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# NORMATIVE VALUES OF NASAL RESONANCE: PRELIMINARY DATA FOR POLISH WORKING-AGE ADULTS

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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## Abstract

**Introduction:** Evaluation of nasal resonance is an important part of everyday otolaryngological, phoniatric, and speech therapy practice. It allows the detection and monitoring of anatomical and functional abnormalities in the nasal and oropharyngeal cavities. Nasal resonance can be objectively measured by assessing acoustic energy emitted by each of the subject's nose and mouth. The ratio is called nasalance. The aim of this study was to develop normative values of nasal resonance on a digital device while adults were reading aloud Polish-language material.

**Material and methods:** The study included 51 patients. Patients were tested with three language tests developed by Gąsiorek in 1996. Nasal resonance was measured using a Nasometer II (Model 6450) from Pentax Medical.

**Results:** The mean nasalance in the vowel test was 18.8% (*SD* = 7.8%). The mean nasalance during the test based on sentences was 14.3% (*SD* = 4.0%), and for reading continuous text it was 11.7% (*SD* = 3.7%). Statistical analysis showed no significant difference between men and women on each test. The limiting normative value for nasalance was determined to be 20% in the sentence test (test III of Gąsiorek 1996).

**Conclusions:** 1. Preliminary normative values of nasal resonance for Polish adults have been established based on current methodology. 2. Language tests developed and already in use can be applied to modern digital devices.

**Key words:** speech • nasality • Polish population • nasal resonance • nasometer • nasalance

# WARTOŚCI NORMATYWNE REZONANSU NOSOWEGO DOROSŁYCH POLAKÓW W WIEKU PRODUKCYJNYM – DANE WSTĘPNE

## Streszczenie

**Wprowadzenie:** Ocena rezonansu nosowego pacjentów stanowi istotny element codziennej praktyki otolaryngologicznej, foniatrycznej i logopedycznej. Umożliwia wykrywanie i monitorowanie anatomicznych i funkcjonalnych nieprawidłowości w jamie ustnej oraz gardle. Rezonans nosowy można obiektywnie zmierzyć poprzez ocenę energii akustycznej emitowanej przez nos i usta pacjenta. Uzyskany w ten sposób stosunek nazywany jest nosowością. Celem niniejszego badania było opracowanie wartości normatywnych rezonansu nosowego na urządzeniu cyfrowym podczas artykulacji dla osób dorosłych przy użyciu polskojęzycznych testów językowych.

**Materiał i metody:** W badaniu wzięło udział 51 osób. Pacjenci zostali przebadani wybranymi testami językowymi opracowanymi przez Gąsiorka. Badania rezonansu nosowego wykonano przy użyciu urządzenia Nasometer II: Model 6450, Pentax Medical.

**Wyniki:** Średni wynik nosowości w teście samogłoskowym wyniósł 18,8% (*SD* = 7,8%). Średni wynik nosowości podczas drugiego testu zawierającego zdania wynosił 14,3% (*SD* = 4,0%), a podczas czytania tekstu 11,7% (*SD* = 3,7%). Analiza statystyczna nie wykazała istotnych różnic pomiędzy mężczyznami i kobietami oraz wynikami uzyskanymi w poszczególnych testach. Wyznaczono graniczną wartość normatywnego wskaźnika nosowości: 20% w teście zdaniowym (test III wg Gąsiorka).

**Wnioski:** 1. Wartości normatywne nosowości dorosłych Polaków w wieku produkcyjnym zostały ustalone na podstawie aktualnych standardów metodologicznych. 2. Opracowane i stosowane dotychczas testy językowe mogą być stosowane w nowoczesnych urządzeniach cyfrowych.

**Słowa kluczowe:** mowa • nosowanie • populacja polska • rezonans nosowy • nazometr • nosowość

## Introduction

Evaluation of nasal resonance is an important part of everyday otolaryngological, phoniatric, and speech therapy practice. It allows the detection and monitoring of anatomical and functional abnormalities in the nasal and oropharyngeal cavities. The subjective assessment of an abnormal nasal resonance value in speech is called nasality. There are three types of nasality: hyponasal speech (called closed nasality), hypernasal speech (open nasality), and mixed nasality. Hyponasality includes cases of decreased nasal resonance as a result of pathology in the nasal cavities or nasopharynx [1]. Hypernasality, on the other hand, is a consequence of an abnormal functional separation of the oral cavity and oropharynx from the nasopharynx and nasal cavities. The organic causes of hypernasal speech are either congenital or an acquired defect. Nasality may also result from paresis or paralysis due to neurological diseases, skull base tumor, or infectious disease [2]; it may also have a functional, habitual basis [3].

In contrast to the subjective term nasality, the objective measure is called nasalance. Fletcher defined this parameter as the ratio of nasal resonance to the sum of nasal and oral resonances [4]. Modern methods of assessing nasal and oral resonances compare the acoustic energy emitted by the subject's nose and mouth. The measurement is performed using 2 directional microphones placed in parallel and separated by a divider (**Figure 1**). The results are presented graphically as the ratio of the energy emitted while speaking through the nose to the sum of the energy emitted through the nose and mouth. The ratio, expressed as a percentage, is called nasalance [5].

Appropriate language tests for the Polish population were first developed in the 1990s by Gąsiorek et al. [4,6]. The authors measured nasal resonance in the Polish population using a custom-made nasometer [4,6]. The original measurements were based on analog recording technique, but nowadays the availability of digital devices in everyday clinical practice allows for greater accuracy. However, due to methodological changes in measurements, it is advisable to verify the accepted normative values.

The aim of this study was to develop normative values of nasalance on a digital device during articulation from adults using Polish-language material. Another goal was to confirm whether the language tests created in the past to assess nasal resonance for the Polish language can be applied in modern digital devices.

## Material and method

The study included 51 native Polish speaking subjects with normal speech development (as assessed by a speech therapist), normal hearing (based on the result of tonal audiometry), and no abnormalities in otolaryngological examination. Only healthy volunteers from the working age population between the ages of 25 and 60 were included, and those with a history of head or neck trauma or surgery were excluded. Participants gave informed consent, and the study was conducted in accordance with the Declaration of Helsinki. Volunteers were tested with selected language tests developed by Gąsiorek [4] which have been adapted to the characteristics of the Polish language. By selecting test material with an appropriate number of nasal sounds, velopharyngeal efficiency can be examined.

Our pilot study on a smaller number of people showed that the language tests developed in the past for Polish language are suitable for tests recorded on modern digital devices [7]. In our study Tests I, III, and VII were used (**Table 1**). Tests I and VII do not contain nasal vowels, only in Test III there is one nasal vowel.

Nasal resonance tests were performed using a nasometer (Nasometer II, model 6450, Pentax Medical, Lincoln Park, USA with software 2.6), following the procedure in the manual (**Figure 1**). The device is placed on the head of the person to be tested and fixed with an elastic band. A separator plate sits firmly between the nose and upper lip. Acoustic energy is measured by two directional microphones placed on either side of the divider. According to the manufacturer's data, the isolation of the plate is about 25 dB [7]. The test was done in an audiometric cabin.

**Table 1.** The various tests according to Gąsiorek [4]

| No. of test according to Gąsiorek [4] | Original content | Content translated into English |
|---|---|---|
| Test I (vowels) | i, y, u, a, o, e | i, y, u, a, o, e |
| Test III (sentences) | Kotek zeskoczył na drugi szczebelek. Kto i kiedy spotkał go u Krzyśka? | The kitten jumped down to the second step. Who met him at Christopher's place and when? |
| Test VII (continuous text) | Dzieci bardzo lubiły przychodzić do parku. Zwykle siadały obok starych akacji i układały wyrazy z patyków albo grały w klasy. Co jakiś czas przerywały swoje zabawy i bez jakiegoś oczywistego powodu biegły wzdłuż szerokiej parkowej alei, by po chwili wrócić pod akacje. Od czasu do czasu zabierały też do parku psa, który biegał dookoła figurki skrzata z bajki i wesoło poszczekiwał. Beztroskie chwile upływały szybko i fakt, że trzeba już opuścić park zawsze dzieci zaskakiwał. | The children really enjoyed coming to the park. Usually they would sit next to the old acacias and make words out of sticks, or play a game of class. Every now and then they would stop their games and for no apparent reason run along the wide park avenue, only to return a short while later under the acacias. From time to time they also took their dog to the park, which ran around the fairy tale gnome figurine and barked merrily. Carefree moments passed quickly, and the fact that they had to leave the park always surprised the children. |

**Figure 1.** The Nasometer II device (Pentax Medical model 6450) used for nasal resonance imaging

Statistical analysis was performed using Microsoft Excel. A Shapiro–Wilk test was carried out to check the normality of data distributions. A Student's *t*-test was used to compare the mean results for women and men. The level of statistical significance was set at $p < 0.05$.

## Results

The study included 51 people. Their mean age was 41 years ($SD = 9.4$ years). The group was divided into two subgroups based on gender. The group of women consisted of 25 subjects (mean age 41.0 years, $SD = 9.5$). The male group consisted of 26 subjects (mean age 41.5 years, $SD = 9.6$).

The mean nasalance in the vowel test (Gąsiorek test I) in the whole study group was 18.8% ($SD = 7.8\%$). The minimum nasalance during this test was on average 4.0% ($SD = 3.4\%$) and the maximum 69.4% ($SD = 19.3\%$). The subjects performed the test in an average of 6 seconds ($SD = 2.4$).

The mean nasalance scores during the second test containing sentences (Gąsiorek test III) in the whole study group was 14.3% ($SD = 4.0\%$). The minimum percentage of nasalance was 2% ($SD = 1\%$) and the maximum 91.5% ($SD = 5.9\%$). The subjects performed the test in an average time of 5.4 seconds ($SD = 1.1$).

In the last test, performed while reading continuous text (Gąsiorek test VII), the subjects performed at an average of 11.7% ($SD = 3.7\%$), with a minimum of 1% ($SD = 0.3\%$) and a maximum of 88.9% ($SD = 9.2\%$). The subjects performed the test in an average time of 35.3 seconds ($SD = 4.5$).

During our research with the digital device, no obstacles were encountered in using the language tests developed by Gąsiorek, the use of which was previously described only on analogue devices. **Figures 2–4** show the mean nasalance values for the entire study group and by gender. **Table 2** shows the results obtained for men and women in all three tests. Statistical analysis showed no significant differences between men and women ($p < 0.05$).

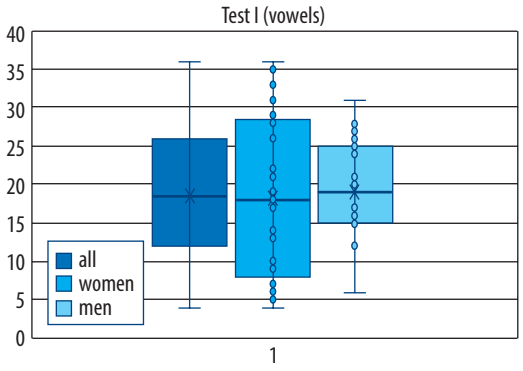


**Figure 2.** Box-and-whisker plot of mean values of nasalance in the entire study group, and by gender, from the Gąsorek test I based on vowels

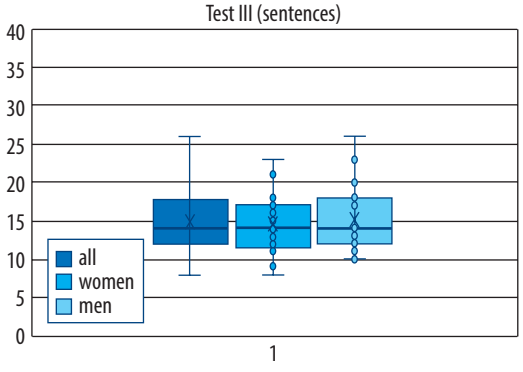


**Figure 3.** Mean values of nasalance in the entire study group, and by gender, from the Gąsorek test III based on sentences

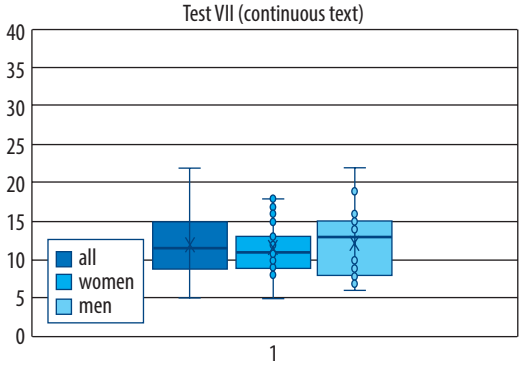


**Figure 4.** Mean values of nasalance in the entire study group, and by gender, in the Gąsorek test VII based on continuous text

**Figure 5** shows histograms of the mean nasalance values for all three tests. Based on a Shapiro–Wilk test for normality of the obtained distributions for test I and test VII, the hypothesis of normality of the population distribution can be rejected at $p < 0.05$. This means that normative values for these two tests cannot be determined from the collected sample. For test III, however, the hypothesis of normality of the distribution cannot be rejected ($p < 0.05$). Therefore, the limiting value of the normative nasalance

**Table 2.** Mean values of individual tests with minimum and maximum values, presented by gender

| Study group by gender | | Test I | | | Test III | | | Test VII | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | mean | min | max | mean | min | max | mean | min | max |
| Women | | 18.3 | 4.1 | 67.9 | 14.5 | 1.9 | 93.0 | 11.6 | 1.0 | 89.6 |
| | *SD* | 10.3 | 4.1 | 22.8 | 3.7 | 0.9 | 3.4 | 3.3 | 0.2 | 10.1 |
| Men | | 19.0 | 4.1 | 71.3 | 15.2 | 2.2 | 89.6 | 12.2 | 1.2 | 88.0 |
| | *SD* | 6.4 | 2.1 | 16.7 | 4.6 | 1.1 | 8.3 | 4.2 | 0.4 | 8.4 |

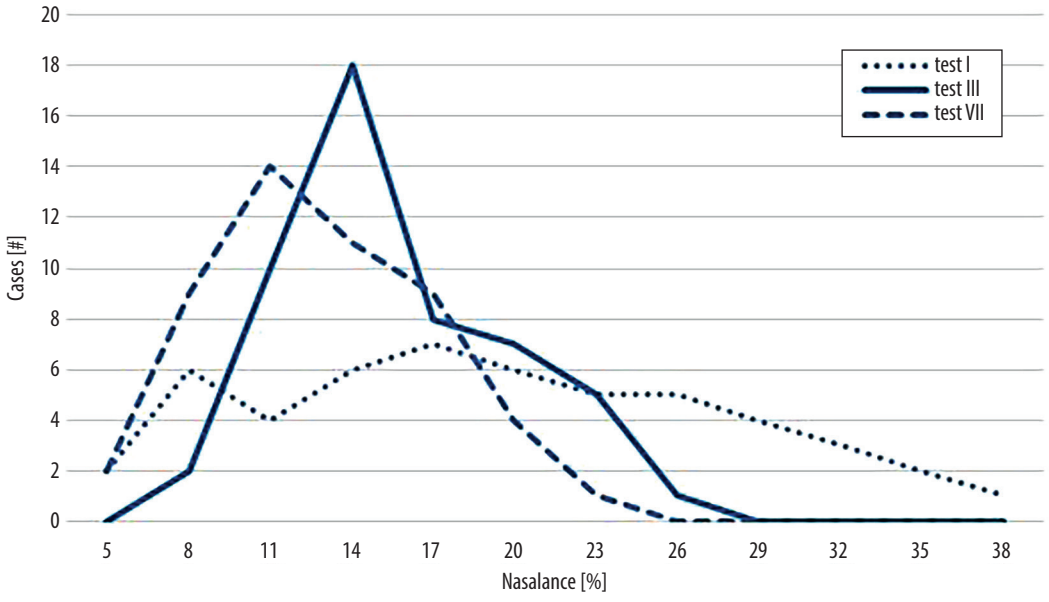


**Figure 5.** Histograms of mean nasalance from tests I, III, and VII

index was determined by adding one standard deviation to the mean value in the studied population. Thus, the normative value obtained with one nasality test (Gąsiorek's test III for sentences) was determined to be 20% (**Figure 6**).

## Discussion

Normative values for nasality were first developed in English by Fletcher and collaborators [8]. A review of the literature suggests that nasality values are not constant and are language dependent [9]. Currently in Poland normative values from the 1990s, developed by Gąsiorek, are used. Gąsiorek's data were recorded and collected on an analogue device. It has been found that the colloquial speech test, containing only oral sounds (test VII), correlates best with the degree of nasalance [10]. In general, the results obtained by Gąsiorek averaged 15.2% while in colloquial speech they averaged 25.6% [4,6]. In addition, the average nasalance values for test VII in the group of children were found to be 17.8%, while for girls and women it was 14.3% and for boys and men 13.5%.

Our own earlier pilot study conducted on a smaller group of people, together with the current research, has shown that it is reasonable to use language tests on modern digital nasometers even though they were developed for analogue

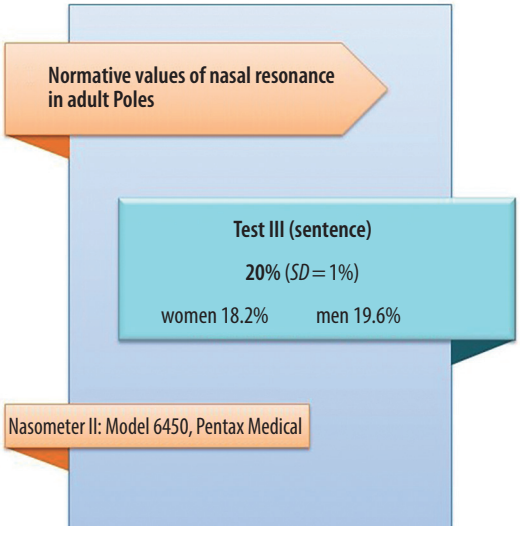


**Figure 6.** Normative values of nasal resonance were established as 20 ± 1% for Polish working age adults based on Test III (sentences)

devices [7]. However, as Woo and colleagues have shown, differences in measurement equipment can cause discrepancies of up to several percent, despite the same language tests being used [11]. This suggests that measurement standards should be checked and adjusted whenever there are significant changes in recording methods [12].

According to the literature, nasality may vary by gender, age, dialect, and race [13–15]. The precise relationship between the acoustics of oral–nasal coupling and the perception of hypernasality remains unclear; nevertheless, measuring oral and nasal outputs is useful in evaluating and treating resonance disorders [16].

In our study, a group of adults was examined on a digital nasometer. The methodology, including digital recording and analysis using computer software, are fundamentally different from measurement methods used in the past. In addition, modern microphones and digital sound processing provide greater measurement accuracy. The group studied here was based on established criteria, and statistical analysis showed no significant difference between the genders. The mean values of nasalance in test VII for women was 11.6% and for men 12.2%.

The results of the present study have allowed us to determine normative values of nasalance in Polish working-age adults. Our results with a digital nasometer have allowed us to determine a normative nasalance value for adults in test III of 20% (**Figure 6**). Due to the non-normal distribution of results, no corresponding normative values can be set for tests I and VII.

Our results can be used as a guide for further studies on a larger numbers of people. Analysis of the results showed that test I (based on vowels only) had the greatest range of results. However, it is the easiest test to administer, allowing it to be widely used. In our study, the recording of both test I and test III took only about 6 seconds each. Due to their brevity and simplicity, these tests can be easily used in a pediatric population. Children who cannot read can be encouraged to memorise each of the sentences used in Test III. The mean percentage of nasalance obtained here from test VII (continuous text) was similar to the results obtained in test III (sentences) (see histogram in **Figure 5**). According to recommendations published earlier by Gąsiorek, test VII should be the primary method in assessing nasalance in adults [4]. However, in our opinion, test III seems to be more practical due to the similar results of tests III and VII, the short period of time needed for measurement, and the ease with which it can assess children. Its potential needs to be confirmed on a larger population of subjects.

According to the literature, new methods of speech assessment are now available [17,18]. The introduction of objective tests in the diagnosis of speech disorders is particularly useful not only in making a diagnosis, but also in improving treatment and rehabilitation [19]. Further work on adults and children is needed, as well as verification and updating of current standards and classification ranges for nasality. Further research should include digital assessment of patients with palatopharyngeal insufficiency. The normative values developed here provide a starting point for updating clinical standards. Nasometry has undeniable value in a wide range of clinical applications regardless of the patient's age [20,21].

## Conclusions

1. A normative value of nasalance in working-age adult Poles was established at 20 ± 1% based on current methodology.
2. The language tests developed and already in use can be transferred to modern digital devices.

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