UNIVERSITY OF CINCINNATI

May 28, 2003

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hereby submit this as part of the requirements for the degree of:

Master of Arts

in Speech-Language Pathology

It is entitled The Nasometer I versus the Nasometer II: A comparison of normative data using the MacKay-Kummer SNAP Test

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The Nasometer I versus the Nasometer II: A comparison of normative data using the MacKay-Kummer SNAP Test

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UMI Number: EP26325

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Abstract

Since its introduction, the Nasometer I (Model 6200) has been used along with other methods in clinical diagnosis of individuals with velopharyngeal impairment. The McKay-Kummer SNAP test was developed to be included in the Nasometer software. Release of the Nasometer II (Model 6400) necessitated gathering new normative data. Use of the Nasometer II resulted in lower percent nasalance scores for some syllables (especially containing /a/), and phrases. Possible reasons for these findings are discussed.

Introduction

The Nasometer has been in the forefront as a valuable diagnostic as well as therapeutic tool for abnormal resonance for more than two decades. Since its introduction in 1987 by Kay Elemetrics, the Nasometer Model 6200 has been widely documented for its utility on individuals with velopharyngeal insufficiency/inadequacy/impairment (VPI) or velopharyngeal dysfunction (VPD). The Nasometer was preferred over and/or used along with the methods then available to clinicians for best clinical practices (Seaver, Dalston, Leeper & Adams, 1991). The Nasometer's popularity is due to its ease of use, non-invasiveness, simplicity and validity (Kummer, 2001). After the recent introduction of a newer version of the Nasometer (Model 6400), Model 6200 was referred to as the Nasometer I and the more recent version as the Nasometer II.

Nasometer

The Nasometer is a second generation to earlier instrument/s designed to measure nasal and oral acoustic energy, TONAR and TONAR II, by Fletcher, Adams and McCutcheon (Fletcher, 1970; Fletcher& Bishop, 1970). It was first introduced by Kay Elemetrics in 1987 (Dalston, Warren & Dalston, 1991a, 1991c; Seaver et al., 1991; Dalston, 1992; Kummer, 2001).

The Nasometer is a PC-based, hardware/software system that uses an analog circuitry for measuring the relative amount of acoustic energy emitted through the nose when an individual speaks (Dalston et al., 1991a, 1991c; LaBlance, Steckol & Cooper, 1991; Dalston, 1992; Kummer, 2001). In short, it provides objective data regarding the acoustic results of velopharyngeal function that can then be compared to normative data for analysis (Kummer, 2001). In addition, it can also be used for real-time visual cueing during treatment for nasality disorders as well as for comparison between pre-and posttreatment data. The Nasometer provides additional information that can supplement data from perceptual and direct instrumental evaluations.

The Nasometer consists of an input device, the Nasometer hardware box, and an IBM-compatible or Apple computer for the software (LaBlance et al., 1991; Dalston, 1992; Kummer, 2001). The input device is worn by the subject as a form of a headset with a horizontal steel plate (baffle) that separates acoustic output energy from the oral and nasal cavities. The plate is designed to fit comfortably around the upper lip and the cheeks and is fitted on the individual's face with the help of Velcro headbands. Directional microphones mounted on both sides of the plate pick up acoustic energy through the nasal and oral cavities, respectively. The headgear is connected to the Nasometer box, which in turn is connected to the computer. The oral – nasal ratio is calculated and then converted into a percentage value that is described as the "nasalance score" (Dalston et al., 1991a, 1991c; LaBlance et al., 1991; Dalston, 1992; Kummer, 2001).

LaBlance et al. (1991) described the Nasometer as one of the non-invasive advances in the field of electronic technology for the measurement of vocal acoustics. They further mentioned that the "nasalance has been found to correlate with the perceived nasality" (LaBlance et al., 1991, pp. 679).

The new version of the Nasometer, Model 6400 Nasometer II, is the latest advent by Kay Elemetrics in the assessment of nasality disorders. Nasometer II essentially is similar to the Nasometer I, although it is an all-digital system. With comparison to Nasometer I, Nasometer II offers audio recording and playback, revamped software, and flexible choice of hardware settings for operation.

Diverse use of Nasometry

There have been many studies to document comparisons between listener judgment and Nasometry in patients with cleft VPD or VPI, with benefits and drawbacks of both. Dalston et al. (1991a) found that individuals with nasal emission got high nasalance scores compared to those without, even if their speech was not perceived as being hyper- or hyponasal by a trained listener. The authors attributed this to the Nasometer being sensitive to any form of nasal emission and, consequently, giving high nasalance scores. They concluded that Nasometer measurements could be used with "considerable" confidence to verify clinical impressions. These data are consistent with the studies by Dalston and Seaver (1990), Dalston et al. (1991b, 1991c), Hardin, van Demark, Morris and Payne (1992) and Watterson, Wright and McFarlane (1993). However, the above data are not without opposing evidence. Studies by Nellis, Neiman and Lehman (1992), Watterson, Lewis and Deutsch (1998) and Nandurkar (2002) are among some, where significant relationships were not found between the listener judgments of perceived nasality and nasalance scores. Most of the studies that have used the Nasometer conclude that Nasometry be used in conjunction with clinical judgment of nasality to supplement the latter, but not to substitute it (Seaver et al., 1991; Vallino-Napoli & Montgomery, 1997).

In addition to the use with patients having VPI, Nasometry has been documented for diverse use such as with surgery. They include, assisting surgical procedures associated with VPD or VPI , such as posterior wall augmentation (Gray, Pinborough-Zimmerman & Catten, 1999), retropharyngeal autologous fat transplantation surgery to correct short palates (Dejonskere & van Wijngaarden, 2001) and after-pharyngeal flap or after-adenoidectomy surgeries (Kummer, 2001). Williams et al. (1998) conducted a study to find out the velopharyngeal function after Frolova primary palatoplasty technique, and Nasometry was one the determining measures.

Nasometry is also known to be useful with the hearing impaired population (Fletcher & Daly, 1976; Fletcher & Higgins, 1980; Tatchell, Stewart & Lapine, 1991; Lapine, Stewart & Tatchell, 1991). These studies suggest that the nasalance values obtained may be useful as a biofeedback method for training individuals with hearing impairments to balance nasalance.

The use of Nasometry in voice disorders is mainly concerned with providing an important assessment tool, because voice is multidimensional and may include resonance imbalance (Gray, Smith & Schneider, 1996; Dejonskere, 2000).

Nasometry in diverse cultures/regions/dialects/languages

Literature reveals a large number of studies of the application of Nasometry to different dialects of English and also to different languages. Among them, Seaver et al. (1991) gathered Nasometric values for normal nasal resonance for adults speaking Mid-Western, Mid-Atlantic, Southern and Ontario dialects of English. They found that Mid-Atlantic speakers had higher nasalance scores compared to the rest of the study group. The authors suggested the necessity to establish regional norms for patients with nasal disorders residing in different areas that speak significantly different dialects. They also pointed out the need to gather data for children. Likewise, many researchers have reported similar differences to exist or not among different cultural/regional and dialectal groups of English speakers (Leeper, Rochet & MacKay, 1992; Dalston, Neiman & Gonzalez-Landa, 1993; Kvanaugh, Fee, Kalinowski, Doyle & Leeper, 1994; Mayo, Floyd, Warren, Dalston & Mayo, 1996; van Doorn & Purcell, 1998).

Nasometry has not only been applied to English-speaking populations, but also to populations speaking other languages such as German (Heppt, Westrich, Strate and Mohring, 1991), Spanish (Anderson, 1996), Japanese (Tachimura, Mori, Hirata & Wada, 2000), Flemish (Van Lierde, Wuyts, De Bodt & Van Cauwenberge, 2001), and Marathi, an Indian language (Nandurkar, 2002).

Factors affecting Nasometric measurements

A multitude of factors are known to affect nasalance values. Therefore, it is important to give due consideration to these factors while testing. Among the most salient are the vowel content of the speech sample (Lewis, Watterson & Quint, 2000), stimulus length (Watterson, Lewis & Foley-Homan, 1999), nasal obstruction (Williams, Eccles & Hutchings, 1990; Dalston et al., 1991b, c; Hong, Kwon & Jung, 1997; Neiman, Lopponen, Mirja, Aulikki & Uolevi, 2000), and the presence of prosthetic devices (Pinborough-Zimmerman, Canady, Yamashiro & Morales, 1998). Age and gender have been documented as possible factors affecting Nasometer measurements, but with contradictory evidence (Seaver et al., 1991; Leeper et al., 1992; Litzaw & Dalston, 1992; Kavanaugh et al., 1994; Tachimura et al., 2000; Gildersleeve-Neumann & Dalston, 2001; Van Lierde et al., 2001; Whitehill, 2001). The equipment used during Nasometry, such as the microphone, has also been documented to affect the measurement values (Zajac, Lutz & Mayo, 1996). Hence, they emphasized the importance of determining the response characteristics of the microphones used with Nasometers and the need to be cautious when interpreting such variations.

Simplified Nasometric Assessment Procedures: The MacKay-Kummer SNAP test

When the Nasometer I was first marketed, the only available standardized test passages (e.g. the Zoo or Rainbow passages) were not fully satisfactory in assessing nasality. Problems included the sentences being long, awkward, and syntactically/semantically complex. The sentences could not be used with very young children. It was difficult to isolate phoneme-specific nasal emission because the sentences included a mixture of phonemes (Dalston & Seaver, 1992; Kummer, 2001). In order to address these problems, MacKay and Kummer (1994) developed a comprehensive assessment tool that would be most efficient in determining nasalance.

The Simplified Nasometric Assessment Procedure (SNAP) test has many advantages over the standardized passages. First, it can be used to test not only very young children, but also those who are non-literate and/or not cooperative for testing. Further, it consists of semantically, pragmatically and lexically simple test materials. Because of the ability to isolate certain phonemes/types of phonemes during the syllable subtest, the assessment of phoneme-specific nasal emission is possible. Finally, because the stimulus materials contain a wide variety of phonetic contexts, it may be useful in identifying patients with phonological/articulatory problems (MacKay & Kummer, 1994; Kummer, 2001).

The three subtests of the SNAP test are, (1) Syllable Repetition that contains 14 syllable-repetition passages, (2) Picture-Cued that consists of simple and repeated carrier phrases with illustrable concrete words focusing on bilabials, alveolars, velars, sibilants and nasals, and, (3) Reading that is designed for readers, and consists of two short passages (MacKay & Kummer, 1994; Kummer, 2001). Since its development, Kay Elemetrics Corporation has incorporated it into the Nasometer software (Kay Elemetrics, 1994).

Purpose of the Present Investigation

The SNAP test was normed on about 250 children ranging from 3 to 9 years (MacKay & Kummer, 1994). The advent of the new Model 6400 Nasometer II necessitates the development of new norms for the SNAP test. The purpose of the present investigation is to obtain normative data for the SNAP test using the Model 6400 Nasometer II for children, aged 3-5 years.

Methods

Subjects

Fourteen standard English-speaking male and female children between the ages 3 and 5 participated in the study. All of the subjects had English as their primary language and were born in the United States. They were recruited from outpatient clinics at Cincinnati Children's Hospital Medical Center (CCHMC), and from other nearby facilities, such as schools, preschools, and daycares. Children with a history of speech and/or hearing problems, as per parents' report, were excluded from the study group.

Equipment

The Kay Elemetrics Model 6400 Nasometer II and the accessory equipment (headset, calibrator) were used for data collection. For the purpose of this study, a portable lunchbox version of the Nasometer II was utilized. Prior to starting data collection of each session, the Nasometer was calibrated according to the specifications in the Nasometer manual. In addition, the equipment was positioned in a place that allowed the most comfortable testing situation for the subjects.

Test Stimuli

Test stimuli were the Syllable Repetition subtest and the Picture-Cued Subtest of the SNAP test by MacKay and Kummer (1994). For the purpose of this investigation, five additional phonemes that were not included in the Nasometer software version of the SNAP were included in the Syllable-Repetition subtest. Those were, sustained /a/, /i/, /u/, /m/ and /s/. Because the age group of this investigation was 3-5 years, only the Syllable-Repetition subtest and the Picture-Cued subtest were utilized to obtain normative data.

Procedures

The co-investigators received special training for the use of the PC-based Nasometer II and related equipment by a Kay Elemetrics representative, and were responsible for collecting data.

Permission to recruit children from CCHMC outpatient clinics was obtained through direct contact of clinic directors and/or managers by the principal investigator. Permission from the principals/management of preschools, schools and daycares was attained through a letter explaining the study.

Upon the receipt of permission from the management of CCHMC and other settings, the parents were contacted and given: (a) a permission letter to the parent(s) explaining the study and its procedures, (b) consent form to obtain their consent for the participation of their children in the study, and, (c) a parent questionnaire (Appendix A) that required information about their child's speech and hearing. Those children with no history of speech and/or hearing impairments were selected to participate in the study.

Test sites differed as follows. The subjects from the CCHMC outpatient clinics were taken to the speech pathology department at CCHMC where the testing took place. The subjects from a preschool/school/daycare setting were taken to a quiet room.

Testing process and data collection

Subjects were seated in a comfortable chair. All children underwent a brief speech screening that was conducted by the co-investigator(s) to rule out problems unreported by the parents. This was done simply by asking them to count to twenty prior to testing. Any child who exhibited a voice or a resonance problem or an articulation disorder that was not age-appropriate was eliminated from testing.

Just prior to testing, each child was given instructions as to the resonance assessment procedure in simple language such as following; "We are going to do a game. Look at this (head set). You are going to talk to the computer's ears using this. This is like a pilot's hat. And see this part? It is going to hug your face like this (demonstrate if necessary). When you talk, the computer is going to make pictures. We can practice by saying some silly things. Ready?" (Kummer, 2001).

After familiarizing the subject with the procedure, the headset was fitted properly and the child was given a few practice syllables and sentences from the test. If the child refused to wear the headset despite the prior familiarizations and instructions, the option of the baffle plate held tightly against the upper lip of the child was used. However, these deviations from the standard method of testing were documented and only occurred for 4 subjects. The Syllable-Repetition and the Picture-Cued subtests were conducted and the results were plotted on the score sheet. The Syllable Repetition subtest consisted of five new stimuli: sustained /a/, /i/, /u/, /s/, /m/. Administration of the SNAP test was in accordance with the testing guidelines provided by MacKay and Kummer (1994). The order of giving the two subtests was random for each subject.

At first, responses to stimuli were saved into the memory of the computer. However this process was very lengthy and almost doubled the time needed to test each child. Therefore, score sheets with hand-written scores served as the sole method of data recording.

Data analysis

Data analysis using basic statistical measures of mean and standard deviation were performed. Tables were used to display the appropriate descriptive statistics for each stimulus. Differences between the means gathered in the present investigation and the mean from the Nasometer I norm were calculated for all subtests where the norm was available. Confidence intervals (95%) were created to determine significant differences between the previous and present means. Significant differences between the current data and previous norm were indicated if the confidence interval did not include zero. Analysis of covariance was calculated on the means from each subtest to determine if there were any significant differences due to age or sex. Where significant effects were observed, a regression was calculated to show the direction and extent. Programs developed by SPSS (Chicago, IL) were used.

Results

The focus of the present investigation was on children between the ages of three and five. However, for purpose of analysis, the data were combined with those from children ages six through nine.

Syllable Repetition

The mean percent nasalance and standard deviations for the syllable repetition subtests are contained in Tables 1a, b and c. The data are presented by age and sex, and for the total group (males and females). The norms from the manual of the Nasometer I are also presented

Plosives. Percent nasalance data for the syllables containing plosive consonants are presented in Table 1a. Significant differences between the Nasometer I mean and the observed means were found for the syllables /pa/ (CI=0.995 to 2.365), /ta/ (CI= 1.893 to 3.038), and /ka/ (CI= 1.889 to 2.882). Comparison of the observed means for the total group (all ages and sexes combined) with the previous Nasometer means showed that the current means were lower than the previous norm for each of these variables. Other means were not significantly different from the previous norm.

A significant age effect was found for the syllables /pa/ [F(2,59)=13.55, p=.0005], /ta/ [F(2,59)=13.62, p=.0005], and /ka/ [F(2,59)=5.5, p=.022]. No other significant age effects were found (p>.05). A regression equation resulted in a significant negative effect for each of the variables where significant age effects were shown, indicating that a one-year change in age lowers the mean score by .74, .62, and .37 for /pa/, /ta/, and /ka/, respectively.

There were no significant differences found when the means for males and females were compared (p>.05).

Fricatives. Percent nasalance data for the syllables containing plosive consonants are presented in Table 1a. Significant differences between the Nasometer I mean and the observed means were found for the syllables /sa/ (CI=0.697 to 1.907) and /sha/ (CI=0.968 to 2.155). Comparison of the observed means for the total group (all ages and sexes combined) with the previous Nasometer means showed that the current means were lower than the previous norm for each of these variables. Other means were not significantly different from the previous norm.

Significant age effect was found for syllables /sa/ [F(2,58)=5.23, p=.03] and /sha/ [F(2,58)=4.53, p=.04]. The regression equation resulted in a significant negative effect for each of the variables where significant age effects were shown, indicating that a one year change in age lowers the mean score by .45 for /sa/ and .41 for /sha/.

There were no significant differences found when the means for males and females were compared (p>.05).

Nasals. No significant age effects were found (p>.05). There were no significant differences found when the means for males and females were compared (p>.05). Similarly, no regression equations were significant. Note that standard deviations for nasals were higher than for syllables containing plosives and fricatives.

Sustained Vowels and Consonants

The mean percent nasalance and standard deviations for the sustained vowels and consonants subtests are contained in Table 2. The data are presented by age and sex, and for the total group (males and females). The sustained /s/ is not included because all values were zero. No norms from the Nasometer I are available because this subtest was not used previously.

Analysis of covariance found no significant age or sex effects for any of the sustained vowels or consonants ($p>.05$). Similarly, no regression equations were significant.

Picture Description

The mean percent nasalance and standard deviations for the words produced during the picture description subtest are contained in Table 3. The data are presented by age and sex, and for the total group (males and females). The norms from the manual of the Nasometer I are also presented.

Significant differences between the Nasometer I mean and the observed means were found for the bilabial sentences noted by *book* (CI=1.66 to 3.3), alveolar sentences noted by *turtle* (CI=0.89-2.9), and velar sentences noted by *cookie* (CI=1.17 to 2.99). Comparison of the observed means for the total group (all ages and sexes combined) with the previous Nasometer means showed that the current means were lower than the previous norm for each of these variables. Other means were not significantly different from the previous norm.

Analysis of covariance found no significant age or sex effects for any of the sentences ($p>.05$). Similarly, no regression equations were significant.

Discussion

The purpose of the present investigation was to obtain nasometric values for speech stimuli in Standard English speakers between the ages 3-5 using the McKay-Kummer SNAP Test and the Nasometer II.

Comparison of the Nasometer I and II

Despite the similarities between Nasometer II and Nasometer I, the results obtained on the MacKay-Kummer SNAP suggested that there may be some differences between the two instruments. These differences occurred in both syllable and word contexts. In all cases, the norms from the Nasometer I were higher than those obtained by the Nasometer II. According to literature, these observed differences could be attributed to several factors.

First, it was recently made known to investigators that the Nasometer II requires an upgrade with the systems hardware that will improve the quality of data acquisition (Kunis, personal communication, May 2, 2003). The necessity of the upgrade may have contributed to the differences in the scores using the two instruments, and future data collected with the upgraded system may yield different results.

Second, it is interesting to note that all significant syllable differences between the previous norm and current mean occurred in the context of the /a/ vowel, but not the paired /i/. This was observed both in isolation and in syllable/word contexts. It could be attributed to the tongue height, oral cavity size, and shape differences between the productions of /a/ and /i/. The tongue position for the production of /i/ results in a smaller resonatory chamber in the oral cavity, while tongue position for /a/ results in a relatively larger resonatory chamber (Kummer, 2001). This results in higher oral output. Consequently, with this difference, nasalance (nasal/oral+nasal ratio) values will be higher for /i/ and lower for /a/. It is also known that high vowels such as /i/ have a higher velar height and a greater degree of closure compared to low vowels such as /a/ (Kummer, 2001). Transpalatal transmission of sound energy may also have influenced the observed ratios. Additionally, velopharyngeal closure pattern and extent also vary between individuals (Croft, Shprintzen & Rakoff, 1981), suggesting that the differences of velar height vary among individuals to a great extent. It is possible, therefore, for the data gathered using Nasometer II on the same stimuli to be different from data on Nasometer I, because the subject population used for the present investigation may not have been identical to the subject group used for the previous normative data gathering. The observed lower nasalance scores could also be attributed to possible better microphone response characteristics in the Nasometer II than in the previous version of the Nasometer. Finally, it may be questioned whether some of the children in the present study had some degree of resonance imbalance that contributed to the differences. However, no child in the present study was judged, perceptually, to be either hypernasal or hyponasal. It is possible that normal dialectical differences between children in the present investigation and those tested previously contributed to the differences in measured value during production of the syllables containing /a/.

Objective measures are important in the diagnosis of velopharyngeal impairment, as well as a means of measurable baseline data to be compared against with progress of any intervention. Because the current investigation found differences between norms of some of the speech stimuli in the McKay-Kummer SNAP on Nasometer II, it is vital that the respective norms are used for each instrument when using nasalance scores to supplement diagnosis of velopharyngeal impairment.

Effect of Age and Gender

Age and gender have been documented as possible factors affecting Nasometer measurements, with contradictory evidence over the past (Seaver et al., 1991; Leeper et al., 1992; Litzaw & Dalston, 1992; Kavanaugh et al., 1994; Tachimura et al., 2000; Gildersleeve-Neumann &

Dalston, 2001; Van Lierde et al., 2001; Whitehill, 2001). The present investigation found that significant age differences do exist for some syllable repetition speech stimuli. The lowering of nasalance scores observed for vowel /a/ as an effect of age could possibly reflect the changes in oral cavity size and shape. However, no significant gender differences were observed for the population of the current investigation.

Testing Difficulties

One of the major problems encountered during this study was the inconsistency of the headset responses. This problem was premised to be secondary to technical problems with microphone wiring of the headset, because movement of the connecting wires affected the response. It was sited earlier that the equipment used during Nasometry, such as the microphone, might affect the measurement values, and the response characteristics of the microphones used with Nasometers needs be determined carefully (Zajac, Lutz & Mayo, 1996). The inconsistency of the microphone responses required many repairs, which consequently delayed data collection and caused an inability to collect data on some occasions.

Another major fallback of this study was in the recruitment of subjects. The course of gaining consent from administration at the various testing sites and from legal guardians was a more involved and a lengthy process than expected. This resulted in a lower number of subjects recruited in the study than was originally planned.

The investigators initially encountered another difficulty in data collection. Data collection for each subject took up to 20 minutes. This was because the "Save" option of the software was used for each stimulus. This option, although valuable in terms of allowing later access to the stimuli of each subject, lengthened the time of testing. This resulted in a difficulty in compliance to completion of the testing, especially with younger subjects. Therefore, this method was replaced by the traditional manner of record-keeping involving pen and paper.

Extensive explanation was often required before initiating testing, especially with the younger subjects. These subjects also required more and varied forms of reinforcement to complete the testing, further increasing the testing time for each subject.

Future Research

For future research, it is recommended that the Nasometer II be used to gather norms for a larger, more representative group of subjects. Also, normative data for various populations (geographically, dialectally, linguistically and/or culturally different and varied) needs to be gathered for clinical utilization. This is particularly important given the current multicultural, multilingual level in the United States. It is also highly recommended that the Nasometer II be used in gathering normative data for various age groups, including adolescents and adults. These investigations are essential because it is important and often necessary to have objective measures to validate clinical judgments of velopharyngeal impairment.

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Appendix A

Questionnaire for Parents/Guardians

Please help us by completing the following information and returning with the consent form:

Child's Name: ________________________________ Birthdate:__________

Teacher's Name (if applicable): ______________________________________

1. Is your child's speech normal for his/her age?
   Yes No

2. Is your child's hearing normal?
   Yes No

3. Has your child ever had a speech evaluation?
   Yes No

4. Has your child ever had speech therapy?
   Yes No

Completed by:____

Relationship to the child:____

Thanks for your help!

Tables

Table 1a. Means (% nasalance) and standard deviations (SD) for the syllables containing plosives. The norms (means and SD) from the Nasometer I are presented. Current study data are presented by age and sex, and for the total group.

		/pa/		/pi/		/ta/		/ti/		/ka/		/ki/	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Nasometer I		**7.2**	**2.3**	**17.6**	**6.2**	**8.3**	**2.8**	**19**	**6.1**	**8.6**	**3**	**19.4**	**6.5**
AGE	**SEX**												
3	Male	10.67		26.52		10.76		30.54		7.11		17.3	
	Female	12.46	2.89	20.4	1.61	10.69	1.48	24.48	4.94	10.33	0.97	18.7	10.82
	Total	12.01	2.52	21.9	3.32	10.71	1.21	25.99	5.04	9.53	1.8	18.35	8.86
4	Male	6.31	4.01	24.78	18.37	8.77	2.46	25.01	10.99	7.24	2.73	25.82	11.9
	Female	3.12		16.69		4.31		15		5.02		12.98	
	Total	5.24	3.38	22.08	13.8	7.28	3.11	21.67	9.68	6.5	2.32	21.54	11.21
5	Male	4.24	0.19	12.21	5.5	4.17	0.36	16.66	7.2	5.07	1.59	16.78	11.79
	Female	5.46	1.26	21.43	5.22	5.88	0.8	22.5	0.89	6.16	0.92	20.77	1.15
	Total	4.85	1.04	16.82	6.96	5.028	1.09	19.58	5.59	5.62	1.31	18.77	7.81
6	Male	4.45	1	15.92	2.82	4.96	0.95	30.69	7.46	6.59	1.64	22.17	4.49
	Female	6.39	3.25	17.01	8.21	6.39	2.53	16.78	5.17	6.25	2.12	17.43	6.69
	Total	5.74	2.83	16.64	6.8	5.91	2.21	18.34	4.31	6.36	1.93	19.01	6.34
7	Male	4.572	1.03	19.2	6.27	5.59	1.1	18.4	5.93	5.35	1.25	15.03	6.05
	Female	4.087	0.65	14.45	4.94	4.5	0.84	17.06	6.83	5.28	1.16	17.74	7.54
	Total	4.24	0.79	16.03	5.68	4.86	1.04	17.5	6.36	5.3	1.15	16.84	6.98
8	Male	5.21	2.5	12.39	2.88	5.53	2.04	14.8	6.23	7.01	3.15	16.35	6.54
	Female	5.26	1.92	15.45	9.02	5.51	1.85	18.73	11.54	6.33	2.04	17.88	11.08
	Total	5.24	1.96	14.54	7.63	5.52	1.79	17.55	10.05	6.54	2.26	17.42	9.59
9	Male	4.15	0.43	23.43	6.08	4.35	0.21	28.61	7.12	5.46	0.81	31.04	1.28
	Female	5.34	2.23	19.13	15.34	5.86	3.02	22.13	15.48	5.85	2.09	23.3	14.95
	Total	4.94	1.84	20.56	12.39	5.36	2.47	24.29	12.85	5.72	1.67	25.88	12.26
Total	Male	4.98	1.94	17.65	7.23	5.63	1.98	19.21	3.89	6.14	1.78	19.94	7.85
	Female	5.81	3.01	16.89	7.85	5.94	2.4	18.69	8.1	6.25	2.06	18.41	8.49
	Total	5.51	2.69	17.16	7.59	5.83	2.25	18.28	3.22	6.21	1.95	18.95	8.23

Table 1b. Means (% nasalance) and standard deviations (SD) for the syllables containing fricatives. The norms (means and SD) from the Nasometer I are presented. Current study data are presented by age and sex, and for the total group.

		/sa/		/si/		/sha/		/shi/	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Nasometer I		**7.1**	**2.4**	**17.1**	**5.9**	**7.5**	**2.7**	**16.1**	**5.9**
AGE	**SEX**								
3	Male	10.02		26.74		11.33		28	
	Female	7.96	3.89	10.36	8.69	7.11	2.48	18.52	0.98
	Total	8.65	2.99	15.82	11.27	8.51	3	21.68	5.51
4	Male	8.41	1.05	22.66	15.23	7.65	2.09	19.69	8.64
	Female	4.69		9.73		4.85		9.07	
	Total	7.17	2.27	18.35	13.11	6.71	2.19	16.15	8.66
5	Male	4.13	1.14	14.86	6.94	4.5	1.27	15.83	6.44
	Female	6.59	1.95	22.8	2.45	6.21	1.17	20.33	5.17
	Total	5.36	1.96	18.83	6.37	5.35	1.44	18.08	5.77
6	Male	5.28	0.94	18.07	4.88	5.83	1.29	18.3	4.36
	Female	6.4	3.31	15.67	6.72	6.9	3.37	15.59	5.34
	Total	6.02	2.77	16.47	6.13	6.54	2.85	16.5	5.08
7	Male	5.51	1.12	13.74	5.91	5.63	1.61	13.47	4.73
	Female	5.26	2.37	17.83	8.47	5.09	1.81	16.5	7.79
	Total	5.34	2	16.47	7.75	5.27	1.7	15.49	6.9
8	Male	5.02	2.05	14.82	4.71	5.78	2.46	16.51	5.39
	Female	6.02	2.28	17.77	9.71	5.91	2.56	15.95	10.52
	Total	5.72	2.15	16.88	8.35	5.87	2.39	16.12	8.96
9	Male	4.66	0.57	28.88	11.67	5.47	0.79	26.39	9.59
	Female	4.69	2.28	19.22	12.33	4.42	1.37	18.83	11.28
	Total	4.68	1.78	22.44	11.97	4.77	1.24	21.35	10.49
Total	Male	5.58	1.79	18	7.79	5.98	1.96	17.92	6.41
	Female	5.91	2.64	17.09	8.18	5.91	2.51	16.57	7.44
	Total	5.79	2.36	17.42	7.99	5.93	2.31	17.06	7.06

Table 1c. Means (% nasalance) and standard deviations (SD) for the syllables containing nasals. The norms (means and SD) from the Nasometer I are presented. Current study data are presented by age and sex, and for the total group.

		/ma/		/mi/		/na/		/ni/	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Nasometer I		**58.4**	**7.8**	**78.7**	**7.4**	**59.3**	**8.6**	**79.1**	**6.9**
AGE	**SEX**								
3	Male	75.77		85.5		68.97		81.53	
	Female	58.99	8.6	78.96	3.53	55.09	5.76	73.02	5.8
	Total	63.18	10.94	80.6	4.35	58.56	8.38	75.15	6.36
4	Male	56.26	2.93	85.76	3.4	62.35	5.23	80.42	0.41
	Female	52.54		74.48		50.11		78.87	
	Total	55.02	2.98	82	6.94	58.27	7.98	79.9	0.94
5	Male	66.43	8.08	79.25	8.73	54.06	12.31	73.8	17.1
	Female	59.85	1.55	80.43	6.32	59.62	3.24	82.75	2.69
	Total	63.14	6.33	79.84	6.84	56.84	8.6	78.28	11.99
6	Male	64.81	11.45	79.94	9.14	62.48	11.29	80.07	11.04
	Female	59.99	8.26	77.53	5.72	51.82	7.46	75.64	6.58
	Total	61.6	9.39	78.33	6.87	55.37	10.01	77.12	8.28
7	Male	48.27	23.07	79.53	2.49	62.52	7.78	76.43	5.78
	Female	58.08	14.11	81.2	11.5	57.37	15.65	80.47	10.85
	Total	54.81	17.4	80.64	9.35	59.09	13.45	79.12	9.44
8	Male	64.75	11.62	80.47	2.98	56.14	5.5	78.67	5.91
	Female	62.2	12.92	79.2	8.89	59.44	10.48	79.31	9.32
	Total	62.96	11.95	79.62	7.42	58.45	9.08	79.11	8.11
9	Male	66.15	4.49	87.11	0.99	66.56	0.43	84.95	2.97
	Female	52.34	22.94	82.07	3.77	57.01	7.35	81.39	3.77
	Total	56.94	19.25	83.75	3.93	60.19	7.53	82.58	3.7
Total	Male	61.11	14.73	81.26	6.14	61.13	8.83	78.74	8.75
	Female	58.86	11.97	79.45	7.68	55.85	10.27	78.48	8.01
	Total	59.66	12.94	80.09	7.17	57.72	10.04	78.57	8.21

Table 2. Means (% nasalance) and standard deviations (SD) for the sustained vowels and consonants subtest. Data are presented by age and sex, and for the total group. The sustained /s/ is not included because all values were zero. There are no norms from the Nasometer I because this subtest was not used previously.

		/a/		/i/		/u/		/m/	
AGE	**SEX**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
3	Male	6.17		21		18.37		94.58	
	Female	9.56	3.18	19.1	9.079	12.15	2.49	94.92	1.68
	Total	8.71	3.11	19.54	7.48	13.71	3.71	94.83	1.39
4	Male	4.52	1.67	22.31	7.53	12.68	1.72	90.12	4.18
	Female	5.38		13.26		7.39		98	
	Total	4.81	1.28	19.29	7.46	10.91	3.28	92.74	5.43
5	Male	4.15	0.6	15.17	7.01	7.31	4.78	89	5.31
	Female	5.28	0.41	23.81	4.28	9.99	4	93.24	3.41
	Total	4.72	0.78	19.49	7.03	8.65	4.57	91.12	4.62
6	Male	5.53	1.47	21.56	4.48	8.08	3.03	92.61	2.89
	Female	5.49	2.08	17.32	6.63	7.63	3.83	91.41	4.13
	Total	5.5	1.85	18.73	6.21	7.78	3.49	91.81	3.72
7	Male	8.3	6.92	12.1	4.57	4.68	2.38	93	2.51
	Female	4.46	1.44	19	7.93	8.02	4.77	93.59	2.61
	Total	5.74	4.31	16.7	7.6	6.91	4.35	93.37	2.5
8	Male	5.86	1.53	15.99	5.46	6.78	2.18	93.59	3.68
	Female	5.11	1.33	18.37	12.37	10.17	6.52	93.17	1.94
	Total	5.34	1.35	17.66	10.48	9.15	5.67	93.3	2.35
9	Male	4.47	0.96	30.9	6.55	6.39	1.29	94.28	0.35
	Female	3.63	2.12	29.22	16.53	10.73	8.31	94.23	1.4
	Total	3.91	1.75	29.79	13.16	9.28	6.84	94.24	1.1
Total	Male	5.86	3.51	18.67	7.23	7.75	4.05	92.35	3.32
	Female	5.27	2.17	19.63	9.51	8.99	5.01	93.1	3.13
	Total	5.48	2.71	19.29	8.72	8.55	4.69	92.84	3.19

Table 3. Means (% nasalance) and standard deviations (SD) for the words produced during the picture description subtest. The norms (mean and SD) from the Nasometer I are presented. Current study data are presented by age, sex, and total (male and female).

		Book		Turtle		Cookie		Scissors		Mittens	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nasometer I		**11**	**3.5**	**11.3**	**3.7**	**12.4**	**4**	**12.9**	**4.4**	**56.9**	**7.4**
AGE	**SEX**										
3	Male	13.24	2.01	13.8	3.06	16.41	0.69	18.32	5.46	51.45	0.22
	Female	9.81	2.61	8.32	2.11	12.59	5.26	10.63	4.66	49.66	3.52
	Total	11.18	2.82	10.51	3.68	14.11	4.28	13.7	6.01	50.37	2.68
4	Male	10.88	3.56	11.23	8.83	9.93	4.6	16.92	12.22	49.97	0.94
	Female	5.93		4.76		4.83		7.22		47.77	
	Total	9.23	3.8	9.07	7.28	8.23	4.39	13.69	10.3	49.23	1.43
5	Male	7.32	1.52	6.29	0.84	7.69	1.04	9.92	2.19	55.57	9.88
	Female	11.34	1.9	14.47	0.64	12.36	0.23	15.15	1.85	60.45	4.24
	Total	9.33	2.69	10.38	4.52	10.02	2.64	12.54	3.39	58.01	7.3
6	Male	6.87	2.34	7.87	2.42	8.84	2.6	9.86	3.11	57.72	10.55
	Female	8.57	3.05	9.42	3.17	10.24	2.99	12	3.59	54.22	7.5
	Total	8	2.89	8.9	2.96	9.77	2.87	11.28	3.5	55.39	8.49
7	Male	7.11	1.68	8.03	1.61	9.64	1.33	9.31	2.26	54.72	8.43
	Female	8.61	4.1	9.46	4.55	9.18	3.19	11.31	3.62	58.17	12.69
	Total	8.11	3.48	8.99	3.82	9.34	2.66	10.64	3.29	57.02	11.26
8	Male	8.15	4.93	9.95	5.43	12.33	5.37	12.36	5.7	56.18	5.23
	Female	8.24	2.87	10.81	5.67	11.39	5.28	12.11	5.94	58.12	10.1
	Total	8.22	3.3	10.55	5.31	11.67	5.02	12.18	5.55	57.54	8.66
9	Male	6.99	0.15	9.33	0.02	11.72	0.86	17.26	2.96	64.64	10.65
	Female	8.77	5.67	7.72	4.8	9.57	4.58	9.38	4.44	55.05	2.95
	Total	8.18	4.49	8.26	3.81	10.28	3.74	12.01	5.49	58.25	7.24
Total	Male	8.06	2.97	8.9	3.57	10.32	3.37	12.07	5.18	55.97	8.24
	Female	8.78	3.41	9.68	4.21	10.31	3.78	11.6	4.13	55.93	8.96
	Total	8.52	3.25	9.4	3.98	10.31	3.61	11.77	4.51	55.95	8.64