EDICIONES
COMPLUTENSE

Revista de Investigación en Logopedia
e-ISSN: 2174-5218

ESTUDIOS

Nasalance scores in Spanish-speaking children aged 3 to 5 years according to gender, age, and vowel load

Cristina Peris-Hernández
Speech Therapy Clinic of the Lluis Alcanyís Foundation - University of Valencia.

Vicent Rosell-Clari
Speech Therapy Clinic of the Lluis Alcanyís Foundation - University of Valencia. Professor of Basic Psychology. University of Valencia. (autor de correspondiencia)

Ann W. Kummer
Professor Emeritus. University of Cincinnati College of Medicine.

https://dx.doi.org/10.5209/rlog.88054 Recibido 12 de abril de 2023; Primera revisión 21 de agosto de 2023. Aceptado. 5 de octubre de 2023

ENG **Abstract:** Nasometry is a non-invasive, easy-to-use technique that provides objective data regarding the amount of acoustic energy in the oral and nasal cavities during speech. The goal of this study is to create a Spanish passage and determine normative nasalance values for typical Spanish-speaking children, 3 to 5 years of age, that allows us to compare the values in children of the same age who present hypernasality and velopharyngeal dysfunction. Second, to determine if there are significant differences in nasalance scores based on age or gender. Third, to test the impact of vowel load on nasalance scores. Data were collected from 130 children with no known speech, language, or hearing disorder. Participants were organized into three groups according to age. A nasometric assessment protocol for Spanish was developed based on an adaptation of the MacKay-Kummer Simplified Nasometric Assessment Procedures-Revised (SNAP-R; 2005). All participants were required to repeat the speech stimuli. Data were collected using the icSpeech nasometer and were recorded on EXCEL 365 sheets for further analysis. Normative data is now available for a Spanish version of the SNAP-R Test. No significant differences were found between the genders, but significant differences were found based on age. It was also found that a load of high and anterior vowels, especially the phoneme /i/, increased nasalance scores. This protocol created passages in Spanish that mimic the passages of the SNAP-R Test in English. These Spanish passages were normed for Spanish-speaking children. This study confirms that high vowels result in higher nasalance values and therefore, the vowel composition of a specific passage determines the nasalance score, not the language of the passage.
Keywords: Nasometer; Nasalance; Resonance; Children aged 3 to 5 years; Spanish; vowel load.

ES Puntuaciones de nasalance en niños hispanohablantes de 3 a 5 años en función del sexo, la edad y la carga vocálica.

ES **Resumen:** La nasometría es una técnica no invasiva y fácil de usar que proporciona datos objetivos sobre la cantidad de energía acústica en las cavidades oral y nasal durante el habla. El objetivo de este estudio fue crear un pasaje en español y det rminar valores normativos de nasalance para niños nomotípicos hablantes de español, de 3 a 5 años, que permita comparar los valores en niños de la misma edad que presentan hipernasalidad y disfunción velofaríngea. En segundo lugar, determinar si existen diferencias significativas en las puntuaciones de nasalance en función de la edad o el sexo. Tercero, comprobar el impacto de la carga vocálica en las puntuaciones de nasalance. Se recogieron datos de 130 niños sin trastornos del habla, lenguaje o audición. Los participantes se organizaron en tres grupos según la edad. Se desarrolló un protocolo de evaluación nasométrica en español basado en una adaptación de los Procedimientos Simplificados de Evaluación Nasométrica Revisados de MacKay-Kummer (SNAP-R; 2005). Se pidió a todos los participantes que repitieran los estímulos del habla. Los datos de cada participante se recogieron utilizando el software del nasómetro icSpeech y se registraron en hojas EXCEL 365 para su posterior análisis. En este trabajo se presentan datos normativos para una versión española del Test SNAP-R. No se encontraron diferencias significativas entre los géneros, pero sí en función de la edad. También se encontró que una carga de vocales altas y anteriores, especialmente el fonema /i/, aumentaba las puntuaciones de nasalance. Este protocolo creó pasajes en español adaptados a los pasajes del Test SNAP-R en inglés. Estos pasajes fueron

normalizados para niños hispanohablantes. Este estudio confirma que las vocales altas dan lugar a valores de nasalance más altos y, por tanto, la composición vocálica de un pasaje específico determina la puntuación de nasalance, no el idioma del pasaje.
Palabras clave: Carga vocálica; Español; Nasómetro; Niños; Resonancia.

Cómo citar: Peris-Hernández, C., Rosell-Clari, V., y Kummer, A. W. (2024). *Nasalance scores in Spanish-speaking children aged 3 to 5 years according to gender, age, and vowel load*. Revista de Investigación en Logopedia 14(1), e88054. https://dx.doi.org/10.5209/rlog.88054

Introduction

Nasometry is a noninvasive and easy-to-use procedure that provides objective data regarding the amount of oral and nasal acoustic energy produced during a speech segment. Nasometry is used as a clinical tool to diagnose abnormalities of resonance, including hypernasality due to velopharyngeal insufficiency and hyponasality due to upper airway obstruction (Kummer, 2005; 2020). The nasometer consists of an acoustic separator plate that is placed above the upper lip and is equipped with two microphones: a nasal microphone located at the top of the acoustic separator and an oral microphone located at the bottom of the acoustic separator. Both microphones collect acoustic data during speech simultaneously. According to Kummer (2005, 2020) during the production of a speech passage, the nasometer computes a *nasalance score*. The nasalance score is the percentage of nasal acoustic energy out of the total acoustic energy (nasal plus oral) while a certain stimulus or speech passage is produced. This formula is represented below:

Nasalance = nasal acoustic energy/total acoustic energy (nasal + oral) x 100.

If we compare the data obtained by a given subject with the normative data, a high nasalance score on oral speech stimuli would indicate hypernasality, while a low score on nasal speech stimuli would indicate hyponasality (Kummer, 2005; Watterson, 2020).

Effect of Language on Nasalance

There are many published articles which report normative nasometry data for specific passages in various languages, as spoken by native speakers for English: Dalston et al., 1993; Karnell, 1995; Kummer, 2005; Seaver et al; 1991; Watterson et al, 1996; for Dutch: Bettens et al., 2017; for Swedish: Brunnegard and Van Doorn, 2009; for Flemish: D'haeseleer et al., 2015; Van Lierde et al, 2001; for Vietnamese: Nguyen et al, 2019; for Mandarin-English: Pua et al., 2019; for Turkish: Ünal-Logacev et al., 2020. There are many more normed passages in other languages.

There have been a few publications that provided nasalance norms for Spanish-speaking adults (Anderson, 1996; Inostroza-Allende et al., 2022a; Inostroza-Allende et al., 2022b) and a few for Spanish-speaking children (Santos, González & Sanchez, 1991; Suarez-Brand, Flórez Romero, Espinosa Reyes, 2011). Only one study provided nasalance norms for Spanish-speaking children born in Spain (Santos, González & Sanchez, 1991; Nichols, 1999). However, this study was done using a TONAR nasometer, which was developed in the 1970s and is not in use today.

Several of the authors noted above suggested that there is a need for normative nasometric data for each language, based on the belief that nasalance scores are influenced by language or even regional dialects. However, several studies reported no differences between different dialects (Bettens et al., 2017 [Dutch]; Brunnegard and Van Doorn, 2009 [Swedish]; D'haeseleer et al., 2015 [Flemish]; Pua et al., 2019 [Mandarin–English]; Ünal-Logacev et al., 2020 [Turkish]).

Effect of Age on Nasalance

Some studies have found a slight increase in nasalance values of children with increased age (Ünal-Logacev et al., 2020; Alfwaress, 2022). Others have found no effect of age on nasalance (Bettens et al., 2017). Because ages 3 to 5 years is a critical time in the phonetic-phonological development of children and is also the age where many children are receiving nasometric tests, there is a need for more information about the effect of growth with age on normal nasalance in children (Kummer, 2005).

Effect of Gender on Nasalance

Research on the effect of gender on nasalance scores is equivocal. Some studies have found no gender differences in nasalance scores (Bettens et al., 2017; Okalidou, Karathanasi, & Grigoraki, 2011; D'haeseleer et al., 2015; Fletcher et al., 1989; Saber-Moghadam et al., 2019; Tachimura et al., 2000; Ünal-Logacev et al., 2020). Other studies showed differences between genders where females had significantly higher scores than males, particularly on nasals (Alfwaress et al., 2021; Park et al., 2014; Seaver, 1991; Van Doorn & Purcell, 1998).

Effect of Vowel Composition on Nasalance

Finally, there is strong evidence that vowel composition of a passage can affect the overall nasalance score (Alfwaress et al., 2021; Blanton et al., 2015; Gildersleeve-Neumann and Dalston, 2001; Ha and Cho, 2015; Kummer, 2005; Lewis and Watterson, 2000; Watterson, 2020). The high vowel /i/ results in about 10 percentage points higher in nasalance than the low vowel /a/ (Kummer, 2005). Therefore, a passage with a large percentage of high vowels will have a higher nasalance value than a passage with a larger percentage of low vowels.

Considering the above, the objectives of this study were as follows: 1. To create Spanish passages that are adapted from the MacKay-Kummer SNAP Test-R and establish normal nasalance values for these passages when spoken by typical Spanish-speaking children, ages 3 to 5 years, using the Rose Medical Ltd. nasometer. 2.- To determine if there are significant differences in nasalance scores based on the age and/or gender of the participants. 3.- To determine the impact of high versus low vowels on nasalance scores in these passages.

Methods

Participants

Speech samples were obtained from a group of 130 children (67 girls and 63 boys) who were enrolled in the "Escuela Sedavi" in the city of Valencia, Spain. The ages of the children ranged from 3 to 5 years (3 years: N = 40; 4 years: N = 47; 5 years: N = 43, with a mean age of 4.02 years and a standard deviation of .802). The families of all participants were informed of the characteristics and objectives of the research by means of a letter sent by the school administration. Parents were required to provide signed informed consent for the child to participate in the study. All children with parental consent were assessed to determine whether they met the inclusion criteria of this study and could perform the tasks.

Children were included in this study if they had normal orofacial anatomy and no evidence of a language, speech, hearing, voice, or neurological disorder. Children were excluded from this study if they had an upper respiratory tract infection at the time of data collection or had orofacial abnormalities (i.e., orofacial clefts, velopharyngeal insufficiency, or other features of a craniofacial syndrome), developmental delay, a communication disorder (i.e., speech, language, voice, or hearing disorder), or a neurologic disorder (i.e., sensory, cognitive, psychiatric, or psychomotor disorder). The annual pediatric assessment of each child and an interview with each class tutor and psycho-pedagogical guidance were used to determine if the child met the inclusion criteria.

Equipment and Calibration

The Rose Medical Solutions, Ltd. (2019) nasometer, which is widely used in Europe, was used for data collection in this study. The specification data and system requirements for this nasometer are included in Appendix 1. The nasometer was used according to the manufacturer's instructions and calibration was performed prior to examination.

Speech Passages

The passages developed for this study were based on the SNAP Test-R (Kummer, 2005). Therefore, the first subtest includes syllable repetition of high-pressure consonants with a low-pressure vowel /a/ or with a high-pressure vowel /i/. Given the age of participants we selected the following high-pressure consonants for the syllables: /p, b, k, s/, and nasals syllables with de consonants /m, n, ɲ/. Vowels were also recorded individually so that they could be compared with speakers of other languages. The Spanish phrases and sentences were created to closely match the SNAP-R Test (Appendix 2).

All participants were asked to repeat the speech passages in each of the subtests. For isolated sounds, the participants were asked to prolong the sound for 3 to 5 seconds. The syllables were repeated until the data filled the screen. For the phonetically balanced phrases, the participants repeated the phrase 3 times using the image as a prompt. Due to the age of the children, no reading passages were included in the protocol.

Data Collection

During data collection, one investigator held the sound separator plate against the child's upper lip to ensure a tight seal while the other investigator elicited the stimuli. After the recording of each speech sample, a nasalance score was calculated using the Rose Medical Solutions nasometer software, iSpeech Professional Edition. Nasalance data were transferred to EXCEL 365 for subsequent statistical analysis using IBM SPSS Statistics 26 software.

Statistical Analysis

To achieve the objectives of this work, the following statistical analyses were performed:

1. Internal consistency was tested using Cronbach's alpha coefficient.
2. A repeated measures experiment was designed to test intra and inter-subject reliability. Descriptive statistics were obtained, and significant differences were checked by t-test and correlations were obtained.

3. Descriptive statistics (means and standard deviations) were obtained for each stimulus according to age and gender.
4. The data was analyzed to determine if the data followed the normal distribution for each of the dependent variables using the Kolmogorov-Smirnov test.
5. Although some of the scores obtained did not follow the normal distribution, it was decided to use parametric tests to determine if the differences were significant because these tests are robust, considering the N of the sample (N =130).

Results

Spanish passages with normative data.

To prove the internal consistency of the nasalance data, Cronbach's alpha coefficient was applied to the scores obtained by all participants for each group of stimuli (vowels, syllables, and sentences) and for all protocol stimuli taken together (Table 1). As shown by Cronbach's alpha coefficient values, the nasalance data obtained with the Rose Medical nasometer can be considered highly reliable.

Table 1. Reliability of Nasalance data.

Stimuli	Cronbach's alpha coefficient
Vowels	.865
Syllables	.945
Phrases	.891
Total Stimuli of protocol	.962

Intra-session and inter-session reliability

To check intra-session and inter-session reliability, a repeated measures experiment was conducted using a sample of 15 subjects (5 children aged 3 years, 5 children aged 4 years and 5 children aged 5 years). All children met the inclusion criteria and had no previous experience with the Nasometer. The nasometric assessment procedures presented in Appendix 2 were administered in 2 different sessions (day 1 and day 2). The second session took place one week after the first day's session. Each day the same protocol was administered twice, the second time a few minutes after the first administration (day 1 – time 1 and time 2; day 2 – time 1 and time 2).

Table 2. Intra-session and Inter-session Reliability.

Intra-session Reliability					
	N	**Mean**	**Standard Deviation**	**t-test**	**Correlation coefficient**
Day 1_Time 1	15	24.238	5.215	Pair 1* t_{14} =-1.855; *p* = .085	r_{xy} = .880; *p* = .01
Day 1_Time 2	15	25.424	4.528		
Day 2_Time 1	15	24.108	3.565	Pair 2* t_{14} =-.299; *p* = .770	r_{xy} = .856; *p* = .01
Day 2_Time 2	15	24.252	2.737		
Inter-session Reliability					
	N	**Mean**	**Standard Deviation**	**t-test**	**Correlation coefficient**
Day 1	15	24.831	4.724	Pair 3* t_{14} =-.758; *p* = .461	r_{xy} = .714; *p* = .01
Day 2	15	24.180	3.038		

* Pair 1 = Day 1_Time1 – Day 1_Time 2; Pair 2 = Day 2_Time 1 – Day 2_Time 2; Pair 3 = Day 1 – Day 2.

As shown in Table 2, no significant differences were obtained in the intra-session comparisons (*p* = .085; *p* = .770). Also, no significant differences are obtained when comparing the results obtained inter-session *(p* = .461). Intrasession and intersession correlations are high (.880, .856 and .714, respectively) and statistically significant (*p* = .01).

Effect of age group on nasalance.

Table 3 shows the nasalance scores for vowels and syllables by age. As in the original English version of the SNAP-R (Kummer, 2005), both means, and standard deviations have been rounded in Table 3 to facilitate comparisons of both normotypic and nasalance-impaired subjects. Following previous work (Kummer, 2005; Ünal-Logacev et al., 2020), the mean plus two standard deviations were considered as the threshold of normality.

In all age groups, the highest mean score corresponded to the vowel /i/ and the lowest mean score for the vowels /a/ or /o/, which were 20 percentage points lower than the /i/. In all cases, at 4 years of age, there was a reduction of nasalance for all vowels and at 5 years of age, it increased again, even above the mean score of those at 3 years of age.

Table 3. Nasalance means and standard deviations for sounds and syllables by age.

Sounds & Syllables	Mean (SD)			Threshold		
	3 years	4 years	5 years	3 years	4 years	5 years
/a/	16 (6)	14 (5)	19 (11)	28	24	41
/e/	19 (6)	16 (7)	23 (8)	31	30	41
/i/	26 (7)	23 (9)	33 (10)	40	41	53
/o/	16 (6)	13 (6)	18 (7)	28	25	32
/u/	20 (9)	19 (10)	22 (9)	38	39	40
/pa/	16 (4)	15 (4)	20 (5)	24	24	30
/pi/	26 (7)	24 (6)	32 (7)	40	36	46
/ta/	17 (3)	14 (4)	20 (5)	23	22	31
/ti/	26 (7)	24 (6)	33 (8)	40	35	49
/ka/	18 (6)	14 (4)	20 (5)	30	22	31
/ki/	26 (5)	24 (7)	35 (9)	36	38	53
/sa/	16 (3)	14 (4)	19 (5)	22	21	30
/si/	26 (8)	23 (8)	31 (9)	42	38	49
/ba/	18 (4)	18 (7)	27 (7)	26	31	41
/bi/	28 (7)	26 (8)	35 (9)	41	42	52
/ma/	60 (5)	50 (10)	61 (8)	70	70	77
/mi/	66 (7)	68 (10)	78 (7)	80	88	92
/na/	53 (7)	53 (9)	65 (7)	67	71	79
/ni/	70 (8)	71 (7)	79 (10)	86	85	99
/ña/	68 (8)	57 (9)	68 (8)	74	75	84
/ñi/	72 (8)	72 (9)	81 (7)	88	90	95

As with the vowels, the syllables with the highest nasalance were those with the vowel /i/, as opposed to those with the vowel /a/. As was noted with vowels, there was a reduction of nasalance at 4 years and an increase at 5 years, above that at 3 years of age. As expected, syllables with nasal consonants (/m/, /n/ and /ŋ/) had the highest nasalance at all ages and were highest when paired with the vowel /i/. Although the object of study of this work is focused on the study of resonance alteration by hypernasality and VPI, we took measurements of nasal syllables to determine values of hyponasality or mixed resonance profiles.

Regarding the dispersion measures, no major differences were observed according to age. In most cases, greater dispersion was observed at 5 years of age than at 3 years of age. In some cases, a greater dispersion was also observed at 5 years of age than at 4 years of age, but sometimes the opposite tendency was observed, as in most of the syllables with nasals.

Tables 3 and 4 also present the threshold of normality for each age. To obtain the threshold, the "rule of thumb" in statistics (mean score + 2 standard deviations) has been used (Kummer, 2005). In a normal distribution, values within the interval of the mean plus two standard deviations comprise 95 % of the cases.

Table 4 shows the nasalance scores for phrases by age.

Table 4. Nasalance means and standard deviations for phrases by age.

Phrases	Mean (SD)			Threshold		
	3 years	4 years	5 years	3 years	4 years	5 years
Phrase /p/[1]	23 (6)	21 (5)	26 (5)	36	30	37
Phrase /b/[2]	24 (5)	23 (8)	28 (7)	35	38	42
Phrase /k/[3]	19 (3)	17 (4)	23 (7)	25	26	37
Phrase /s/[4]	20 (5)	17 (5)	22 (5)	30	27	32

1. Phrase /p/ = /pepe pide pipas/ (/pepe asks for pipes/).
2. Phrase /b/ = /bobi bebe bibe/ (/bobi drink bottle/).
3. Phrase /k/ = /karlos koge kikos/ (/Karlos takes kikos (toasted maize)/).
4. Phrase /s/ = /susi sale sola/ (/susi goes out alone/).

The same pattern of reduction of nasalance at 4 years of age and then an increase in the 5-year-old group, above the 3-year-old group, was again observed. Similar patterns were observed for standard deviations as in Table 3. In some cases, a larger dispersion was observed for 5-year-olds than for 3 or 4-year-olds and in some cases, there was little variability by age.

Significance of differences by age

Vowels

Table 5 shows significant differences in all vowels except the /u/ vowel.

Table 5. ONEWAY ANOVA tests vowels by age.

Vowels	ONEWAY ANOVA	p
/a/	$F_{(2,125)} = 4.886$	.009
/e/	$F_{(2,125)} = 9.121$	.000
/i/	$F_{(2,125)} = 14.362$	.000
/o/	$F_{(2,125)} = 5.061$	.008
/u/	$F_{(2,124)} = 1.813$	.167

To determine if there were significant differences when comparing each age group with all other age groups, post hoc analyses were carried out. For equal variances, according to Levene's test, the HSD Tukey statistic was used for the post hoc analysis, and when no equal variances were assumed, the Tamhane test was used. The following results were observed:

With the exception of the vowel /u/, statistically significant differences were observed when comparing the results obtained in 5-year-old children with 4-year-old children (/a/, $p = .006$; /e/, $p = .000$; /i/, $p = .000$; /o/, $p = .006$). For the vowel /i/ statistically significant differences were also observed when comparing the results obtained in 5-year-old children with 3-year-old children (/i/, $p = .001$).

Syllables

Table 6 shows statistically significant differences by age for all syllables.

Table 6. ONEWAY ANOVA syllables by age.

Syllables	ONEWAY ANOVA	p
/pa/	$F_{(2,126)} = 14.595$	.000
/pi/	$F_{(2,126)} = 15.373$	.000
/ta/	$F_{(2,126)} = 22.133$	.000
/ti/	$F_{(2,126)} = 23.015$	.000
/ka/	$F_{(2,126)} = 14.683$	.000
/ki/	$F_{(2,126)} = 26.484$	.000
/sa/	$F_{(2,124)} = 20.109$	.000
/si/	$F_{(2,124)} = 12.568$	.000
/ba/	$F_{(2,115)} = 28.526$	.000
/bi/	$F_{(2,115)} = 14.172$	.000
/ma/	$F_{(2,115)} = 22.969$	.000
/mi/	$F_{(2,115)} = 25.911$	.000
/na/	$F_{(2,115)} = 31.853$	.000
/ni/	$F_{(2,115)} = 12.672$	.000
/ña/	$F_{(2,115)} = 23.608$	.000
/ñi/	$F_{(2,115)} = 16.620$	.000

Post hoc analyses were done to determine if there were significant differences in age.

For all syllables, statistically significant differences were observed when comparing the results obtained in 5-year-olds with 4-year-olds and when comparing 5-year-olds with 3-year-olds.

For the syllables /ta/ and /ka/, statistically significant differences were also observed when comparing the results obtained in 3-year-olds with those obtained in 4-year-olds (/ta/, $p = .013$; /ka/, $p = .012$).

Phrases

Table 7 shows statistically significant differences by age for all sentences. The results observed in the post hoc analyses showed no significant differences when comparing the results obtained by the 3-year-olds with those obtained by the 4-year-olds. Significant differences are observed for all sentences when comparing the results obtained by 5-year olds with those obtained by 3 or 4-year-olds.

Table 7. ONEWAY ANOVA phrases by age.

PHRASES	ONEWAY ANOVA	p
Phrase /p/	$F_{(2,124)} = 11.683$	.000
Phrase /b/	$F_{(2,123)} = 5.985$	.003
Phrase /k/	$F_{(2,125)} = 16.287$	.000
Phrase /s/	$F_{(2,124)} = 32.313$	.000

Effect of gender on nasalance.

As can be seen in Table 8, higher means were obtained for females than for males for all vowels, except for /e/ and /i/, where higher scores were obtained for males for all vowels, except for /e/ and /i/, where higher scores were obtained for males. In most cases, the differences in means according to gender were not statistically significant, except for the vowel /u/ (*p* = .024) and for sentences with /p/ (*p* = .028) and sentences with /b/ (*p* = .020).

Table 8. Descriptive statistics by gender

Stimuli	Male			Female		
	N	Mean	SD	N	Mean	SD
/a/	63	15.505	5.944	65	16.987	9.321
/e/	63	19.392	7.907	65	18.912	6.869
/i/	63	27.299	10.165	65	26.240	9.654
/o/	63	14.674	5.385	65	16.660	7.222
/u/	63	18.308	7.806	64	22.064	40.461
/pa/	63	16.279	4.786	66	17.932	5.017
/pi/	63	26.906	6.938	66	28.126	7.849
/ta/	63	16.533	5.079	66	17.292	4.766
/ti/	63	26.874	6.853	66	28.382	9.197
/ka/	63	17.004	5.360	66	17.700	5.959
/ki/	63	26.841	7.803	66	29.433	9.345
/sa/	62	15.999	4.909	65	16.318	4.752
/si/	62	25.664	8.131	65	27.358	9.633
/ba/	56	19.874	7.572	62	22.038	7.425
/bi/	56	28.645	9.216	62	30.339	8.571
/ma/	57	53.769	10.554	61	54.313	10.224
/mi/	57	70.018	10.423	61	71.612	8.481
/na/	57	56.643	9.642	61	57.918	9.384
/ni/	57	72.221	10.779	61	74.768	7.015
/ña/	57	59.736	9.969	61	62.601	9.754
/ñi/	57	74.242	8.952	61	75.473	9.040
Phrase /p/	62	22.038	6.546	65	24.301	6.340
Phrase /b/	60	23.553	5.780	66	26.428	7.648
Phrase /k/	62	19.065	4.244	66	20.384	6.546
Phrase /s/	62	25.381	6.491	64	26.279	7.466

Discussion

Using the SNAP Test R (Kummer, 2005) as a model, passages in Spanish were developed for Spanish-speaking children. Using the Rose Medical Nasometer, normative data were obtained for these passages from 130 children between the ages of 3 and 5. The internal consistency of the nasalance data allowed us to combine the speech data for each passage in order to establish norms for clinical use. This protocol can be used in the clinic to diagnose resonance disorders (hypernasality and hyponasality) in Spanish-speaking children with the Rose Medical Nasometer, which is widely used in Europe. Values above the 2 Standard Deviation threshold on oral passages should be considered pathological. As such, a further evaluation of velopharyngeal function through a craniofacial team would be appropriate. Values below the 2 Standard Deviation threshold on nasal syllables indicate hyponasality due to upper airway obstruction. This finding should be followed by a referral to an otolaryngologist for evaluation and treatment.

This study did not find significant differences between the genders, except for the stimuli listed above (/u/, /pa/ and /ba/), which is hard to explain. This research did find significant differences between the age groups. Of interest is that the 4-year-old children had significantly lower nasalance scores than the 3-year-old children and the 5-year-old children, which is also hard to explain. These results differ from the reported nasalance scores by Suarez-Brand, Florez Romero, and Espinosa-Reyes (2011) who observed differences with age. However, their study was conducted with nasal stimuli only, while this study included primarily oral stimuli of vowels, syllables and phrases. It is apparent that more research is needed to confirm or reject differences in nasalance between the genders and with age.

Finally, the vowel composition of the passage was noted to have a significant effect on the nasalance score. In particular, the vowel /i/ consistently resulted in higher nasalance than the rest of the vowels, and the vowel /a/ consistently resulted in low scores by comparison. This finding is consistent with other studies, regardless of language (Alfwaress et al., 2021; Blanton et al., 2015; Dow et al. 2009; Ha and Shine, 2017; Kummer, 2005; Kummer, 2020; Lewis and Watterson, 2000; Mandulak and Zajac, 2009; Nett-Cordero, 2008; Ünal-Logacev et al., 2020; Watterson, 2020). In the MacKay-Kummer SNAP-R study, it was found that syllables with the low vowel /a/ result in a nasalance score of about 7%, whereas syllables with the high vowel /i/ result in a nasalance score of about 17%, a full 10 percentage points higher (Kummer, 2005).

It is important to recognize that the nasometer collects data on resonance during production of speech sounds (regardless of language). Voiceless sounds have no resonance, so an isolated voiceless sound has a nasalance value of 0. The nasalance score is actually a measure of the resonance on vowels (and to a lesser degree voiced consonants). All vowels have some nasal resonance. This is due to partial transmission of acoustic energy through the velum and into the nasal cavity as the sound goes from the pharynx to the oral cavity (Gildersleeve-Neumann and Dalston, 2001). The amount of sound that is transmitted through the velum depends on the position of the tongue for each vowel (Dow et al., 2019; Kummer 2020). If the back of the tongue is elevated for a high vowel, the area between the tongue and velum becomes smaller. This increases the sound pressure level, causing more sound to go through the velum than when the tongue is low and there is a larger passageway. Therefore, a speech passage with many high vowels will have a higher nasalance score than a passage with low vowels.

As previously noted, it is commonly believed that normal nasalance is influenced by language, or even regional dialects, and therefore, there needs to be normative data for each language. That is only partly true. The nasalance score of a syllable, phrase, or sentence is determined by the vowel and consonant composition, not by the language spoken. Therefore, differences in normative data between different languages are probably due to the different vowel composition of the passage, rather than differences in the language itself.

So, do we need normative data for every language? Normative data for consonant-vowel syllables can be used, regardless of language as long as both the consonant and vowel are used in the child's native language. On the other hand, passages that are used should be in the child's native language so that they are easy for a child to understand and repeat (Perry et al., 2019). For example, there are speech stimuli that Spanish-speaking children in Spain would not understand (e.g., "Susi se zafa su saya" for a Spanish child this would translate into: "Susi se pone su camisón" (Susi puts on her nightgown), so they would not be able to understand its meaning. The same would happen with "Hago jugo de guayaba" (I make guava juice) which for a Spanish child "guayaba" (guava) would be an unfamiliar fruit. It should also be recognized that different passages in the same language would have slightly different normative values unless the vowel and consonant composition is the same. However, the differences may not be clinically significant. Regardless of language, dialect, or even passage, oral speech passages without the /i/ vowel should have an average nasalance value of less than 25%.

Limitations

Although Kay Pentax and now PENTAX Medical nasometers (Nasometer 6200 and Nasometer II, Model 6450) have been used for previous nasometry studies, PENTAX Medical nasometers were not available for purchase in Spain and other European countries at the time of this investigation. There are currently no studies comparing the nasalance results obtained on both nasometers so the data are not directly comparable, could be a limitation.

Although we included nasal syllables in the test, we did not include nasal phrases because our focus was on hypernasality and velopharyngeal insufficiency (VPI). The addition of nasal phrases will be considered in future works on the Spanish adaptation of the SNAP R Test.

Finally, a larger number of subjects may have resulted in more definitive results regarding differences in gender based on age.

Conclusions

The SNAP Test-R (Kummer, 2005) nasometry test was adapted to Spanish and norms were obtained for children between 3 and 5 years of age. These norms are valid for Rose Medical Solutions, Ltd. nasometer and have proved to be statistically reliable with high internal consistency. Our research showed statistically significant differences in nasalance by age group, although these differences may not be clinically significant. In general, no differences by gender were found. No differences were found by gender. Finally, this study confirms that high vowels result in higher nasalance values than low vowels. Because the vowel composition determines the nasalance score, the number of high vowels was taken into account in the stimuli used in our sentences.

References

Alfwaress, F., Kummer, A. W., & Weinrich, B. (2022). Nasalance Scores for Normal Speakers of American English Obtained by the Nasometer II Using the MacKay-Kummer SNAP-R Test. *The Cleft Palate-Craniofacial Journal, 59(*6),765-773. https://doi.org/10.1177/10556656211025406

Anderson, R. T. (1996). Nasometric Values for Normal Spanish-Speaking Females: A Preliminary Report. *The Cleft Palate-Craniofacial Journal, 33*(4),333–336. https://dx.doi.org/10.1597/1545-1569(1996)033<0333:nvfnss>2.3.co;2

Bettens, K., Wuyts, F. L., Jonckheere, L., Platbrood, S., & Van Lierde, K. (2017). Influence of gender and age on the nasality severity index 2.0 in Dutch-speaking Flemish children and adults. *Logopedics Phoniatrics Vocology, 42*(3),133–140. https://doi.org/10.1080/14015439.2016.1245781

Blanton, A., Watterson, T., & Lewis, K. (2015). The differential influence of vowels and palatal covering on nasalance scores. *Cleft Palate Craniofacial Journal, 52*(1),82-87. DOI: 10.1597/13-092

Bressmann, T. (2021) Nasometry. In Ball, M.J. (Ed.1). *Manual of Clinical Phonetics.* (pp. 322-338). Routledge.

Brunnegård, K., & van Doorn, J. (2009). Normative data on nasalance scores for Swedish as measured on the nasometer: influence of dialect, gender, and age. *Clinical linguistics & Phonetics, 23*(1), 58-69. https://doi.org/10.1080/02699200802491074

Cordero, K.N. (2008). *Assessment of Cleft Palate Articulation and Resonance in Familiar and Unfamiliar Languages: English, Spanish, and Hmong*. University of Minnesota.

Dalston, R. M., Neiman, G. S., & Gonzalez, G. (1993). Nasometric sensitivity and specificity: a cross-dialect and cross-culture study. *The Cleft Palate-Craniofacial Journal, 30*(3), 285-291. https://doi.org/10.1597/1545-1569_1993_030_0285_nsasac_2.3.co_2

D'haeseleer, E., Bettens, K., De Mets, S., De Moor, V., & Van Lierde, K. (2015). Normative data of nasalance scores for Flemish adults using the Nasometer II: influence of dialect and gender. *Folia Phoniatrica et Logopaedica, 67*(1),42-48. https://doi.org/10.1159/000374110

Dow, M., Gibson, M., & Johnson, C. (2019). Tongue height, vowel quality and nasality in Quebec French: an acoustic and articulatory study. *Journal of the Phonetic Society of Japan, 23*, 130-147. https://doi.org/10.24467/onseikenkyu.23.0_130

Fletcher, S.G. (1978). *Diagnosing Speech Disorders from Cleft Palate*. New York: Grune & Stratton.

Fletcher, S.G., Adams, L.E., & McCrutcheon, M.J. (1989). Cleft palate speech assessment through oral-nasal acoustic measures. In Bzoch KR. (Ed.). *Communicative Disorders Related to Cleft Lip and Palate*. (pp.246-257). Little-Brown.

Gildersleeve-Neumann, C. E., & Dalston, R. M. (2001). Nasalance scores in noncleft individuals: why not zero? *The Cleft Palate-Craniofacial Journal, 38*(2),106-111. https://doi.org/10.1597/1545-1569_2001_038_0106_nsiniw_2.0.co_2

Ha, S., & Cho, S. H. (2015). Nasalance scores for normal Korean-speaking adults and children: Effects of age, vowel context, and stimulus length*. International Journal of Pediatric Otorhinolaryngology, 79*(8),1235-1239. https://doi.org/10.1016/j.ijporl.2015.05.019

Inostroza-Allende, F., Palomares-Aguilera, M., Jara, M. G., Gaponov, C. Q., Villarroel, C. G., & Pegoraro-Krook, M. I. (2022a). Normative nasalance scores in Chilean adults. *CoDAS, 34*(6), e20210152. https://doi.org/10.1590/2317-1782/20212021152

Inostroza-Allende, F., Palomares-Aguilera, M., Jara, M. G., Gaponov, C. Q., & Villarroel, C. G. (2022b). Valores de nasalancia para vocales, serie numérica y oraciones producidas por adultos hablantes de español chileno. *Revista de Logopedia, Foniatría y Audiología*, *42*(3),126-133. https://doi.org/10.1016/j.rlfa.2021.02.006

John, A., Sell, D., Sweeney, T., Harding-Bell, A., & Williams, A. (2006). The cleft audit protocol for speech—augmented: A validated and reliable measure for auditing cleft speech. *The Cleft Palate-Craniofacial Journal*, *43*(3),272-288. https://doi.org/10.1597/04-141.1

Karnell, M. P. (1995). Nasometric discrimination of hypernasality and turbulent nasal airflow. *The Cleft Palate-Craniofacial Journal*, *32*(2),145-148. https://doi.org/10.1597/1545-1569_1995_032_0145_ndohat_2.3.co_2

Kummer, A. W. (2005). The Mackay-Kummer Simplified Nasometric Assessment Procedures-Revised (SNAP-R). *In: PENTAX Medical Instruction manual for Nasometer II: Model 6450.* PENTAX Medical.

Kummer, A.W. (2020). Nasometry. In Kummer, A.W. *ed. Cleft Palate and craniofacial conditions: a complete guide to clinical management. 4^{th} ed.* Massachusetts. Jones & Bartlett Learning. (pp.367-398).

Henningsson, G., Kuehn, D. P., Sell, D., Sweeney, T., Trost-Cardamone, J. E., & Whitehill, T. L. (2008). Universal parameters for reporting speech outcomes in individuals with cleft palate. *The Cleft Palate-Craniofacial Journal, 45*(1),1-17. DOI: 10.1597/06-086.1

Lewis, K. E., Watterson, T., & Quint, T. (2000). The effect of vowels on nasalance scores. *The Cleft Palate-Craniofacial Journal, 37*(6),584-589. https://doi.org/10.1597/1545-1569_2000_037_0584_teovon_2.0.co_2

Mandulak, K. C., & Zajac, D. J. (2009). Effects of altered fundamental frequency on nasalance during vowel production by adult speakers at targeted sound pressure levels. *The Cleft Palate-Craniofacial Journal, 46*(1),39-46. DOI: 10.1597/07-120.1

Moreno-Sandoval, A.M., Toledano, D. T., Curto, N., & Torre, R. (2006). Inventario de frecuencias fonémicas y silábicas del castellano espontáneo y escrito. *IV jornadas en tecnología del habla.77-81.*

Nguyen, V. T., Lehes, L., Truong, T. T. H., Hoang, T. V. A., & Jagomägi, T. (2019). Normative nasalance scores for Vietnamese-speaking children. *Logopedics Phoniatrics Vocology, 44*(2),51-57. https://doi.org/10.1080/14015439.2017.1389985

Nichols, A. C. (1999). Nasalance Statistics for Two Mexican Populations. *The Cleft Palate-Craniofacial Journal, 36*(1),57–63. https://dx.doi.org/10.1597/1545-1569_1999_036_0057_nsftmp_2.3.co_2

Okalidou, A., Karathanasi, A., & Grigoraki, E. (2011). Nasalance norms in Greek adults. *Clinical Linguistics & Phonetics, 25*(8),671-688. https://doi.org/10.3109/02699206.2010.549993

Park, M., Baek, W. S., Lee, E., Koh, K. S., Kim, B. K., & Baek, R. (2014). Nasalance scores for normal Korean-speaking adults and children. *Journal of Plastic, Reconstructive & Aesthetic Surgery, 67(2)*, 173-177. https://doi.org/10.1016/j.bjps.2013.10.035

Pua, E., Holt, Y., Kollara, L., Rangarathnam, B., Fang, X., & Perry, J. L. (2019). Evaluating nasalance values among bilingual Mandarin–English speakers. *The Cleft Palate-Craniofacial Journal, 56*(4), 462-470. https://doi.org/10.1177/1055665618791942

Saber-Moghadam, R., Faham, M., Ghavami, F. S., & Ghayoumi-Anaraki, Z. (2019). Normative data on nasalance scores for Farsi speaking children: Influence of age, gender and phonetic context. *International Journal of Pediatric Otorhinolaryngology, 127*, 109680. https://doi.org/10.1016/j.ijporl.2019.109680

Santos-Terron, M. J., Gonzalez-Landa, G., & Sanchez-Ruiz, I. (1991). Normal patterns of nasalance in children who speak Castilian. *Revista Española Foniatrica, 4*,71-5.

Seaver, E. J., Dalston, R. M., Leeper, H. A., & Adams, L. E. (1991). A study of nasometric values for normal nasal resonance. *Journal of Speech, Language, and Hearing Research, 34*(4),715-721. https://doi.org/10.1044/jshr.3404.715

Suárez-Brand, J., Flórez-Romero, R., & Espinosa-Reyes, P. (2011). Empleo del nasómetro 6200 en la evaluación fonoaudiológica de la nasalidad en infantes colombianos. *Revista de la Facultad de Medicina*, *59*(3), 245-254.

Ünal–Logacev, Ö., Kummer, A. W., Çetin, C., & Topbaş, S. (2020). Nasometric evaluation of resonance disorders: A norm study In Turkish*. International Journal of Pediatric Otorhinolaryngology, 131*, 109888. https://doi.org/10.1016/j.ijporl.2020.109888

Tachimura, T., Mori, C., Hirata, S. I., & Wada, T. (2000). Nasalance score variation in normal adult Japanese speakers of Mid-West Japanese dialect. *The Cleft Palate-Craniofacial Journal, 37*(5),463-467. https://doi.org/10.1597/1545-1569_2000_037_0463_nsvina_2.0.co_2

Van Doorn, J., & Purcell, A. (1998). Nasalance levels in the speech of normal Australian children. *The Cleft Palate-Craniofacial Journal, 35*(4),287-292. https://doi.org/10.1597/1545-1569_1998_035_0287_nlitso_2.3.

Van Lierde, K. M., Wuyts, F. L., De Bodt, M., & Van Cauwenberge, P. (2001). Nasometric values for normal nasal resonance in the speech of young Flemish adults. *The Cleft Palate-Craniofacial Journal, 38*(2),112-118. https://doi.org/10.1597/1545-1569_2001_038_0112_nvfnnr_2.0.co_2

Watterson, T., Hinton, J., & McFarlane, S. (1996). Novel stimuli for obtaining nasalance measures from young children. *The Cleft Palate-Craniofacial Journal, 33*(1),67-73. https://doi.org/10.1597/1545-1569_1996_033_0067_nsfonm_2.3.co_2

Watterson, T. (2020). The use of the nasometer and interpretation of nasalance scores. *Perspectives of the ASHA Special Interest Groups, 5*(1),155-163. https://doi.org/10.1044/2019_PERSP-19-00029

Appendix 1

Specification

Microphones

Left channel	Nasal speech
Right channel	Oral speech
Type	Electret condenser
Directionality	Uni-directional
Frequency response (band-pass filter disabled)	100 – 15,000Hz
Frequency response (band-pass filter enabled)	350 - 650Hz
Sensitivity	-40dB at 1kHz (0dB = 1V/Pa)
Output impedance	2.2k ohm
Power supply	1.5V – 10V

USB audio adaptor

Microphone input	2 channel stereo
Sample rates	48kHz, 44.1kHz. 16kHz and 8kHz
Resolution	16bit
THD	-90dB
Frequency response	20 – 20,000 Hz
Input range	0 – 1.25 Vrms
Dynamic range	96dB
Record gain range	-6 - 33dB
Supply voltage	4.5 - 5.5 VDC via USB
Total power consumption	33 mA

System requirements

Supported operating systems	Windows 10, 8, 7 or Vista
Supported computers	Desktop, laptop, tablet
CPU	Minimum 1 GHz Intel® Pentium® or equivalent
Memory	Minimum 1 GB of RAM
Storage	100 MB of free hard disk space
Connectivity	USB 1.0, 2.0, 3.0
Power	USB bus powered

Appendix 2

(In brackets English version)

Propuesta de procedimientos de evaluación nasométrica para hablantes de castellano, con edades comprendidas entre los 3 y 5 años (Peris y Rosell; 2021). Basados en MacKay-Kummer SNAP Test- R (2005).

(Proposal of nasometric assessment procedures for Spanish speakers aged 3 to 5 years (Peris and Rosell; 2021) (English version). Based on MacKay-Kummer SNAP Test- R (2005)).

Nombre (Name): Fecha (Date):	
Edad (Age):	Examinador (Examiner):

Repetición sílabas / Subtest Sonidos prolongados
(Syllable repetition / Subtest Prolonged sounds)
Instrucciones: (Repita o prolongue hasta que la pantalla esté llena).
(Instructions: (Repeat or prolong until the screen is full)).

Oral + /a/ Sílabas (Oral + /a/ syllables)	**Media (Mean)**	**D.T. (S.D.)**	**Puntuación (Límite: ≥) (Score (Threshold: ≥))**
pa, pa, pa...			
ta, ta, ta...			
ka, ka, ka...			
sa, sa, sa...			

Oral + /i/ Sílabas (Oral + /i/ syllables)	**Media (Mean)**	**D.T. (S.D.)**	**Puntuación (Límite: ≥) (Score (Threshold: ≥))**
pi, pi, pi...			
ti, ti, ti...			
ki, ki, ki...			
si, si, si...			

Nasal+ /a/ Sílabas (Nasal+ /a/ Syllables)	**Media (Mean)**	**D.T. (S.D.)**	**Puntuación (Límite: ≥) (Score (Threshold: ≥))**
ma, ma, ma...			
na, na, na...			

Nasal+ /i/ Sílabas (Nasal+ /i/ Syllables)	***Media (Mean)***	***D.T. (S.D.)***	***Puntuación (Límite: ≥) (Score (Threshold: ≥))***
mi, mi, mi...			
ni, ni, ni...			

Sonidos prolongados (Prolonged sounds)	**Media (Mean)**	**D.T. (S.D.)**	**Puntuación (Límite: +/-) (Score (Threshold: ≥))**
Prolongada /a/ (Prolonged /a/)			
Prolongada /i/ (Prolonged /i/)			
Prolongada /u/ (Prolonged /u/)			

Subtest con indicaciones de imagen.
(Subtest with image prompts).
Instrucciones: Producir una frase por imagen. Repetir 2 veces.
(Instructions: Produce one sentence per picture. Repeat 2 times).

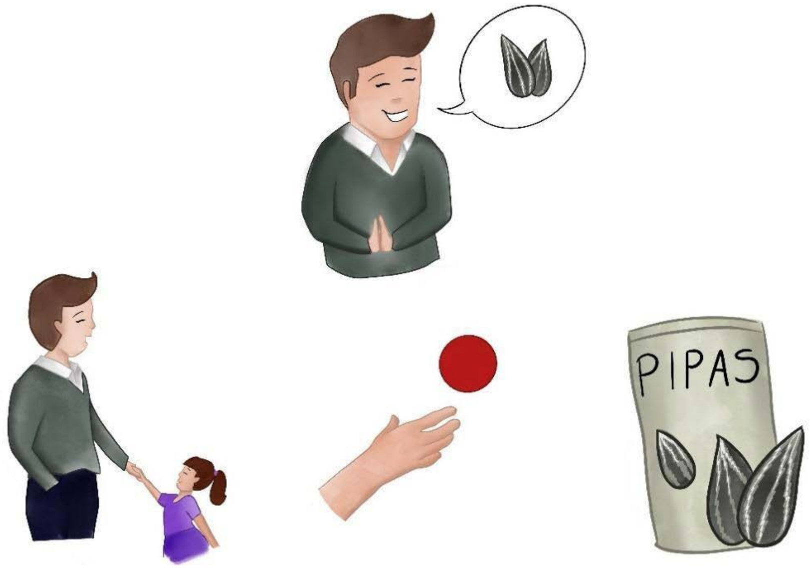
Frases orales* (Oral phrases)	***Media (Mean)***	***D.T. (S.D.)***	**Puntuación (Limite: ≥)**
Bilabial oclusivas (Bilabial plosives)			
Lingual-Alveolar oclusivas (Lingual-Alveolar plosives)			
Velares oclusivas (Velar plosives)			
Fricativas sibilantes (Sibilant fricatives)			

*Phrases used:

1. Phrase /p/ = /pepe pide pipas/ (/pepe asks for pipes/).
2. Phrase /b/ = /bobi bebe bibe/ (/bobi drink bottle/).
3. Phrase /k/ = /karlos koge kikos/ (/Karlos takes kikos (toasted maize)/).
4. Phrase /s/ = /susi sale sola/ (/susi goes out alone/).

Notas:
(Notes):

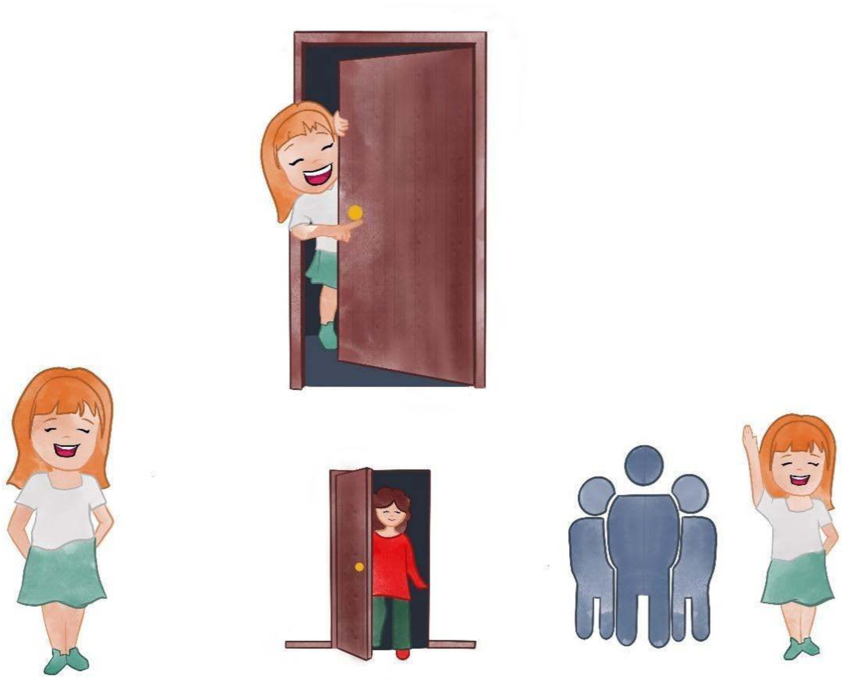
Imágenes para elicitación de frases
(Images for sentence elicitation)



Pepe pide pipas
(Pepe asks for pipes)

Bobi bebe bibe
(Bobi drink a bottle)

Carlos coge Kikos
(Karlos takes kikos (toasted maize))



Susi sale sola
(Susi goes out alone)