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Original Article

Artigo Original

# Nasopharyngeal dimensions in normal individuals: normative data

## *Dimensões nasofaríngeas em indivíduos sem anomalias craniofaciais: dados normativos*

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**Keywords**

Nasopharynx
Respiration
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Reference Values

## ABSTRACT

**Objective:** To establish normative values of minimum cross-sectional nasopharyngeal area in individuals without craniofacial anomalies at different age ranges. **Material and Method:** Ninety-six individuals of both genders, without craniofacial anomalies, and with normal body mass index and neck circumference were evaluated. Participants were divided into 4 age groups: children, aged 6 to 10 years (G1); adolescents, aged 11 to 17 years (G2); young adults, 18 to 39 years (G3), and middle-aged adults, 40 to 59 years (G4). Minimum cross-sectional nasopharyngeal area (nasopharyngeal area – NPA) was assessed by means of modified anterior rhinomanometry (pressure-flow technique) using a PERCI-SARS system (version 3.50 – Microtronics Corp.). **Results:** Mean±SD values of NPA were 1.025±0.054cm$^2$, 1.055±0.081cm$^2$, 1.050±0.083cm$^2$, and 1.054±0.081cm$^2$, respectively for groups G1, G2, G3, and G4, showing that there were no differences between the four age groups. **Conclusion:** Normative data of NPA were established for individuals without craniofacial anomalies from different age ranges, and they may be used as reference values in the clinical routine and for future studies regarding nasopharyngeal obstruction diagnosis, particularly in cases of craniofacial anomalies.

**Descritores**

Nasofaringe
Respiração
Rinomanometria
Fenda Palatina
Valores de Referência

## RESUMO

**Objetivo:** Determinar os valores controles da área de secção transversa mínima nasofaríngea de indivíduos sem anomalias craniofaciais e em diferentes faixas etárias. **Material e Método:** Participaram do estudo 96 indivíduos sem anomalias craniofaciais, de ambos os sexos, com índice de massa corpórea e circunferência cervical normais, subdivididos em 4 grupos etários: crianças com idade entre 6 e 10 anos (G1), adolescentes de 11 a 17 anos (G2), adultos jovens entre 18 e 39 anos (G3) e adultos de meia-idade entre 40 e 59 anos (G4). A área seccional transversa mínima nasofaríngea (área nasofaríngea – ANF) foi determinada por meio de rinomanometria anterior modificada (técnica fluxo-pressão), utilizando o sistema PERCI-SARS (versão 3.50 – Microtronics Corp.). **Resultados:** Os valores médios±DP da ANF foram de 1,025±0,054cm$^2$, 1,055±0,081cm$^2$, 1,050±0,083cm$^2$ e 1,054±0,081cm$^2$, respectivamente, para G1, G2, G3 e G4, não havendo diferença entre as 4 faixas etárias. **Conclusão:** Os valores controles da ANF foram determinados para indivíduos sem anomalias craniofaciais de diferentes faixas etárias e servirão de referência na rotina clínica e em estudos envolvendo diagnóstico de obstrução nasofaríngea, principalmente na presença de anomalias craniofaciais.

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## INTRODUCTION

Breathing and speech are the most impaired orofacial functions in the presence of craniofacial anomalies, especially cleft lip and palate. Even after primary surgical repair of the lip and palate, nasal deformities are common, leading to a reduction of nasal cavity dimensions[1,2] and an increase of the proportion of oral breathers in this population[3,4]. According to literature, it is estimated that 60% of individuals with cleft lip and palate present with a compromised nasal airway leading to an oral breathing that may influence the craniofacial development, lower airway performance and speech, chewing and swallowing functions[5].

Speech disorders are common in patients with cleft lip and palate. In some cases, primary surgeries are not enough for an adequate velopharyngeal function, resulting in specific speech symptoms, such as hypernsality, nasal air emission and weak intraoral pressure. In these cases, a secondary surgery involving the palate and pharyngeal area is necessary in the attempt to correct velopharyngeal insufficiency (VPI)[6-9].

Pharyngeal flap is a surgical procedure widely applied in the VPI management. This method aims to create a partial mechanical nasopharyngeal obstruction, favoring velopharyngeal closure during the speech[9,10]. Thus, due to the pharyngeal patency reduction caused by the flap, some cases may exhibit respiratory changes resulting from the nasopharyngeal obstruction[11].

Therefore, the knowledge of nasal and nasopharyngeal dimensions is essential for the diagnosis and treatment of changes due to upper airways patency, as well as to the follow-up of different procedures repercussion involving the rehabilitation of orofacial functions in craniofacial anomalies. Instrumental methods of evaluation, among which we highlight the rhinomanometry with the pressure-flow technique[12] are employed in order to measure the nasal and nasopharyngeal airway, help with the diagnosis of respiratory changes and follow up therapeutic procedures.

The pressure-flow technique is based on the principle that the cross-sectional area of a constriction (or orifice) may be estimated by the simultaneous measurement of the differential pressure between the two sides of the constriction and the rate of airflow through it[13]. In children and adults without craniofacial abnormalities, the normative values of the smallest nasal cross-sectional area (nasal area), as well as the lower limits of normality, from which the nasal obstruction is considered, were established. In adults, the lower values at 40mm$^2$ are indicative of reduced nasal patency. At 6 years old, for example, this limit is reduced to 14mm$^2$[7,13].

In cleft lip and palate population, several studies using the pressure-flow method confirmed the hypothesis that nasal cross-sectional area in adults is considerably smaller when compared to noncleft adults[1,13-17]. In the Laboratório de Fisiologia of the Hospital de Reabilitação de Anomalias Craniofaciais of the Universidade de São Paulo, researches verified that the cleft type affects the internal dimensions of the nasal cavity, considering that the bilateral cleft lip and palate has a nasal area significantly smaller than the isolated cleft palate, with the unilateral cleft lip and palate showing intermediate values[1].

Regarding the nasopharyngeal dimensions, determined by the pressure-flow technique, it is observed that this issue has been not much explored in the literature. The only preliminary study, performed at the Laboratório de Fisiologia of Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo, verified the average values of the nasopharyngeal cross-sectional section area in 40 individuals from 6 to 33 years old, with no craniofacial anomalies. The average value obtained for the total group was 78mm$^2$, with minimum of 57mm$^2$ and maximum of 80mm$^2$. However, some study limitations reinforce the need to obtain more normative data with higher control of variables such as age, nasal patency, dental and facial deformities, among other physical aspects[18].

The determination of normative data in different age groups is justified by the craniofacial features related to growth, as well as the specific therapeutic needs in the presence of a cleft lip and palate, in the different rehabilitation steps. In addition, the comparison of reference values allows the clinical practice to establish more effective proceedings.

Thus, knowing the consequences of the nasopharyngeal patency reduction on the respiratory function and quality of life, this study aimed to determine the control values for the nasopharyngeal minimum cross-sectional area in individuals with no craniofacial abnormalities in different age groups, using well controlled inclusion criteria.

## MATERIAL AND METHODS

### Participants

This study was approved by the local institutional review board (protocol 407.841). All participants and/or parents/guardians signed the informed consent form. We evaluated 96 individuals with no craniofacial abnormalities, both gender, subdivided into 4 age groups: Group 1 (G1): children between 6 and 10 years old; Group 2 (G2): adolescents between 11 and 17 years old; Group 3 (G3) young adults between 18 and 39 years old; and Group 4 (G4): middle-aged adults between 40 and 59 years. The number of individuals was defined after sampling planning, considering 5% alpha, test power of 80% and standard deviation of 9.0, according to preliminary study data[18].

Participants were selected from the local community based on the following inclusion criteria: adequate relationship between dental arches and tonsil grade 0 (tonsils in tonsillar fossa), 1 (tonsil occupies less than 25% of the oropharynx) or 2 (25% to 50% of the oropharynx)[19], according to the oral cavity inspection; body mass index (weight/height$^2$) indicating normal weight[20,21]; cervical circumference not suggesting risk of obesity and obstructive sleep apnea[22] for participants above 18 years old, and adequate nasal patency in the rhynomanometric exam by means of pressure-flow technique, considering each age group[13,23]. The procedures involved in the participant selection were performed in the Laboratório de Fisiologia of the Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo, by three experienced speech therapists including the principal investigator. Those that met the established criteria were immediately submitted to the study specific procedure.

The study did not include genetic syndromes, dental facial deformities, respiratory symptoms as nasal obstruction, mouth breathing, snoring and respiratory obstruction during sleep, individuals already submitted to nasal and/or orthognatic surgery. In the group of children and adolescents, tonsillectomy and adenoidectomy procedures were additional exclusion factors.

**Procedures**

The nasopharyngeal dimension was determined by the minimum nasopharyngeal cross-sectional area, herein called nasopharyngeal area (NPA) during nasal resting breathing by means of modified anterior rhinomanometry by pressure-flow technique using computerized PERCI-SARS system, updated version 3.50 (Microtronics Corp.), as shown schematically in Figure 1. The technique is based on the principle that the cross-sectional area of a constriction (or orifice) may be estimated by the simultaneous measurement of the differential pressure between the two sides of the constriction and the rate of airflow through it[23]. In this method, NPA is determined during resting breathing, positioning a catheter within the oral cavity and the other in the nostril with lower flow (identified by Glatzel mirror), which is held in position by an obturator. Both catheters measure static air pressures that are transmitted to pressure transducers. The nasal airflow is measured by means of a plastic tube adapted to the nostril of greater flow, which is connected to a heated pneumotachograph and also connected to a pressure transducer. The signals of the three transducers (nasal pressure, nasal oral pressure and flow) are sent to PERCI system for analysis by specific software. Measurements are made on the of the inspiratory and expiratory peak flows in two to four successive breaths. The area considered for analysis is the average of these multiple measures and is calculated by the equation: $A= V/k\ (2\Delta P/d)^{1/2}$, were A= orifice area in $cm^2$; V= nasal flow in $cm^3/s$; K= 0,65; ΔP= oral-nasal pressure in $dinas/cm^2$; d= air density ($0.001 g/cm^3$).

The NPA values calculated as $>1.200cm^2$ were adjusted to the exact value of $1.200cm^2$ since PERCI-SARS system does not guarantee the accuracy of measurements above this limit, according to the manufacturer's instructions.

**Data analysis**

The NPA mean (± SD) was calculated for each age group and for the total group of individuals. The difference between the average of the four age groups was verified by the Kruskal-Wallis

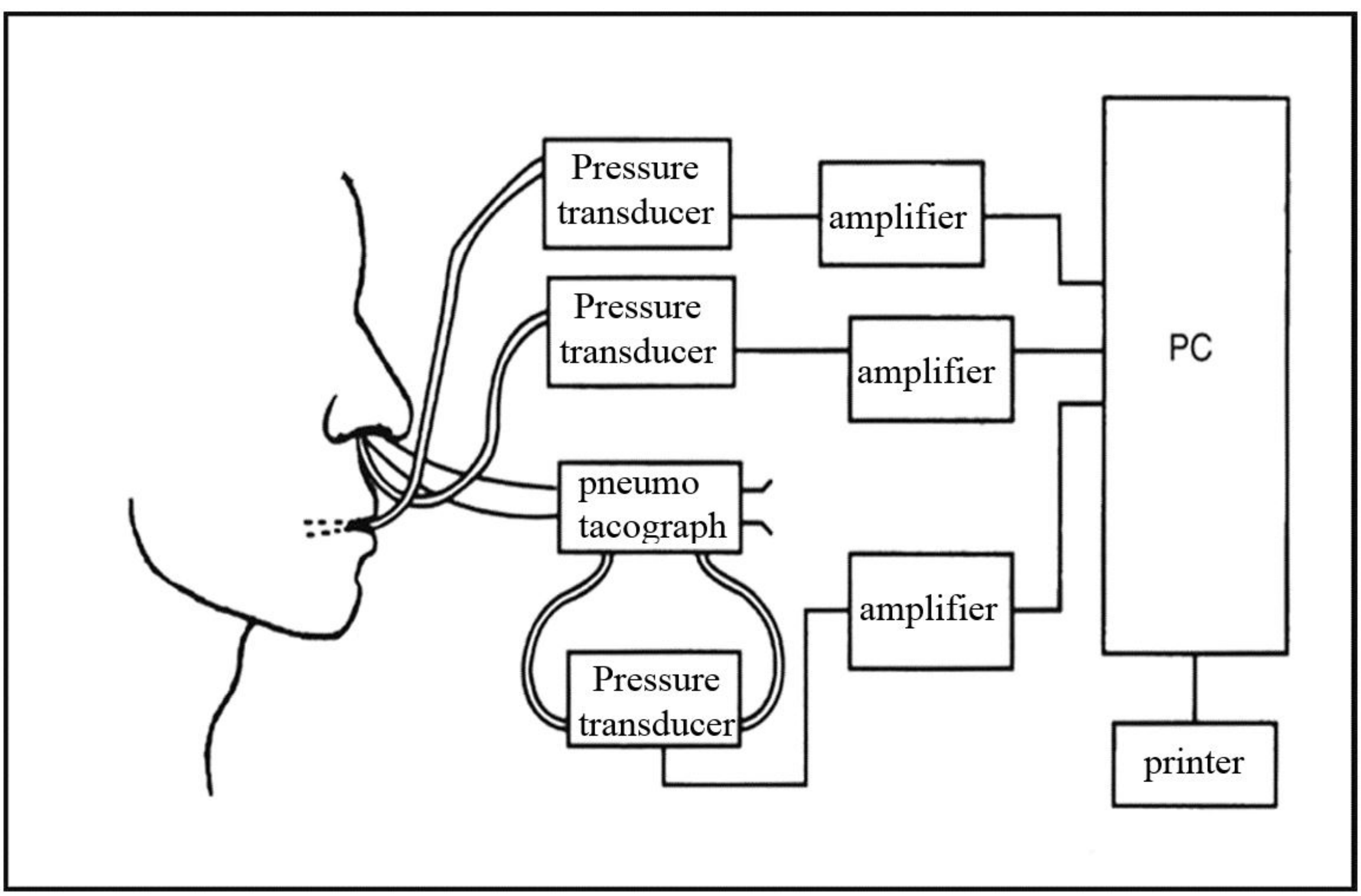


Figure 1. Schematic instrumentation for estimating the minimum nasopharyngeal cross-sectional area (PERCI-SARS system, Microtronics Corp.). Source: Trindade et al.[12]

test for unpaired samples. The comparison between genders in each age group was performed using the t test, with a significance level of 5%.

## RESULTS

Table 1 presents the mean age values of NPA from the 4 age groups. For children, mean NPA corresponded to 1.025±0.054cm$^2$, with values of 1.049±0.070cm$^2$ and 1.000±0.000cm$^2$, respectively for females and males, with no difference between genders (t test, p = 0.199). For the adolescents group, mean NPA corresponded to 1.055±0.081cm$^2$, with values of 1.037±0.065cm$^2$ and 1.077±0.094cm$^2$, respectively for females and males, with no difference between genders (t test, p = 0.116). In the group of young adults, the mean value for NPA was 1.050±0.083cm$^2$, with similar values of 1.050±0.816cm$^2$ and 1.050±0.090cm$^2$, respectively, for females and males (t test, p = 1.000). Finally, in the group of middle-aged adults, the average NPA corresponding to 1.054±0.081cm$^2$, with mean values of 1.031±0.063cm$^2$ e 1.081±0.093cm$^2$, respectively, for women and men, with no difference between them (t test, p = 0.065).

The total average value of each group was considered for the comparison between ages in which there was no difference in NPA among the four age groups (p = 0.622).

## DISCUSSION

With knowledge of the effects of cleft lip and palate on the respiratory function, the upper airway patency investigation must be part of the diagnosis process in this population. The concern relates mainly to the obstructive factors caused by the cleft itself, by changes in the craniofacial growth, primary surgery or even surgical procedures for the treatment of VPI, which may reduce the airway passage, preventing an efficient nasal breathing.

Thus, the use of specific instrumental methods that allow the measurement of nasal and nasopharyngeal dimensions is indicated for assisting in the diagnosis and verify the clinical impressions(12).

In this study, the rhinomanometry by pressure-flow technique was elected the procedure for the determination of nasopharyngeal dimensions. The technique is already used in studies and in clinical practice of the Laboratório de Fisiologia do Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo, there are approximately 20 years, giving considerable experience to researchers in the interpretation of its results.

The determination of control values is critical to the functionality of any diagnostic method that involves measurement of a variable. Therefore, strict sample selection criteria and well-controlled variables are crucial to ensure the reliability of data.

Thus, in order to eliminate or minimize some factors that could influence nasorespiratory function, the study used rigorous selection criteria. For the purpose of including only individuals with "normal" breathing, the nasal area has been previously determined by the posterior rhinomanometry. Thus, adults with nasal area under 0.400cm$^2$ and children with values below expectations for each age were not included in the study, even in the absence of respiratory complaints(5,13,14). Additionally, dentofacial deformities exclusion criteria also contributed to the composition of a control sample, since it may be related to the reduction of the nasopharyngeal space.

Another important factor in the sample selection was the strict criteria of "normal weight", measured from the anthropometric measurements of weight and height, and was adopted due to the close relationship between weight gain and reduced airway patency caused by increased pharyngeal adipose tissue, leading to respiratory symptoms during sleep, such as snoring and obstructive apnea(24).

In the case of children, one of the most important criteria was the control of aspects related to palatine tonsils and adenoids due to the significant influence on upper airways patency. Thus, the sample consisted of children without respiratory symptoms (mouth breathing, snoring and breathing disorders during sleep) and without history of palatine tonsils and adenoids removal. Complementing the variable control, the palatine tonsils were analyzed by oral inspection and only included participants with tonsil to grade 2, i.e. without significant interference in the oropharynx area.

Analyzing the findings of rhinomanometry, it was observed that children and adults presented nearly identical mean values of 1.025±0.054cm$^2$ and 1.054±0.081cm$^2$, respectively. This unexpected result led to some questions, since it does not seem to justify the conclusion that the nasopharynx does not change with age.

Unlike the observed in the present study, other researches observed a significant increase in the nasopharyngeal space, using cephalometric study, especially among children and adults, with a growth spurt especially at the stage of puberty(25).

From the 1990s, the technological advancement of imaging enabled by means of computed tomography, determining the airways dimensions in various segments of the pharynx. By means of this technique, subsequent studies have shown a proportional increase of the nasopharyngeal space along the craniofacial growth and determined the normative values for different age groups, from the age of 6 years(26). According to the study that analyzed 1300 CT scans of healthy individuals aged 6 to 60 years,

**Table 1.** Mean values±standard deviation of age and nasopharyngeal area (NPA) and minimum and maximum NPA values obtained from the 4 age groups: G1 (children), G2 (adolescents), G3 (young adults) and G4 (middle-aged adults) and from the total group

| Age groups | Age (years) | NPA±SD (cm$^2$) | Minimum value (cm$^2$) | Maximum value (cm$^2$) |
|---|---|---|---|---|
| G1 (n=20) | 8±2 | 1.025±0.054* | 0.966 | 1.182 |
| G2 (n=23) | 14±1 | 1.055±0.081* | 1.000 | 1.200 |
| G3 (n=28) | 26±4 | 1.050±0.083* | 1.000 | 1.200 |
| G4 (n=25) | 48±5 | 1.054±0.081* | 1.000 | 1.200 |
| Total (n=96) | 25±15 | 1.047±0.081 | 0.966 | 1.200 |

**Caption:** * p= 0,622, non-significant - Kruskal-Wallis test

> [...] the size and extent of air gradually increases up to 20 years, age in which there is a variable period of stability. After this period, the airway slowly reduces in size until 50, from which the decrease is faster to older ages(27). (p. 2182).

When analyzing the average values of nasopharyngeal minimum cross-sectional area of studies using computed tomography in normal individuals, it is observed that the average values determined by imaging are superior to those obtained by rhinomanometry in this study(26-28).

A study(28), for example, observed the average value of 174mm² when evaluating a control group of 10 volunteers with variation from 110 to 402mm². Another group of researchers found cross-sectional areas of 82.9±16.5mm² for children between 0 to 5 years old, 122.2±39.3mm² in the group between 6 and 11 years old, 165.4±48.5mm² in the age group between 12 and 16 years old and 179.4±51mm² for adults, when assessed 30 children under 16 years and 30 adults with no clinical evidence of nasopharyngeal diseases and larynx, complaints related to sleep nor diagnosis of obstructive sleep apnea(26).

Thus, it is possible to assume that the dimensions could be even greater than observed, especially in adults. The variation of 110 to 402mm² in normal adults helped in the understanding of the present study findings(28).

It occurs that pressure-flow technique uses nasal airflow and oral/nasal air pressure during breathing to calculate the area. Thus, according to the mathematical equation for the determination of the area is required a minimum differential pressure of 0.05cmH$_2$O to the upper limit, that corresponds to 1200cm², be calculated by the system (Microtronics Corp, personal communication). Areas above this value are displayed by the system as 1200cm². It is believed, therefore, that in the case of nasal and oral similar pressures, i.e. in the absence of constrictions to airflow passage, the differential pressure is minimal enough not to be captured.

A single study, also developed at the Laboratory of Physiology, addressed the reference values of the NPA by using the pressure-flow technique(18). Concerned with airway obstruction related to pharyngeal flap for the VPI treatment, the authors sought to determine reference values in 40 normal individuals aged 6-33 years. They found average value of 78mm² for the overall group, lower than the average of 105mm² observed in the 96 studied individuals. Among the factors that could explain this difference are the strict inclusion criteria of this study, which favored the composition of a homogeneous normal sample, and the fact that the maximum value allowed by the system used at the time was 80mm², for the same reasons already exposed.

Several years ago, studies employing pressure-flow technique in the diagnosis of reduced nasal patency and nasopharyngeal after pharyngeal flap surgery has been of great importance in the definition of therapeutic approaches of the Hospital de Reabilitação de Anomalias Craniofaciais. Researchers investigated the long-term effects of pharyngeal flap surgery on nasal and nasopharyngeal area, correlating nasopharyngeal dimensions to respiratory complaints. They found that pharyngeal flap produced a significant reduction in the dimensions of the upper airways, observed mainly in those with complaints of snoring, mouth breathing and obstructed breathing during sleep(11). Values below 57mm² were considered subnormal, whereas this was the minimum value observed in the first control study(18). Other researchers also observed by CT scan, average of 73mm² (63 to 95mm²) in patients with moderate apnea and 37mm² (14 a 52mm²) for a group of 28 patients with severe apnea(28).

Thus, in clinical practice, the pressure-flow technique has been shown to be a non-invasive method of great importance in the diagnosis of nasal respiratory disorders in the presence of cleft lip and palate. It is observed that is an effective method in determining areas suggesting obstruction due to constriction provides the physical parameters necessary to calculate the method.

Once certain values in normal individuals, we intend to initiate a series of investigations about the dimensions of the airways in specific clinical conditions and its relation to other aspects involved in the diagnosis, such as respiratory symptoms.

## CONCLUSION

This study determined the control values of the minimum nasopharyngeal cross-sectional area in individuals without craniofacial anomalies that may be used as reference values in the investigation of nasopharyngeal obstruction.

The determination of normative values also presents great importance in clinical practice, since it will assist in the diagnosis of respiratory changes related to nasopharyngeal region, mainly due to surgical treatment of VPI.

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## Author contributions

*LLA was responsible for data collection and analysis and article composition; ASCS collaborated with data collection and analysis; BMAMA collaborated with data collection and analysis; RPY collaborated with data analysis and article writing; IEKT participated in the data analysis and article writing; APF was responsible for the project, study design and overall orientation of execution steps and manuscript preparation.*