifying children with and without speech sound disorders.

RESUMO

Objetivo: Verificar a sensibilidade, especificidade e estabelecer pontos de corte para o índice Porcentagem de Consoantes Corretas Revisado (PCC-R) em crianças com e sem transtorno fonológico falantes do Português Brasileiro. **Método:** Participaram 72 crianças com idade entre 5:00 e 7:11 anos, sendo 36 sem queixas de alteração de fala e linguagem e 36 crianças com diagnóstico fonoaudiológico de transtorno fonológico. O índice de gravidade PCC-R foi aplicado nas provas de nomeação de figuras e de imitação de palavras do Teste de Linguagem Infantil ABFW. Os resultados foram analisados estatisticamente. Foi realizada a curva Roc e obtidos os valores de sensibilidade e especificidade do índice. **Resultados:** O grupo de crianças sem transtorno fonológico apresentou valores do PCC-R maiores nas duas provas, independentemente do gênero dos participantes. O valor de corte na prova de nomeação de figuras foi de 93,4%, com sensibilidade de 0,89 e especificidade de 0,94, independentemente da idade. Já na prova de imitação de palavras, os valores obtidos variaram de acordo com a idade. Para a faixa etária $\leq 6:5$ anos, o valor de corte foi de 91,0%, com sensibilidade de 0,77 e especificidade de 0,94. Para a faixa etária $> 6:5$ anos, o valor de corte foi de 93,9%, com sensibilidade de 0,93 e especificidade de 0,94. **Conclusão:** Dada a alta sensibilidade e especificidade do PCC-R, o índice foi efetivo na discriminação e identificação de crianças com e sem transtorno fonológico.

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Received: February 19, 2016

Accepted: October 24, 2016

Study carried out at Departamento de Fisioterapia, Fonoaudiologia e Terapia Ocupacional, Faculdade de Medicina, Universidade de São Paulo – USP - São Paulo (SP), Brazil

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Financial support: Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), process nº 2008/57145-2.

Conflict of interests: nothing to declare.

INTRODUCTION

Children with Speech Sound Disorder (SSD) widely differ with respect to their manifestations of speech and language^(1,2). Some distort sounds, others replace them, yet others omit them. These simplifications of speech and sound patterns are called phonological processes. The literature cites three most common types of phonological processes: the syllabic structure, which alters the syllabic structure of words, following the general trend of reducing words to the structure of Consonant Vowel (CV); those of substitution, in which a sound is replaced by another one belonging to another class, sometimes reaching an entire class of sounds; and those of assimilation, in which the sounds change, becoming similar to an adjacent sound (preceding or succeeding)^(3,4). Analysis of phonological processes is useful to describe the phonological manifestations present in SSD⁽⁵⁾.

The severity of SSD can vary at different degrees, and for this reason numeric indexes have been proposed to classify the disorder's degree of compromise, whose classification is obtained by means of speech samples. Several indexes are described in the literature with specific characteristics and applications. One of the indexes proposed is the Percentage of Consonants Correct (PCC)⁽⁶⁾, which counts the total amount of consonants correctly produced from a speech sample, divided by the total number of consonants existing in the sample.

In 1997, variations of the PCC index⁽⁷⁾ were proposed with the objective of helping to differentiate the subtypes of SSD: the PCC-Adjusted index (PCC-A), which does not consider typical distortions as mistakes, and the PCC-Revised (PCC-R), which does not consider any type of distortion as mistakes. For the authors, these indexes have specific characteristics and applications. The PCC is a meritorious index to compare children with SSD between 3 and 6 years old, the PCC-A is used to compare children at different ages with speech impairment, while the PCC-R is applied when research involves speakers at different ages and varying characteristics.

The latter index has been widely cited in the literature in order to verify its efficacy in classifying the degree of speech impairment in speech sound disorder⁽⁸⁻¹³⁾. However, there is no age curve that demonstrates progress by means of its values and that makes it possible to verify if a child, at a certain age, is found within the expected value or not, which would aid identification of speech sound disorders.

In a study conducted in 2007⁽⁹⁾, the authors developed a curve with PCC-R values during progress, supported by speech samples of English speakers taken from databases of various researchers. Although incomplete, it allows us to see that this index demonstrates children's phonological competence. It is observed that the values found by these authors varied between 94% and 97% for the age range between 67 and 88 months.

In another study⁽¹⁴⁾, children without SSD at the age range between 4 and 7 years old (mean age of 5:5 years) presented, on average, a PCC-R of 97%. In 2012 and 2015^(15,16), some authors described the PCC-R profile in children without and with SSD, respectively. For children with normal speech development between 5 and 7 years of age, the authors indicated mean PCC-R values between 98.3% and 98.8%. For children with SSD aged

between 30 and 65 months, the PCC-R was on average from 73.8% to 80.7%.

Since these indexes were originally applied to English speakers, some studies were carried out to apply the indexes to the speech samples of Brazilian Portuguese speakers^(8,17-19). These indexes were effective in that they aided identification of SSD in Brazilian Portuguese-speaking children. They also allowed for the quantitative indication of the child's improvement during the therapeutic process and facilitated the decision about the appropriate time for discharge from speech-language therapy.

As the PCC-R index has proven to be effective in helping to identify SSD, obtaining evidence of cutoff values that indicates the presence of the disorder in children aged between 5:00 and 7:11 years may contribute to a greater precision of the classification of the impairment caused by the disorder.

Thus, the objective of this study was to verify the sensitivity and specificity, and to establish cutoff points of the PCC-R index in Brazilian Portuguese-speaking children with and without Speech Sound Disorder.

METHODS

This cross-sectional and observational study was approved by Comissão de Ética para Análise de Projetos de Pesquisa - CaPPesq of the Clinical Board of Hospital das Clínicas and Faculdade de Medicina da Universidade de São Paulo – HC/FMUSP under No. 0958/08. The parents and/or guardians of all individuals participating in the research have signed the Informed Consent and answered the anamnesis questions.

Seventy-two children aged between 5:00 and 7:11 of both genders participated in the research, where 36 did not present speech and language impairment complaints (CG) and came from public schools in São Paulo, and 36 children were diagnosed with speech sound disorder (SSD), having been assessed at a specific laboratory of a university in São Paulo.

The inclusion criteria for the children in the CG were: lack of complaint from parents and/or teachers related to hearing, speech and language impairments; to present adequate performance on the ABFW Child Language Test⁽²⁰⁾ and on spontaneous speech assessed from reading the story book *Esconde-Esconde*⁽²¹⁾, as well as on the vocabulary test of the ABFW Child Language Test⁽²²⁾. For the SSD, the inclusion criteria were: to present impaired performance on the ABFW Child Language Test⁽²⁰⁾ and spontaneous speech language tests from reading the story book *Esconde-Esconde*⁽²¹⁾, to present adequate performance on the vocabulary test of the ABFW Child Language Test⁽²²⁾, and not to be undergoing or have undergone speech-language therapy. All children were evaluated by speech-language therapists with experience in the field of SSD, and were submitted to the evaluation protocols of the laboratory in which they were selected.

From the speech-language tests, calculation of the severity index Percentage of Correct Consonants - Revised (PCC-R) was applied separately for the speech samples obtained by means of the figure naming (PCC-RN) and word imitation (PCC-RI) tasks. Each test contains a specific number of stimuli and correct consonants. The naming task is composed of 34 figures and 90 consonants, and the imitation task contains 39 words and

107 consonants. It should be noted that this index considers the distortions performed as correct⁽⁷⁾.

The speech-language tests of all children were recorded during evaluation and later phonetically transcribed by two experienced speech-language therapists, who also calculated the PCC-R. In all cases, there was a minimum agreement of 80% between speech therapists.

Statistical methodology

Comparison of the age and gender distribution between the groups was performed by means of the statistical tests Student's t-test and Qui-square, respectively. Comparison between the PCC-R index values measured in the figure naming (PCC-RN) and word imitation (PCC-RI) tasks for the groups was performed by the Mann-Whitney test. When there was a significant correlation, demonstrated by the Spearman correlation coefficient, between the index analyzed and age, both groups (CG and SSD) were subdivided into four new subgroups. Considering that the median age of the groups was 6:5 years old, the new groupings were: ≤6:5 years and >6:5 years. The combination of groups with age ranges gave rise to four subgroups: CG aged ≤6:5 years, CG aged >6:5 years, SSD aged ≤6:5 years, and SSD aged >6:5 years. The Kruskal-Wallis test was used to compare the four subgroups. When necessary, p-values were corrected by means of the Bonferroni method.

To determine the cutoff value of the PCC-R index, which allows to classify a new child as presenting a speech sound disorder or not, based on the naming and imitation tasks, the ROC curve was constructed. The cutoff value corresponds to the highest values of sensitivity and specificity (simultaneously), represented by a square in the Figure constructed, for which the area is determined⁽²³⁾.

RESULTS

The results showed that the average age was 64 months in both groups. There was no difference for this variable ($p=0.935$) (Student's t-test).

The majority of children in the CG were female (22 individuals), while in the SSD, the majority was male (25 individuals). The application of the chi-square test indicated a significant difference between the distributions as to gender in both groups ($p=0.009$).

Comparison between the genders for PCC-R in the figure naming task (PCC-RN) in the two groups showed no significant difference between the PCC-RN distributions in both the CG ($p = 0.466$) and the SSD ($p=0.216$) (Mann-Whitney test). The descriptive values of PCC-RN according to the group and gender are found in Table 1.

Upon comparing the CG and SSD, the results showed a significant difference between the PCC-RN distributions in the two groups ($p<0.001$), where the GC values were higher than in the SSD (Mann-Whitney test). In the correlation between PCC-RN and age, the results showed that, for the CG, the value observed was $r=0.04$ ($p=0.800$) and for SSD, $r=0.19$ ($p=0.274$) (Spearman's correlation test), indicating that there

was no significant correlation between the PCC-R and age in both groups. Thus, the age variable was not considered for the analysis of the ROC curve.

The ROC curve (Figure 1) for the PCC-RN showed an area under the curve of 0.96, indicating a good ability of the test to discriminate. The cutoff value corresponding to the highest sensitivity and specificity values (simultaneously) was 93.5%, indicating that any PCC-R value above this classifies the child as not presenting SSD. A sensitivity of 0.89 and specificity of 0.94 are associated with this value.

On the word imitation task, it was observed that the PCC-R mean and median values were higher in the CG than in the SSD, in both the female and male genders (Table 2). The PCC-R values on the imitation task (PCC-RI) were more homogeneous in the CG than in the SSD. The results showed no significant difference between the PCC-RI distributions between the two

Table 1. Distribution of PCC-R descriptive values for the Figure Naming test according to group and gender

Group	Gender	N	Mean	Standard deviation	Median
CG	F	22	97.8	6.0	100
	M	14	98.0	2.7	99.4
	Total	36	97.9	4.9	100
SSD	F	11	71.8	15.6	75.9
	M	25	77.5	18.2	81.1
	Total	36	75.8	17.4	81.1

Caption: N = Number of children; CG = Control Group; SSD = Group with Speech Sound Disorder; F = Female; M = Male

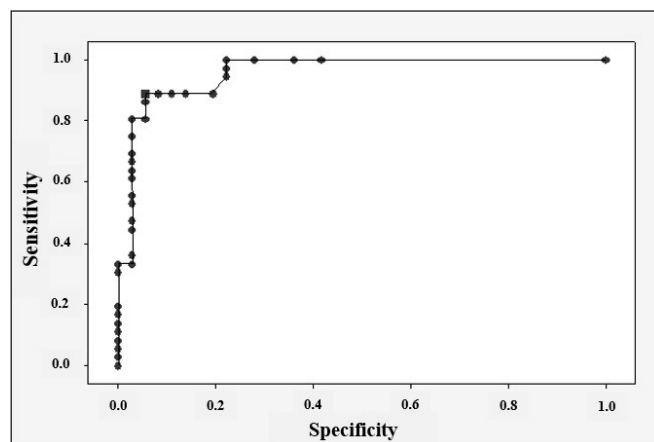


Figure 1. ROC Curve for the PCC-R of Figure Naming Test

Table 2. Descriptive statistics for comparison between group and gender in the PCC-R phonological measurement of the Word Imitation Test

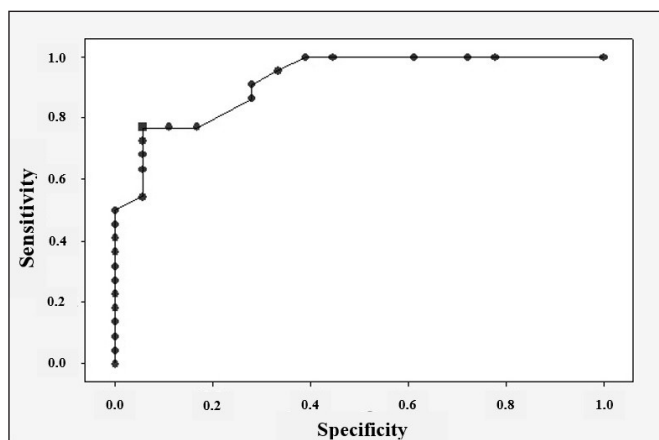
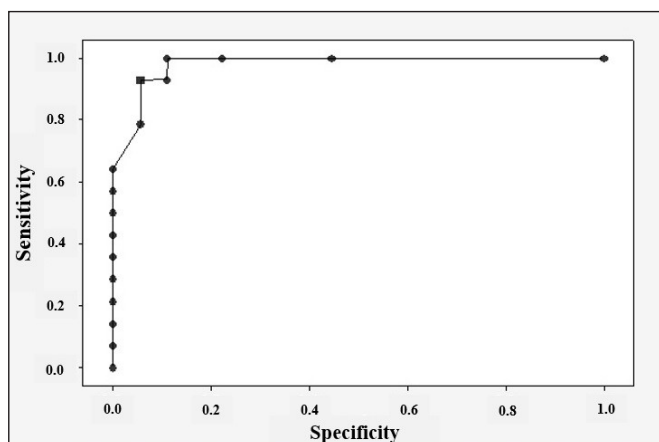
Group	Gender	N	Mean	Standard deviation	Median
CG	F	22	98.2	3.7	99.8
	M	14	96.9	3.6	98.9
	Total	36	97.7	3.6	99
SSD	F	11	75.3	13.7	76.6
	M	25	79.4	17.0	84.1
	Total	36	78.2	16.0	80.4

Caption: N = Number of children; CG = Control Group; SSD = Group with Speech Sound Disorder; F = Female; M = Male

Table 3. Description of the number of individuals above the cutoff point in each phonology test for the CG and SSD

Group	Naming (PCC-R 93.4%)		Imitation			
	N Total	N of children above cutoff point	≤ 6:5 years (PCC-R 91.0%)		≤ 6:5 years (PCC-R 93.9%)	
			N Total	N of children above cutoff point	N Total	N of children above cutoff point
CG	36	34	17	16	18	18
SSD	36	4	19	3	17	3

Caption: PCC-R = Percentage of Consonants Correct; N = Number; CG = Control Group; SSD = Group with Speech Sound Disorder

**Figure 2.** ROC Curve for the imitation PCC-R in age range ≤6:5 years**Figure 3.** ROC Curve for the imitation PCC-R in age range >6:5 years

genders, both in the CG ($p=0.081$) and in the SSD ($p=0.303$) (Chi-square test).

In the correlation between PCC-RI and age, the results showed that, for the CG, the observed value of the Spearman correlation coefficient was $r=0.49$ ($p=0.003$) and for the SSD, $r=0.08$ ($p=0.663$), indicating a significant correlation between the PCC-RI and age only in the CG.

Due to this significant correlation and considering that the median age was 6:5 years, we chose to create two new groups according to age ranges: ≤6:5 years and >6:5 years. The combination of the groups with age ranges gave rise to four subgroups: CG aged ≤6:5 years, CG aged >6:5 years, SSD aged ≤6:5 years, and SSD aged >6:5 years. There was a significant difference between the PCC-R distributions in the four subgroups

($p<0.001$) (Kruskall-Wallis), with values in the CG tending to be higher than in the SSD for the age range ≤6:5 years ($p<0.001$) and >6:5 years ($p<0.001$).

The ROC curve for the PCC-RI in the age range ≤6:5 is presented in Figure 2, and for the age group >6:5, in Figure 3. The cutoff value corresponding to the highest sensitivity and specificity values (simultaneously) for the PCC-RI in the age range ≤6:5 years was 91.0%. A sensitivity of 0.77 and specificity of 0.94 are associated with this value. For the age range >6:5 years, the cutoff point was 93.9%. A sensitivity of 0.93 and specificity of 0.94 are associated with this value.

The results showed that in both the word imitation and figure naming tasks the number of individuals above the cutoff values found for each task was higher in the CG than in the SSD (Table 3).

DISCUSSION

The PCC-R⁽⁴⁾ index was applied in several studies that aimed to analyze speech impairment in children with SSD, both at diagnosis^(10,14,16) and in treatment progression⁽¹³⁾. In particular, several studies with Brazilian Portuguese speakers have shown significant differences in PCC-R values as they compared children with and without SSD at different ages^(8,17-19).

With the constant use of this index, it was observed that studying its sensitivity and specificity and verifying the cutoff value of PCC-R in the ROC curve for two different speech samples would provide very important data both for clinical practice and research. Thus, that was the objective of this study, where results indicated high sensitivity and specificity values both in the figure naming and word imitation tasks. We also observed that, in both phonology tasks, the PCC-R index presented higher values for specificity, which demonstrates greater accuracy to indicate the children who do not present Speech Sound Disorders.

The results of the sensitivity and specificity analysis indicated the cutoff value (ROC curve) of 93.4% for the PCC-R in the figure naming task. As for the analysis of the PCC-R on the word imitation task, a correlation with age was observed in the control group and, therefore, the children were grouped according to age for this task. For the subgroup ≤6:5 years, the cutoff value was 91.0%, while for the group >6:5 years the value was 93.9%.

Regarding the influence of age on the PCC-RI, one aspect to be highlighted is that, on the imitation task, the child hears the stimulus and repeats it immediately - unlike the figure naming task, in which they need to access their lexicon, recognize the

stimulus and, subsequently, pronounce the word according to their knowledge. As demonstrated in several studies, cognitive and linguistic skills may facilitate the motor skills involved in the production of speech sounds^(24,25). Thus, naming as a result of linguistic and cognitive interference can act as a stimulus for the articulatory gestures involved in the production of speech sounds and minimize the age difference in production of speech sounds.

As pointed out before, since its proposal in 1997⁽⁷⁾ the PCC-R index has been applied in different studies with children in order to describe phonological competence and accuracy, as it reflects the speech-language acquisition in the child's linguistic environment⁽²⁶⁾. However, there is no age curve that demonstrates phonological development by means of its values. The studies conducted for the English language^(9,14-16) found values close to those presented here, and small variations may occur depending on the language itself and/or the test used for data collection.

Therefore, this study's results show that the PCC-R index is effective to indicate the absence of SSD in children aged between 5:00 and 7:11 years. It also indicates that the index can be applied to speech samples collected in figure naming and word imitation tasks. The values obtained in this study are close to those presented for English speakers.

The contribution of the study is reflected in the speech-language pathology research as well as in clinical practice, insofar as it allows greater safety in indicating the absence of SSD. In particular, in clinical practice, the application of the PCC-R to the phonology test may aid in indicating immediate intervention or parent/guardian guidance to achieve adequate speech development. In addition, the PCC-R index can also be used throughout the speech-language intervention to verify the change in the child's speech impairment profile.

CONCLUSION

The cutoff value obtained by means of the ROC curve suggests that, for the word imitation task of ABFW Child Language Test, there was an influence of age, where the cutoff values for the age range ≤6:5 years were 91.0% and for the age range >6:5 years, 93.9%. For the figure naming task, the cutoff value was 93.4%. Thus, although the PCC-R index has shown to be more specific than sensitive, we can conclude that its application is effective in identifying children with and without SSD.

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Author contributions

TFB participated in data collection, analysis, and interpretation, as well as in the article drafting; LOPN and JPS participated in the analysis and article drafting; HFW designed the study, supervised data collection, analysis, and interpretation, as well as writing of the article.