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NORMATIVE NASALANCE VALUES ACROSS LANGUAGES

Carolyn M. Mayo, PhD
North Carolina A&T State University
Greensboro, NC

Robert Mayo, PhD
University of North Carolina at Greensboro
Greensboro, NC

ABSTRACT

The Nasometer is an objective computer-based instrument designed to measure the acoustic correlates of resonance and velopharyngeal function. The device has proven to be useful for early identification of persons at risk for velopharyngeal dysfunction. Since its introduction, the Nasometer has been used in craniofacial centers and other clinical settings both in the United States and around the world. The purpose of this paper is to describe the Nasometer and its clinical uses, discuss speaker characteristics that might influence nasalance values, and provide a compilation of published normative nasalance data across English, Spanish, Asian, and European languages. Additionally, languages in need of normative nasalance data are discussed.

KEY WORDS: Nasometer, Nasalance, Normative data, Objective acoustic analysis

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Carolyn M. Mayo, PhD
North Carolina A&T State University
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Robert Mayo, PhD
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INTRODUCTION

Paired with perceptual speech assessment, objective instrumental devices have enabled clinicians to reliably identify persons at risk for velopharyngeal (VP) dysfunction and related resonance disorders (e.g., hypernasality). Over the last thirty years, instrumental systems have increased our understanding of the structure and workings of the velopharyngeal mechanism, allowed professionals to acquire quantifiable reproducible data, and render informed treatment recommendations to persons presenting with or at risk for velopharyngeal dysfunction (Dalston and Warren, 1985; Kummer, 2008; Moon, 1992). In a study of the importance of instrumental assessment of velopharyngeal function reported by 63 craniofacial centers in the United States, 88 percent of these centers rated such devices as very important or important to the evaluation process (Pannbacker et al. 1992). These devices can either allow clinicians to directly visualize and assess the structure and function of the velopharyngeal mechanism (e.g., nasoendoscopy) or indirectly make inferences about velopharyngeal adequacy during speech (e.g., acoustic measures). Indirect objective measures of velopharyngeal function have the advantage of being comparatively non-invasive or non-obtrusive to subjects---limiting exposure to radiation or discomfort associated with insertion of scopes into the confines of the nasopharynx and can be used with young children.

Within the category of indirect objective assessment procedures, nasometry is a method of measuring the acoustic correlates of resonance and velopharyngeal function and can be compared to standardized norms for interpretation (Kummer, 2008). Acoustic events associated with velopharyngeal function during speech involve the movement of sound pressure/vibrational energy through the vocal tract and the proper transmission of that energy through the oral and/or nasal cavities as required by the particular speech activity. Nasometric measures have been shown to be strongly correlated with aerodynamic and perceptual measures of velopharyngeal function and have proven to be useful for early identification of patients at risk for velopharyngeal dysfunction (Dalston, Warren, & Dalston, 1991).

The Nasometer has gained widespread clinical and research usage within the United States and internationally. Consequently, normative nasometric data have been obtained from children and adults in numerous separate studies in North America, Europe, Asia, Australia, and the Caribbean. However, to our knowledge, these data have not been presented in a single report. Thus, the purpose of this paper is to describe the Nasometer and its clinical uses, discuss speaker characteristics that might influence nasalance values, and provide a compilation of normative nasalance data across English, Spanish, Asian, and European languages. Additionally, languages in need of normative nasalance data are discussed.

THE NASOMETER

A computer based system, the Nasometer allows clinicians to determine the relative amount of oral and nasal energy in an individual's speech (Dalston & Seaver, 1992; Kummer, 2008). With the device, nasal (N) and oral (O) acoustic components of a subject's speech are sensed by microphones separated by a horizontal head set-mounted sound separator that rests on the upper lip (see Figure 1). The signal from each of the microphones is filtered and digitized by custom electronic modules. The data can then be processed by a personal computer and displayed in real-time on a computer screen. The resultant signal is a ratio of nasal-plus-oral acoustic energy. The ratio is multiplied by 100 and expressed as a percentage "nasalance" score. Specifically, the nasalance score can be described thusly:
Nasalance = N ÷ (N + O) x 100.

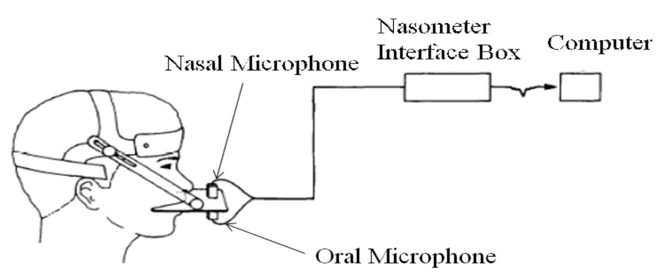

Figure 1. Headset, microphones, and computer interface for the Nasometer.

Nasalance is, perhaps, the most widely used objective, non-invasive measure that relates to perceived nasality (Awan & Virani, 2010). Presently, there are two Nasometer models. The Nasometer 6200 (Kay Elemetrics Corporation, Lincoln Park, NJ) first introduced in 1987, represents the original model of the device and is the source of much of the normal and disordered nasalance data that has been used to describe speech resonance in normal and clinical populations. Subsequently, in 2003 the Nasometer 6200 was replaced with the Nasometer II 6400 (Kay Elemetrics/PENTAX, Lincoln Park, NJ).

There are some differences in the hardware and software characteristics between the two systems. Awan and Virani (2010) reported that in the Nasometer 6200-1, the nasal and oral microphone signals are separately preamplified and then fed to bandpass filters (center frequency = 500 Hz; -3 dB bandwidth of 300 Hz) to capture the lower frequency region of the speech spectrum. The data acquisition routines in the Nasometer 6200-1 software sample the root mean square (RMS) level of the nasal and oral microphone signals at a rate of 120Hz at 8 bits of resolution (Fletcher, Adams, & McCutcheon, 1989).

The Nasometer II Model 6400 v. 2.70 incorporated several changes to the original Nasometer. While the headgear (separator plate and microphones) and the bandpass filtering procedure were maintained, the oral and nasal microphone signals are now digitally sampled at 11,025 Hz per channel at 16 bits of resolution. Nasalance is then calculated using the digitized data by means of an 8 ms averaging frame to approximate the procedure used in the Nasometer 6200 (Awan & Virani, 2010). In addition, changes in the microphone calibration procedures, and the capability for signal playback were also incorporated into the Nasometer II 6400.

The hardware and software changes rendered by the manufacturer appear significant enough to warrant caution when interpreting nasalance data derived from the Nasometer 6200 and Nasometer II 6400. Specifically, in a study comparing measures of nasalance obtained from a group of normal adult males and females using the Nasometer 6200 versus the Nasometer II 6400, Awan and Virani (2010) reported that the two units differed significantly on mean nasalance for the Zoo and Rainbow Passages but not for the Nasal Sentences. The authors stated that mean nasalance scores obtained from the Nasometer II 6400 were statistically lower than those derived from the Nasometer 6200. Based on this finding, Awan and Virani (2010) cautioned clinicians and researchers against interpreting nasalance data obtained from each unit as equivalent and recommended that professionals "consult norms that have been developed for the specific system that is being used (Nasometer 6200 or Nasometer II 6400)."

CLINICAL USES OF THE NASOMETER

The Nasometer has proven to be a useful, non-invasive method of assessing persons at risk for velopharyngeal impairment (e.g., those with cleft palate and other oral-facial disorders, motor speech disorders, etc.) and upper airway impairment (e.g., those with nasal or nasopharyngeal obstruction). The nasometer is an effective adjunct to perceptual and aerodynamic findings as well as endoscopy and/or videofluoroscopy assessments. Moreover, the data obtained from the Nasometer are easily interpretable and can be understood by a lay person with no more than a brief explanation (Dalston & Warren, 1985). Table 1 provides a listing of the many clinical uses of the Nasometer,

As noted by Kummer (2008), when an individual's nasalance score is compared to normative data, a judgment can be made regarding the normalcy of resonance. High scores, in comparison to normative data, suggest hypernasality; low scores, in comparison, suggest hyponasality. Nasalance scores are typically obtained by having the client read or repeat a standardized passage, sentences, or syllables. The level of nasalance varies depending on the type of vowel produced (Lewis & Watterson, 2003). There are greater levels of nasalance on high vowels than on low vowels. For example, nasalance for /i/ is usually 10 percentage points higher than that for the low vowel /a/ (Kummer, 2005; 2008). Most English language nasalance norms have been established using three standardized passages---the Zoo Passage (Fletcher, 1972), the Rainbow Passage (Fairbanks, 1960), and Nasal Sentences (Fletcher, 1978).

Table 1. Clinical Uses of the Nasometer.

Clinical Uses	Representative Studies
Assessment of resonance in children with hearing impairment.	Tatchell et al.(1991)
Assessment of upper airway obstruction and hyponasality.	Dalston et al. (1991); Nieminen et al. (2000); Williams et al. (1990)
Selection of at-risk individuals for adenoidectomy.	Gonzalez-Landa et al. (1990); Kummer et al. (1993); Williams et al. (1992)
Measure changes in resonance following surgical procedures such as pharyngoplasty, uvulopalatopharyngoplasty, maxillectomy, and functional endoscopic sinus surgery.	David et al. (1999); Dejonckere & van Wijngaarden (2001); Nellis et al. (1992); Prunkngarmpun et al. (2008); Soneghet et al. (2002); Van Lierde et al (2002)
Measure effects of various forms of therapy such as CPAP and prosthetic management.	Sweeney et al. (2004); Reiger et al. (2002)
Assessment of nasality in children with apraxia of speech.	Skinder-Meredith et al. (2004)
Assessment of post-speech treatment intelligibility in persons with dysarthria.	Cahill et al. (2003); McHenry (1999); Roy et al. (2001); Wenke et al. (2010)
As a biofeedback instrument in speech therapy.	Van Lierde et al. (2011); Zajac et al. (1996)

The Zoo Passage contains no nasal phonemes and is useful in determining if velopharyngeal closure can be obtained and maintained throughout connected speech (Kummer, 2008). Listeners generally perceive inadequate velopharyngeal closure during speech as hypernasality (Watterson et al. 1993). The Rainbow Passage contains both oral and nasal phonemes (11.5% of the phonemes in this passage are nasal consonants) and it is useful for examining the timing of velopharyngeal closure. Problems with the timing of velopharyngeal closure during speech can be perceived by listeners as hypernasality, assimilative nasality, or mixed hypernasality-hyponasality. The Nasal Sentences contain a preponderance of nasal consonants (i.e., 35% of its sounds are nasal phonemes) and they have proven useful in identifying obstruction at the level of the nasopharynx and nasal cavity which would reduce the transmission of acoustic energy through the nasal airway. The perceptual consequence of such obstruction during speech is typically identified by listeners as hyponasality.

Thus, in interpreting nasalance scores for the Zoo Passage or a similar passage devoid of nasal phonemes, a nasalance score of 28 percent obtained from a speaker of American English via the Nasometer 6200 would be the threshold for differentiating speakers with borderline velopharyngeal function from those who are normal speakers (Kummer, 2008). Likewise, norms derived from the Nasometer II Model 6400 suggest that for a passage devoid of nasal phonemes, a speaker with a score less than 20 percent does not have hypernasality; scores between 20 to 30 percent are in the borderline range; and scores over 30 percent are considered abnormal (Kummer, 2008).

Finally, it is important to understand that nasalance values can be affected by articulation errors (e.g., glottal stop substitutions, sound deletions, sound-specific nasal air emission). Thus, interpretation of nasalance scores should also be based on an accompanying perceptual assessment by a qualified speech-language pathologist (Kummer, 2008).

EFFECTS OF SPEAKER CHARACTERISTICS ON NASALANCE VALUES

Researchers have examined the effects of speaker characteristics on nasalance scores in normal persons. These speaker characteristics have included age, gender, regional dialect, and native language. For example, normal nasalance values have been shown to be statistically lower in school age children (9 – 19 years) compared to adults (20 – 85 years) (Hutchinson et al. 1978; Seaver et al. 1991; Rochet et al., 1998). Explanations for this trend include (a) age-related lengthening of the vocal tract from childhood to adulthood that may influence the acoustic resonance characteristics of the oral and nasopharyngeal cavities; (b) physiological changes with age that may influence the maintenance of neuromuscular control of the velopharyngeal port across the ongoing demands for VP closure during non-nasal connected utterances, and the rapid adjustments in the VP port required for production of nasal phonemes; and (c) soft tissue, bony tissue, and muscle changes associated with the advanced aging of the vocal tract (Rochet et al. 1998). It is important to note that while differences in nasalance values between young children and adults have been reported to be statistically significant, these scores differ on average by a mere three percentage points. Thus, the differences would not be viewed as clinically significant (Mayo et al. 1996; Rochet et al. 1998).

Gender differences typically are not seen in nasalance scores (Litzaw & Dalston, 1992) or, if evident, are not considered clinically significant (Seaver et al. 1991). In those instances in which gender differences in nasalance values have been reported, women have been found to exhibit higher scores than men on oral passages, mixed oral-nasal passages, and nasal sentences. The small but persistent gender differences in nasalance values reported by some studies might be related to (a) sensitivity variations in the frequency response of the two Nasometer microphones (oral and nasal) that could interact differently with the female vocal tract (Zajac et al. 1996); (b) females possibly requiring more time to achieve velopharyngeal closure during speech (Zajac & Mayo, 1996); or gender differences in 'transpalatal nasalance', i.e., vibration of palatal structures during production of vowels and other voiced phonemes that transfers acoustic energy to the nasal cavity (Bundy & Zajac, 2006). However, at this point, the aforementioned explanations for gender differences in nasalance values remain unconfirmed.

Nasalance scores have been reported to vary with speaker regional dialect when the same reading passage is used. For example, Seaver, Dalston, Leeper, and Adams (1991) found significantly higher Zoo Passage and Rainbow Passage nasalance scores among normal speakers from the Mid-Atlantic dialectal region compared to speakers from the Southern and Mid-western dialectal regions of the United States and Ontario, Canada. However, similar patterns were not seen during readings of the Nasal Sentences. Additionally, Leeper, Rochet, and MacKay (1992) reported the presence of regional dialectal variations for nasalance among speakers of Canadian English.

In her explanation of why nasalance scores might differ across regional dialects, Kummer (2008) noted that since consonants are produced essentially the same, regardless of dialect, these dialect-related differences in nasalance must be in the production of the vowels. Kummer (2008) further observed that "it might be presumed that dialects, accents, or even languages that use more high vowels or a higher tongue position might be expected to have higher nasalance scores as compared to those with greater incidence of low vowels or a lower tongue position." (p. 391). Elsewhere, Mayo, Floyd, Warren, Dalston, and Mayo (1996) hypothesized that across dialects, there may be differences in the timing of VP closure when transitions are made between nasal consonants and vowels. Thus, it is possible that these linguistically-related VP timing differences during speech might influence nasalance characteristics. However, similar to reported gender-related differences in nasalance values, dialect-associated variations in such scores have been described as not large enough to be clinically significant (Mayo et al. 1996; Rochet et al. 1998; Seaver et al. 1991).

Since its introduction in 1987 by Kay Elemetrics Corporation in the United States, use of the Nasometer has spread internationally across English and non-English-speaking countries. Several studies have indicated that nasalance values can vary with language. In North America, Leeper, Rochet, and MacKay (1992) reported significantly higher nasalance values for speakers of Canadian English than of Canadian French. However, in a later study, Rochet, Rochet, Sovis and Mielke (1998) observed that the nasalance scores of speakers of Canadian English and French were similar during readings of non-nasal passages but differed for mixed oral-nasal and nasally loaded passages. In a European investigation, Santos-Terron, Gonzalez-Landa, and Sanchez-Luis (1991) found higher nasalance scores among native speakers of Castilian Spanish than among speakers of American English during reading of a passage devoid of nasal consonants.

Based on the findings of the studies discussed in this section, the following statements can be made. First, normal nasalance values appear to differ based on the age of a speaker. Thus, nasalance scores of children, on average, tend to be slightly lower than those of young or older adults. While, these age differences in nasalance are not clinically significant, they may provide clinicians with useful information about the development of the vocal tract within a speaker (e.g., lengthening of the vocal tract, involution of the adenoids and tonsils in children, and the aging of the vocal tract structures). Second, gender and regional speaker dialects appear to influence nasalance values but not to the extent of requiring separate nasalance norms for either speaker characteristic. Third, in those published studies where nasalance values have been directly compared across languages (e.g., Canadian English vs. Canadian French, Castilian Spanish vs. American English), the findings suggest that the native language of a speaker should be considered by clinicians when using the Nasometer.

With respect to the latter statement, as the Nasometer technology spread outside of the United States, clinicians and researchers began to establish nasalance norms for sounds, words, and sentences in many other languages to accurately reflect the linguistic and nasalance characteristics of those languages. As Whitehill (2001) observed, “the primary purpose in providing normative data for a given language is clinical; such information is necessary to assist in the evaluation and management of speakers with resonance disorders. However, investigations and comparisons of nasalance data from different languages are also of theoretical benefit because they facilitate our understanding of the influence of linguistic and sociocultural factors on resonance judgment measurement.” (p. 120).

In the next section of this paper, the authors have compiled normative nasalance data from 18 published studies around the world (including two from the United States). The compilation was derived from studies published in English for ease of clinician/researcher accessibility and interpretation. The authors acknowledge that there are a small number of published normative nasalance studies written in languages other than English as well as theses or dissertations that offer such data.

These nasalance data provide useful reference information for clinicians who evaluate resonance disorders at cleft palate-craniofacial centers in other countries. Additionally, as the treatment-seeking population of the United States continues to diversify culturally and linguistically, these nasalance data and those obtained in the future might be used with children and adults whose primary languages are not American English. Unless otherwise indicated, the reading passages or sentences used by these studies to obtain nasalance values were translated into the language of the speakers and represent speech stimuli either devoid of nasal phonemes, having a mix of oral and nasal phonemes, or heavily loaded with nasal phonemes.

Mean nasalance scores and standard deviations were available for most of these normative nasalance studies and are reported in this compilation. The majority of the nasalance values (72%) were obtained from the Nasometer 6200 system. The reader is reminded that nasalance scores obtained from the Nasometer 6200 tend to be higher than those derived from the Nasometer II 6400 and therefore, he/she should interpret the nasalance values reported in this compilation based on norms that have been developed for the specific Nasometer system. Finally, the reader should note that the normative nasalance data made available in this compilation were obtained from 2,100 speakers worldwide with as few as nine and as many as 315 persons represented in the studies.

NORMATIVE NASALANCE VALUES ACROSS LANGUAGES

English Language Nasalance Norms

Normative nasalance data for four varieties of English---American, Canadian, Irish, and Australian, are shown in Tables 2 and 3. Major points from the American English speaker data include (a) nasalance values of white adult speakers of the Mid-Atlantic dialect are slightly higher than those of speakers of Mid-Western or Southern regional dialects (Seaver et al. 1991) and (b) African American speakers generally exhibit lower scores for the Nasal Sentences than white speakers (Mayo et al. 1996). In general, oral passage nasalance scores of the Canadian speakers are somewhat lower than those of American English speakers. The Irish English (Sweeney et al. 2004) and Australian English (Van Doorn & Purcell, 2004) nasalance data for like-age children are similar. No published nasalance data are available for either Irish or Australian adults. However, one unpublished study (Lee & Browne, 2008) indicated that adult speakers from Southern Ireland exhibit lower nasalance values than English speakers from North America. Missing from the normative database are values for speakers of British English.

Canadian French Nasalance Norms

Canadian French nasalance values are shown in Table 4. Noteworthy is the fact that mixed oral-nasal passage and nasal sentences scores for these speakers are quite lower than those of English talkers when compared directly (Rochet et al. 1998). An explanation for this finding may lie in the fact that phonemic nasal vowels exist in the French spoken language and these phonemes were contained in the reading passages used to obtain Canadian French nasalance norms. These nasal vowels produce both oral and nasal energy because the mouth and velopharyngeal port are open during their production. That is, languages such as French use the velopharyngeal port to achieve a phonemic contrast between oral and nasal vowels. For example, in French, *pain* /pɛ̃n/ (‘bread’) and *paix* /pɛ̃/ (‘peace’) are distinguished by the presence or absence of nasalization. Therefore, nasal vowels in French will generate less nasalized acoustic energy to be detected by the nasal microphone of the Nasometer resulting in lower mixed oral-nasal or nasal sentences values. Presently, there are no published nasalance data for European French or the many varieties of the language spoken globally.

Table 2. Mean Normative Nasalance Scores (in %) from Studies of English Speakers in the United States and Canada. Standard Deviations are in Parentheses. M’ Indicates Male. ‘F’ Indicates Female. ‘NA’ Indicates Data Not Available for a Reading Passage or Sentences.

		Mean Nasalance Score (%)			
Speakers	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
United States White Adult men & women (16-63 yrs) from three geographic/ dialectal regions in the United States N = 148	Nasometer 6200	Mid-Western[1]:			Seaver et al. (1991)
		15.0	35.0	62.0	
		(6.0)	(5.0)	(6.0)	
		Mid-Atlantic[2]:			
		21.0	39.0	65.0	
		(5.0)	(6.0)	(5.0)	
		Southern[3]:			
		13.0	34.0	61.0	
		(7.0)	(6.0)	(6.0)	
African American Adult men & women (23.2 yrs) from the Mid-Atlantic region of the United States N = 40		M = 15.3	NA	56.5	Mayo et al.
		(4.4)		(8.2)	(1996)
		F = 18.6	NA	58.9	
		(6.0)		(2.4)	
Canada Adult men, women & children (9-85 yrs) from Western Canada N = 315	Nasometer 6200	M = 11.3	32.9	61.6	Rochet et al.
		(5.0)	(5.3)	(6.7)	(1998)
		F = 11.5	34.5	62.7	
		(4.4)	(4.6)	(6.2)	

[1]Illinois, [2]North Carolina, [3]Alabama

Table 3. Mean Normative Nasalance Scores (in %) from Studies of English Speakers in Ireland, and Australia. Standard Deviations are in Parentheses. 'NA' Indicates Data Not Available for a Reading Passage or Sentences.

		Mean Nasalance Score (%)			
Speakers	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
Ireland Children (4-13 yrs) from Dublin, Ireland N = 70	Nasometer 6200	14.0 (5.0)	26.0 (5.0)	51.0 (7.0)	Sweeney et al. (2004)
Australia Children (4-9 yrs) from Sydney, Australia N = 245	Nasometer 6200	13.1 (5.9)	NA	59.6 (8.1)	Van Doorn & Purcell (2004)

Table 4. Mean Normative Nasalance Scores from a Study of Speakers of Canadian French[1]. Standard Deviations are in Parentheses. 'M' Indicates Male. 'F' Indicates Female. All Reading Passages and Sentences Were Translated into French and Read in that Language.

		Mean Nasalance Score (%)			
Speakers[1]	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
Children & Adolescents (9-19 yrs) N = 59	Nasometer 6200	M = 9.2 (4.1)	24.0 (4.4)	33.4 (6.1)	Rochet et al. (1998)
		F = 8.8 (2.3)	25.3 (3.5)	35.6 (5.1)	
Young & Early Middle-Age Adults (20-44 yrs) N = 56		M = 13.9 (5.3)	28.3 (5.5)	38.6 (7.0)	
		F = 14.5 (5.8)	30.1 (6.0)	40.3 (6.8)	
Middle-Age & Older Adults (45-85 yrs) N = 38		M = 12.4 (4.8)	26.0 (5.1)	35.0 (6.0)	
		F = 14.1 (4.6)	29.7 (5.2)	39.5 (6.6)	

[1]Speakers were from the Canadian provinces of Alberta, Manitoba, and Saskatchewan.

Spanish Language Nasalance Norms

Normal nasalance values for speakers of Spanish are presented in Table 5. These data were obtained from adult men and women from two dialectal regions in Mexico (Nichols, 1999) and adult women in Puerto Rico (Anderson, 1996). The differences in nasalance scores between the Mexican and Puerto Rico groups might be accounted for by the fact that the latter group consisted of female speakers who, as previously noted, typically exhibit slightly higher values. Given the vast disperson of the Spanish language in the United States and around the world, more studies are called for to account for possible geo-linguistic variations in normal nasalance among speakers of this language.

Table 5. Mean Normative Nasalance Scores from Studies of Spanish Speakers in Mexico and Puerto Rico. Standard Deviations are in Parentheses. 'NA' Indicates Data Not Available for a Reading Passage or Sentences.

		Mean Nasalance Score (%)			
Speakers	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
Adult men & women (20-40 yrs) & children (6-13 yrs) from Mexico City and Cuernavaca N = 152	Nasometer 6200	17.0 (6.7)	NA	55.62 (6.0)	Nichols (1999)
Adult women (21-43 yrs) from Puerto Rico N = 40	Nasometer 6200	21.9 (8.6)	36.0 (7.0)	63.0 (7.7)	Anderson (1996)

European Languages

Published normative nasalance data, displayed in Table 6, are available for five European languages---Portuguese, Flemish, Finnish, Hungarian, and Swedish. Most of these data were collected using the newer Nasometer II 6400 system. The reader should note that the lower average nasal sentences values for Portuguese (a language spoken in Europe, Africa, South America, North American, and Asia) are most likely a function of its use of phonemic nasal vowels (similar to French) resulting in less nasalized acoustic energy to be detected by the nasal microphone of the Nasometer. Notable in the their absence from the normative database are nasalance values for European French, German, Italian, Greek and Slavic languages (e.g., Russian).

Asian Languages

Normative nasalance data for Japanese, Thai, and Cantonese are shown in Table 7. All three are considered tonal languages though Japanese is said to have a simpler tone system (Bao, 1999). The Japanese data, collected from five regions in Japan, revealed no significance differences in nasalance values due to dialect (Mishima et al. 2008; Tachimura et al. 2000). Currently, there are no published normative nasalance data for children in Japan. Nasalance values of speakers of Thai and Cantonese (the latter the official language of Hong Kong and Macau and spoken by about 70 million persons worldwide) are reported to be similar to those of English speakers (Prathanee et al. 2003; Whitehill 2001). Nasalance data for children who speak Marathi (Nandurkar, 2002) are presented in Table 8. Marathi is one of the languages of India and is spoken by approximately 90 million persons globally. While the number of speakers that comprised the Marathi normative nasalance database are small (N = 9), it should be noted that the values are very similar to those reported by Kummer (2005) for consonant-vowel-consonant syllables of the same phonetic categories (i.e., plosive, fricative, and affricates) produced by American English-speaking children ranging in age from three years to nine years (N = 272). There are currently no published nasalance data for Mandarin, Filipino/Tagalog, Korean, Vietnamese, the other languages of India or Pacific Island languages.

Table 6. Mean Normative Nasalance Scores from Studies of European Language Speakers (Portuguese, Flemish, Finnish, Hungarian, Swedish). Standard Deviations are in Parentheses. 'NA' Indicates Data Not Available for a Reading Passage or Sentences.

		Mean Nasalance Score (%)			
Speakers	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
European Portuguese Adult men & women (19-27 yrs) N = 25	Nasometer 6200	10.0	NA	44.0	Falé & Faria (2008)
Flemish (Belgium) Children (7-13 yrs) N = 33	Nasometer II 6400	11.3 (4.7)	31.9 (4.8)	51.6	Van Lierde et al. (2003)
Adult men & women (19-27 yrs) N = 58		10.9	33.8	55.8	Van Lierde et al. (2001)
Finnish Adults & preschool/school age children (3-54 yrs) N = 42	Nasometer 6200	13.6 (5.6)	NA	69.4 (8.2)	Haapanen (1991)
Hungarian Adults (20-25 yrs)	Nasometer II 6400	13.4	39.5	56.0	Hirschberg et al. (2006)
Children (5-7 yrs) N = 75		11.0	31.7	50.6	
Swedish Children (6-11 yrs) N = 245	Nasometer II 6400	12.7 (5.6)	29.5 (6.1)	56.5 (6.0)	Brunnegard & Van Dorn (2009)

Table 7. Mean Normative Nasalance Scores from Studies of Asian Language Speakers (Japanese, Thai, and Cantonese). Standard Deviations are in Parentheses. 'NA' Indicates Data Not Available for a Reading Passage or Sentences.

		Mean Nasalance Score (%)			
Speakers	**Nasometer Model**	**Oral Passage**	**Oral-Nasal Passage**	**Nasal Sentences**	**Authors**
Japanese Adult men & women speakers from four geographic regions in Japan (men: 23.8 yrs; Women: 23.2 yrs) N = 68	Nasometer II 6400	M = 10.3 (5.8) F = 15.6 (8.4)	NA NA	NA NA	Mishima et al. (2008)
Adult men & women speakers of Osaka dialect of Mid-West Japan (19-35 yrs) N = 100	Nasometer 6200	M = 8.3 (4.0) F = 9.8 (3.5) Total = 9.1 (3.9)	NA NA NA	NA NA NA	Tachimura et al. (2000)
Thai Children from Khon Kaen municipality, Thailand (7-12 yrs) N = 141	Nasometer 6200	14.3 (5.8)	35.6 (5.9)	51.1 (6.4)	Prathanee et al. (2003)
Cantonese Adult women from Hong Kong, China (18-33 yrs) N = 141	Nasometer 6200	13.6 (7.1)	35.4 (6.2)	55.6 (7.3)	Whitehill (2001)

Table 8. Mean Normative Nasalance Scores from Studies of Asian Language Speakers (Marathi). Standard Deviations are in Parentheses.

		Mean Nasalance Score (%)	
Speakers	**Nasometer Model**	**Consonant-Vowel-Consonant Syllables**	**Authors**
Maranthi Children from Mumbai, India (5-11 yrs) N = 9	Nasometer 6200	Plosives 8.6 (1.5) Fricatives 7.9 (1.5) Affricates 11.4 (3.0)	Nandurkar (2002)

CLINICAL AND RESEARCH CONCLUSIONS AND RECOMMENDATIONS

Velopharyngeal dysfunction can have a profound effect on resonance, articulation, and overall speech intelligibility. The Nasometer has proven to be useful in evaluating persons suspected of having velopharyngeal dysfunction. Likewise, the safety, noninvasiveness, and ease of use of the Nasometer system are significant factors in its increasing application in clinical settings throughout the world (Krakow & Huffman, 1993). Normative nasalance values are available for languages spoken by millions of persons internationally. This article has provided a compilation of nasalance data for several of these languages. With a few exceptions (i.e., Canadian French and European Portuguese), normative nasalance values appear remarkably similar across the languages discussed and adhere to previously reported trends in gender and age variations. One explanation for the latter observation is that regardless of how time-varying patterns of nasalization are specified phonologically or phonetically within a language, the Nasometer appears to effectively capture these phenomena and represent them as nasalance values.

As discussed in this paper, there are languages in need of normative nasalance data and clinicians and researchers are encouraged to acquire and share these data. Among these tongues are the varieties of African and Middle Eastern languages, other varieties of English (e.g., Caribbean, British, New Zealand), European languages (e.g., French, Italian, Slavic), and Asian languages (e.g., Korean, Vietnamese, Mandarin, language varieties of India and Pakistan). We must also remember that a number of these languages have been 'exported' to other countries in the world. For example, English, French, Spanish, Portuguese, and Dutch are spoken as primary or secondary languages in countries in Africa, the Caribbean, etc. Likewise, in the United States, 20 percent of the population speaks a language other than English in the home (Shin & Kominski, 2010). Thus, research is needed that compares nasalance values in a primary versus secondary language (e.g., Spanish vs. English). Additionally, more effort should be directed toward culturally and linguistically relevant translation of speech materials to facilitate ease of production by native speakers during nasometric assessment.

REFERENCES

Anderson, R.T. (1996). Nasometric values for normal Spanish-speaking females; A preliminary report. Cleft Palate-Craniofacial Journal, 33, 333-336.

Awan, S.N. and Virani, A. (2010, November). System effects on nasalance: Nasometer 6200 vs. Nasometer II 6400. Paper presented at the annual convention of the American Speech-Language-Hearing Association, Philadelphia, PA.

Bao, Z. (1999). The Structure of Tone. New York: Oxford University Press.

Brunnegard, K. and Van Doorn, J. (2009). Normative data on nasalance scores for Swedish as measured on the Nasometer: Influence of dialect, gender, and age. Clinical Linguistics and Phonetics, 23, 58-69.

Bundy, E.L. and Zajac, D.J. (2006). Estimation of transpalatal nasalance during production of voiced stop consonants by noncleft speakers using an oral-nasal mask. Cleft Palate-Craniofacial Journal, 43, 691-701.

Cahill, L., Theodoros, D., Murdoch, B., and MacMillan, J. (2003). Physiological features of dysarthria in Friedreich's Ataxia. Asia Pacific Journal of Speech, Language and Hearing, 8 221-228.

Dalston, R.M. and Seaver, E.J. (1992). Relative value of various standardized passages in the nasometric assessment of patients with velopharyngeal impairment. Cleft Palate-Craniofacial Journal, 29, 17-21.

Dalston, R.M. and Warren, D.W. (1985). The diagnosis of velopharyngeal inadequacy. Clinics in Plastic Surgery, 12, 685-695.

Dalston, R.M., Warren, D.W., and Dalston, E.T. (1991). Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. Cleft Palate-Craniofacial Journal, 28, 184-189.

Dalston, R.M., Warren, D.W., and Dalston, E.T. (1991). A preliminary investigation concerning the use of nasometry in identifying patients with hyponasality and/or nasal airway impairment. Journal of Speech and Hearing Research, 34, 11-18.

David, L.R., Blalock, D., and Argenta, L.C. (1999). Uvular transposition: A new method of cleft palate repair. Plastic and Reconstructive Surgery, 104(4), 897-904.

Dejonckere, P.H. and van Wijngaarden, H.A. (2001). Retropharyngeal autologous fat transplantation for congenital short palate: A nasometric assessment of functional results. Annals of Otology, Rhinology, and Laryngology, 110(2), 168-172.

Fairbanks, G. (1960). Voice and Articulation Drillbook. New York: Harper and Row, (pp. 127).

Falé, I. and Faria, I.H. (2008). Nasometric values for European Potuguese: Preliminary results. Proceedings of the 2nd ISCA Workshop on Experimental Linguistics, Athens, Greece, 85-88.

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

Fletcher, S.G. (1972). Contingencies for bioelectric modification of nasality. Journal of Speech and Hearing Disorders, 37, 329-346.

Fletcher, S. G., Adams, L. E., and McCutcheon, M. J. (1989). Cleft palate speech assessment through oral nasal acoustic measures. In K. R. Bzoch (Ed.), Communicative Disorders Related to Cleft Lip and Palate (pp. 246–257). Boston: Little, Brown.

Gonzalez Landa, G., Sanchez-Ruiz, I., Santos Terron, M.J., Miro Viar, J.L., and Sanchez-Ruiz, I. (1990). [Post-adenoidectomy velopharyngeal insufficiency in children with velopalatine clefts]. Acta Otorrinolaringologica Espanola, 51(7), 581-586.

Haapanen, M.L. (1991). Nasalance scores in normal Finnish speech. Folia Phoniatrica, 43, 197-203.

Hirschberg, J., Bok, S., Juhasz, Trenovszki, Z., Votisky, P., and Hirschberg, A. (2006). Adaptation of nasometry to Hungarian language and experiences with its clinical application. International Journal of Pediatric Otorhinolaryngology, 70, 785-798.

Hutchinson, J.M., Robinson, K.L., and Nerbonne, M.A. (1978). Patterns of nasalance in a sample of normal gerontologic subjects. Journal of Communication Disorders, 11, 469-481.

Krakow, R.A. and Hufffman, M.K. (1993). Instruments and techniques for investigating nasalization and velopharyngeal function in the laboratory: An introduction. In M.K. Huffman and R.A. Krakow (eds.), Phonetics and Phonology: Nasals, Nasalization, and the Velum, Volume 5. Academic Press: San Diego, (pp. 3-59).

Kummer, A.W. (2008). Cleft Palate and Craniofacial Anomalies: Effects on Speech and Resonance, 2nd Edition. Delmar Cengage Learning: Clifton Park, NJ.

Kummer, A.W. (2005). The MacKay-Kummer SNAP Test-R: Simplified nasometric assessment procedures. KayPENTAX. Retrived 9/25/2010, from http://www.kaypentax.com/index.php?option=com_support&controller=support_miscellaneous&task=view&menu_id=4&Itemid=4&task=download&file=MacKay-Kummer SNAP Test-R 2005.pdf

Kummer, A.W., Myer, C.M.I., Smith, M.E., and Shott, S.R. (1993). Changes in nasal resonance secondary to adenotonsillectomy. American Journal of Otolaryngology, 14(4), 285-290.

Lee, A. and Browne, U. (2008). Nasalance scores for normal Irish-English speaking adults; A cross-gender comparative study. Paper presented at the annual convention of the American Speech-Language-Hearing Association, Chicago, IL.

Leeper, H.A., Rochet, A.P., and MacKay, I.R. (1992). Characteristics of nasalance in Canadian speakers of English and French. Proceedings of the International Conference on Spoken and Language Processes, 5, 49-52.

Lewis, K.E. and Watterson, T. (2003). Comparison of nasalance scores obtained from the Nasometer and the NasalView. Cleft Palate-Craniofacial Journal, 40, 40-45.

Litzaw, L.L. and Dalston, R.M. (1992). The effect of gender upon nasalance scores among normal adult speakers. Journal of Communication Disorders, 25, 55-64.

MacKay, I.R. and Kummer, A.W. (1994). Simplified nasometric assessment procedures. In Kay Elemetrics Corp. (Ed.), Intruction Manual: Nasometer Model 6200-3 (pp. 123-142). Lincoln Park, NJ: Kay Elemetrics Corp.

Mayo, R., Floyd, L.A., Warren, D.W., Dalston, R.M., and Mayo, C.M. (1996). Nasalance and nasal cross-sectional area: Cross-racial study. Cleft Palate-Craniofacial Journal, 33, 143-149.

McHenry, M.A. (1999). Aerodynamic, acoustic, and perceptual measures of nasality following traumatic brain injury. Brain Injury, 13, 281-290.

Mishima, K., Sugii, A., Yamada, T., Imura, H., and Sugahara, T. (2008). Dialectal and gender differences in nasalance scores in a Japanese population. Journal of Cranio-Maxillofacial Surgery, 36, 8-10.

Moon, J.B. (1992). Evaluation of velopharyngeal function. In K.T. Moller and C.D. Starr (eds.), Cleft Palate: Interdisciplinary Issues and Treatment. Pro-Ed: Austin, TX, (pp. 251-310).

Nandurkar, A. (2002). Nasalance measures in Marathi consonant-vowel-consonant syllables with pressure consonants produced by children with and without cleft lip and palate. Cleft Palate-Craniofacial Journal, 39, 59-65.

Nellis, J., Neiman, G., and Lehman, J. (1992). Comparison of Nasometer and listener judgments of nasality in the assessment of velopharyngeal function after pharyngeal flap surgery. Cleft Palate Craniofacial Journal, 29, 157-163.

Nichols, A.C. (1999). Nasalance statistics for two Mexican populations. Cleft Palate-Craniofacial Journal, 36, 58-63.

Nieminen, P., Lopponen, H., Varynen, M. Tervonen, A., and Tolonen, U. (2000). Nasalance scores in snoring children with obstructive symptoms. International Journal of Pediatric Otorhinolaryngology, 52(1), 53-60.

Pannbacker, M., Lass, N.J., Scheurle, J.F., and English, P.J. (1992). Survey of services and practices of cleft palate-craniofacial teams. Cleft Palate-Craniofacial Journal, 29, 165-167.

Prathanee, B., Thanaviratananich, S., Pongjunyakul, A., and Rengpatanakij, K. (2003). Nasalance scores for speech in normal Thai children. Scandinavian Journal of Plastic and Reconstructive and Hand Surgery, 37, 351-355.

Prunkngarmpun, C., Sumita, Y.I., and Taniguchi, H. (2008). Three monosyllables for standard words in Nasometer test: To evaluate air leakage in maxillectomy patients. Journal of Japan Prosthodontic Society, 52, 507-512.

Rieger, J., Wolfaardt, J., Seikaly, H., and Jha, N. (2002). Speech outcomes in patients rehabilitated with maxillectomy obturator prostheses after maxillectomy: A prospective study. International Journal of Prosthodontics, 15(2), 139-144.

Rochet, A.P. Rochet, B.L., Sovis, E.A., and Mielke, D.L. (1998). Characteristics of nasalance in speakers of western Canadian English and French. Journal of Speech-Language Pathology and Audiology, 22, 94-103.

Roy, N., Leeper, H.A, and Blomgren, M. (2001). A description of phonetic, acoustic, and physiological changes associated with improved intelligibility in a speaker with spastic dysarthria. American Journal of Speech-Language Pathology, 10, 274-290.

Santos-Terron MJ, Gonzalez-Landa G, Sanchez-Ruiz I. (1991). Normal patterns of nasalance in children who speak Castilian [in Spanish]. Revista Espanola Foniatrica, 4, 71–75.

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 and Hearing Research, 30, 522-529.

Shin, H.B. and Kominski, R.A. (2010). Language Use in the United States: 2007, American Community Survey Reports, ACS-12. U.S. Census Bureau, Washington, DC.

Skinder-Meredith, A., Carkoski, S., and Graf, N. (2004). A comparison of nasality measures between children with childhood apraxia of speech, children with repaired cleft palate, and typically developing children. SpeechPathology.com, 3, Available at http://www.speechpathology.com/articles/article_detail.asp?article_id=227.

Soneghet, R., Santos, R.P., Behlau, M., Habermann, W., Friedrich, G. and Stammberger, H. (2002). Nasalance changes after functional endoscopic sinus surgery. Journal of Voice, 16, 392-397.

Sweeney, T., Sell, D., and O’Regan, M. (2004). Nasalance scores for normal Irish-speaking children. Cleft Palate-Craniofacial Journal, 41, 168-174.

Tachimura, T., C. Mori, et al. (2001). Nasalance score variation in normal adult Japanese speakers of Mid-West Japanese dialect. Cleft Palate-Craniofacial Journal, 37, 463-467.

Tatchell, J.A., M. Stewart, and P.R. LaPine (1991). Nasalance measurements in hearing-impaired children. Journal of Communication Disorders, 24, 275-285.

Van Doorn, J. and Purcel, A. (l998). Nasalance levels in the speech of normal Australian children. Cleft Palate-Craniofacial Journal, Vol. 35, 287-92.

Van Lierde John Van Borsel, Cardinael, A., Reeckmans, S., and Bonte, K. (2011). The impact of vocal intensity and pitch modulation on nasalance scores: A pilot study. Folia Phoniatrica et Logopedia, 63, 21-26.

Van Lierde, K.M., Wuyts, F.L., De Bodt, M., and Van Cauwenberge, P. (2003). Age-related patterns of nasal resonance in normal Flemish children and young adults. Scandinavian Journal of Plastic and Reconstructive and Hand Surgery, 37, 344-350.

Van Lierde, K.M., Van Borsel, J. and M. Moerman (2002). Nasalance, nasality, voice, and articulation after uvulopalatopharyngoplasty. Laryngoscope, 112, 873-878.

Watterson, T., McFarlane, S, and Wright, D.S. (1993). The relationship between nasalance and nasality in children with cleft palate. Journal of Communication Disorders, 35, 13-28.

Wenke, R.J., Theodoros, D., Cornwell, P. (2010). Effectiveness of Lee Silverman Voice Treatment (LSVT)® on hypernasality in non-progressive dysarthria: the need for further research. International Journal of Language and Communication Disorders, 45, 31-46.

Whitehill, T. L. (2001). Nasalance measures in Cantonese-speaking women. Cleft Palate-Craniofacial Journal, Vol. 38, 119-125.

Williams, R.G., Eccles, R., and Hutchings, H. (1990). The relationship between nasalance and nasal resistance to airflow. Acta Otolaryngology (Stockholm), 110(5/6), 443-449.

Williams, R.G., Preece, M., Rhys, R., amd Eccles, R. (1992). The effect of adenoid and tonsil surgery on nasalance. Clinical Otolaryngology and Allied Sciences, 17(2), 136-140.

Zajac, D.J., Lutz, R., and Mayo, R. (1996). Microphone sensitivity as a source of variation in nasalance scores. Journal of Speech and Hearing Research, 39, 1228-1231.

Zajac, D.J. and Mayo, R. (1996). Aerodynamic and temporal aspects of velopharyngeal function in normal speakers. Journal of Speech and Hearing Research, 39, 1199-1207.

Zajac, D.J., Mayo, R., Kataoka, R., and Kuo, J.Y. (1996). Aerodynamic and acoustic characteristics of a speaker with turbulent nasal emission: A case report. Cleft Palate-Craniofacial Journal, 33, 440-444.

About the Author(s)

Carolyn M. Mayo, PhD, CCC-SLP is an Associate Professor in the Division of Speech-Language Pathology & Audiology, Department of English/Speech at North Carolina A&T State University in Greensboro, North Carolina. E-mail: cmmayo@ncat.edu.

Robert Mayo, PhD, CCC-SLP is a Professor in and Head of the Department of Communication Sciences and Disorders at the University of North Carolina at Greensboro in Greensboro, North Carolina. E-mail: r_mayo@uncg.edu.