Perceptual-Auditory and Acoustical Analysis of the Voices of Transgender Women

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Summary: Voice is an important gender marker in the transition process as a transgender individual accepts a new gender identity. The objectives of this study were to describe and relate aspects of a perceptual-auditory analysis and the fundamental frequency (F0) of male-to-female (MtF) transsexual individuals. A case-control study was carried out with individuals aged 19–52 years who attended the Gender Identity Program of the Hospital de Clínicas of Porto Alegre. Vocal recordings from the MtF transgender and cisgender individuals (vowel /a:/ and six phrases of Consensus Auditory Perceptual Evaluation Voice [CAPE-V]) were edited and randomly coded before storage in a Dropbox folder. The voices (vowel /a:/) were analyzed by consensus on the same day by two judge speech therapists who had more than 10 years of experience in the voice area using the GRBASI perceptual-auditory vocal evaluation scale. Acoustic analysis of the voices was performed using the advanced Multi-Dimensional Voice Program software. The resonance focus and the degrees of masculinity and femininity for each voice recording were determined by listening to the CAPE-V phrases, for the same judges. There were significant differences between the groups regarding a greater frequency of subjects with F0 between 80 and 150 Hz ($P = 0.003$), and a greater frequency of hypernasal resonant focus ($P < 0.001$) in the MtF cases and greater frequency of subjects with absence of roughness ($P = 0.031$) in the control group. The MtF group of individuals showed altered vertical resonant focus, more masculine voices, and lower fundamental frequencies. The control group showed a significant absence of roughness.

Key Words: Transgender people–Voice–Brazil–Transsexual–Voice Quality.

INTRODUCTION

Gender dysphoria (GD) is a marked incongruence between one's experienced gender and one's assigned gender, resulting in a strong and persistent desire to belong to the other gender by hormone therapy, speech therapy, or surgical procedures.[1]

In general, transgender women desire a tone of voice consistent with their appearance.[2] Cisgender women have a higher fundamental frequency (F0) than cisgender men.[3] The expected F0 for the female voice in Brazil varies between 150 and 250 Hz.[4] However, the F0 of the cis masculine voice has been reported as between 100 and 150 Hz,[5] 80 and 150 Hz,[6] and 110 and 146.7 Hz.[7] In addition, other aspects of human communication, such as semantics, pragmatics, intonation, sound pressure level, and voice resonance, are relevant to the recognition of a female voice.

A study[8] aiming to quantify the perception of gender in telephone communication found that female transgender voices were perceived as more masculine than female cis voices. Only the voices of seven transgender women were recognized as female.[8] Transgender women tend to work their voice to raise their F0 through natural compensation, surgery, or speech therapy.

Changes in vocal resonance characteristics may contribute to the perception of femininity in the voices of transgender women.[9,10] In cisgender women, the formant frequencies are on average 20% higher than those of men[11] as a consequence of differences in anatomy (smaller resonance cavities and forward tongue carriage in women), ways of speaking, lip spreading, and smile formation.[9] The importance of oral resonance characteristics for gender identification is still not entirely clear. A study including 10 transgender women demonstrated that therapy targeting lip spreading and forward tongue carriage results in resonance characteristics that more closely approximate that of cisgender women.[9] Furthermore, analyzing 15 transgender women demonstrated that subjects with voices perceived as more female had vowel frequencies higher than those voices perceived as more masculine.[10]

One study examined the usefulness of phonetograms and aerodynamic measures for voice assessment of 25 male-to-female (MtF) transsexual individuals.[12] The results showed that breathiness is not significantly related to gender classification; the importance of F0 in gender perception was confirmed, and the speech sound pressure level was higher than the normal patterns of cisgender women.[12] The authors concluded that the

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Time of the study: January 2015 and July 2016.

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evaluated tools are important for visual feedback and documentation of changes in the vocal therapy of transgender people. In addition, the lower level of speech sound pressure may contribute to the feminization of transgender women voices.[12]

The GRBASI scale is based on the auditory perception of a trained therapist and relies on previously standardized assessment scales.[13] The scale is used internationally as a simple method to assess the overall degree of dysphonia (G). The evaluator identifies four independent aspects: roughness (R), breathiness (B), asthenia (A), and strain (S), which is considered most important in the definition of a dysphonic voice. Subsequently, the authors[14] added instability (I), which represents the fluctuation in vocal quality. The evaluator should establish a four-point scale, helping to identify the degree of each deviation of each of the factors (0 = normal or absent, 1 = mild, 2 = moderate, and 3 = severe). Such perceptual analysis is a subjective method because it depends on the judgment of one or more evaluators. This subjectivity still generates discussions among speech therapists; however, the contributions of the GRBASI scale to scientific evidence and clinical practice is indisputable.[15]

In contrast, acoustic analysis is an objective, noninvasive approach that allows for the integration of perceptual-auditory evaluation data with the physiological plane. It details the process of generating the sound signal and provides an indirect estimate of the vocal fold vibratory patterns to determine the individual's F0.[16,17]

The perceptual-auditory and vocal acoustic characteristics of the female transsexual individual associated with the perceptual evaluation of masculinity and femininity and the characteristics of the focus of resonance are not yet fully known. The present article aimed to describe and associate aspects of perceptual-auditory analysis and the F0 of the voices of transgender women.

METHODS

Design overview

This is a prospective case-control study.

Setting and participants

The institution's ethics committee approved this study (number 14075). All participants were informed regarding the procedure and signed the informed consent prior to participating in the research, according to Resolution 466/12 from the National Commission of Ethics in Research. The sample comprised 58 transgender women and 28 cisgender women recruited between January 2015 and July 2016 (Figure 1).

All transgender persons fulfilled the criteria for GD according to the DSM-5 criterion and were diagnosed by a specialized physician. The individuals diagnosed with GD attended both group and individual medical appointments on a biweekly basis in a GD outpatient clinic at the Hospital de Clínicas de Porto Alegre.

All transgender women included in this study had at least 2 years of experience as a woman and 1 year of hormonal therapy. Adolescents were excluded due to changes in vocal characteristics (DeCS, 2016), and subjects older than 55 years old were excluded on account of pronounced age alterations in their voices. Additional exclusion criteria included self-report of smoking, current use of illicit substances and/or alcoholism, hearing loss, self-report of consultation with a speech therapist or otorhinolaryngological treatment of laryngeal prominence, self-report of diseases that could interfere with efficient vocal production (such as gastroesophageal reflux disease and respiratory problems), or self-report of psychiatric or neurological diseases that could impede the comprehension of the study tasks. All transgender women included were androphiles and did not perform vocal therapy.

The following inclusion criteria were applied for selecting the control group: heterosexual cisgender women using contraceptives, with the aim of standardizing the sample, because the group of subjects also underwent hormonal treatment. We chose to include only heterosexual women because current literature suggests that the voice pitch characteristics, also called F0 features, of lesbians and gay men are shifted from what is typical for straight women and men.[18] Average voice pitch has been found to be lower in straight compared with gay men[19] and higher in straight women compared with lesbians.[20] Hence, we assumed gender-typical masculinity-femininity self-ratings to be reflected in gender-typical patterns of voice pitch characteristics. The same exclusion criteria for the cases were applied in the control group. Differently from the transgender sample, the control group was invited through websites and Facebook.

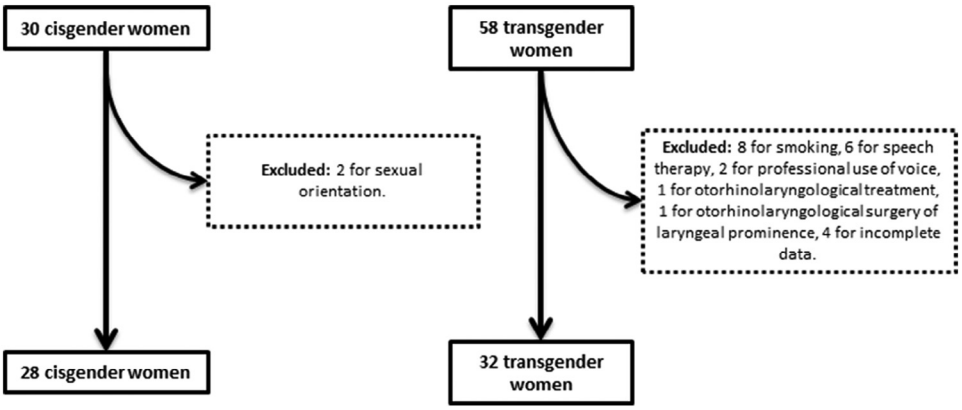

FIGURE 1. Sample composition.

Individuals from both groups answered one questionnaire regarding personal identification, demographic characteristics, gender identity specifications (history of GD was asked only for the transgender sample), sexual orientation, use of medications, vocal complaints, professional use of voice, and previous phonotherapeutic or otorhinolaryngological treatment, as well as diseases that could interfere in the efficiency of vocal production, difficulties in chewing and swallowing, and hormonal and surgical treatments. The number of individuals and the exclusion reasons of both groups are shown in Figure 1.

The participants were also subjected to a hearing screening. Audiological evaluation was performed inside audiometric booths with meatoscopy to discard possible earwax plugs and other audiological alterations. The Ad229 audiometer (Interacoustics, Middelfart, Denmark) is capable of detecting frequencies from 500 to 4,000 Hz. Those individuals who presented audiological alterations were referred for otorhinolaryngological evaluation. Furthermore, an oral peripheral examination was performed to rule out possible dysfunctions that could compromise vocal assessments.

Data collection

Participant voices were recorded inside audiometric cabins with ambient noise lower than 50 dB as measured with a decibel meter. A condenser microphone (Model ECM 8000; Behringer, Willich-Münchheide II, Germany) with ruler-flat frequency response from 15 to 20 KHz and a digital recorder, Zoom H4n (Tokyo, Japan), were utilized to document participant voices.

All participants were instructed to maintain a sustained vowel production /a:/ with the microphone in front of the mouth and a distance of 4 cm[21] between the mouth and the microphone at a 90° angle three times. With this vowel the acoustic measurement of F0 was extracted using the advanced Multi-Dimensional Voice Program (KayPentax, Montvale, New Jersey).

Afterwards, the participants repeated the six sentences of the Consensus Auditory Perceptual Evaluation Voice (CAPE-V, American Speech-Language-Hearing Association 2006)[22] with the microphone in front of their mouths and a distance of 10 cm[21] between the mouth and the microphone at a 90° angle.

Data analysis

The vocal samples (transgender and cisgender individuals) were edited and randomly stored in a Dropbox folder by two speech therapists who are not authors of the study. They have more than 10 years of experience in the area of voice analysis and were blinded to the objective of the study. The judges were instructed to listen to the voices in a quiet environment at a comfortable volume and to repeat as many times as necessary to accurately judge the voices. The vowel /a:/ was assessed using the scale perceptual-auditory evaluation of the voice, GRBASI,[13,23] modified. The following written instruction was provided to the evaluating judges: "Through sustained vowel audios, you should evaluate each aspect of the GRBASI scale using the linear analogue scale, with a score of 0 to 10 cm, and mark with a vertical line any point on the ruler as observed in each aspect. The value will correspond to the degree of deviance of each aspect: 0 cm = no deviance and 10 cm = maximum degree of deviance."

A linear analogue scale, with scores of 0–10 cm, was also used to evaluate the six sentences of CAPE-V. During the listening period, the same judges evaluated the resonance focus in Horizontal[24]:

Balanced: the sound energy is dispersed from the wall of the oropharynx to the lips.

Anterior: the individual speaks with protrusion of the lips, concentrating the energy near the lips, or the tongue can be anteriorized with the elevated larynx in an individual with infantile voice, for example.

Posterior: the concentration of the sound energy is in the posterior region, in the oropharynx. This resonance can be found in individuals with a metallic or tense voice.

Or Vertical focus[21,24]:

Balanced: no predominance in the concentration of sound energy.

Hypernasal: generally associated with excessive air leakage through the nose, associated with changes in the anatomy or velopharyngeal sphincter. Other authors[21] report that the hypernasal voice, when discreet, can reflect emotional changes, affectivity, or sensuality.

Hyponasal: when obstruction of the nasal cavity occurs.

Pharyngeal: it occurs due to a retraction of the tongue toward the pharyngeal wall, associated with a deviation of pitch and excessive nasal resonance.

Laryngeal-pharyngeal: when the sound seems to be "stuck in the throat," coexisting with a tense or damped characteristic.

The following written instructions were provided to the evaluating judges: "using the audio from each case, quantify the degree of impairment of the resonant focus using the linear analogue scale with a score of 0 to 10 cm. Mark a vertical line at any point on the ruler according to the degree of deviance observed: 0 = no deviance and 10 cm = maximum degree of change." The evaluators could mark more than one option.

The evaluators also utilized the analogue scale to evaluate the masculinity and femininity of the voice. The written instructions given to the judges were as follows: "in this item you should evaluate the vocal emission genre using the linear analog scale, with a score of 0 to 10 cm, and mark with a vertical line any point on the ruler according to the evaluated aspect: 0 (more masculine) and 10 cm (more feminine)."

Statistical analysis

Statistical analysis was conducted using Statistical Product and Service Solutions Version 18.0 (SPSS, Armonk, NY). Shapiro-Wilk's W test was applied to verify normality. To describe the sample profile, absolute and relative frequencies (%) of categorical variables and descriptive statistics of numerical variables were calculated including values of mean, standard deviation, minimum and maximum values, median and quartiles. Pearson's test, chi-square test, or Fisher's Exact test were used to compare the categorical variables when the expected values were lower than five. The Mann-Whitney test and the Kruskal-Wallis test were used for comparing numerical variables between 2 groups and 3 or more groups, respectively. Spearman's correlation coefficient was used to measure associations between the numerical variables. The data are presented as the median

TABLE 1.
Sample Profile

	Cisgender Women (n = 28)				Transgender Women (n = 32)				
Variables	M	SD	Max	Min	M	SD	Max	Min	*P*
Age	32.21	8.15	48.00	20.00	33.84	9.35	52.00	19.00	*P* = 0.568
Masc/fem	7.07	0.77	8.00	5.00	5.47	0.98	8.00	4.00	***P* < 0.001***
G	0.32	0.51	2.00	0.00	0.44	0.45	2.00	0.00	*P* = 0.147
R	0.21	0.35	1.50	0.00	0.38	0.38	1.00	0.00	*P* = 0.069
B	0.30	0.48	2.00	0.00	0.22	0.33	1.00	0.00	*P* = 0.615
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	†
S	0.00	0.00	0.00	0.00	0.09	0.32	1.50	0.00	*P* = 0.099
I	0.23	0.48	2.00	0.00	0.30	0.44	2.00	0.00	*P* = 0.240
F0	191.21	19.14	243.07	144.42	159.66	21.21	197.79	118.40	***P* < 0.001***

P value for the Mann-Whitney test for comparison of values between the 2 groups.
* Statistically significant value.
† The result of the variable "A" (asthenia) was homogeneous throughout the sample. It was not possible to carry out a comparison test.
Abbreviations: A, asthenia; B, breathiness; F0, fundamental frequency; G, degree of dysphonia; I, instability; M, mean; Masc/fem, masculinity and Femininity; Max, maximum value; Min, minimum value; R, roughness; S, strain; SD, standard deviation.

and the first and third quartiles, and *P* values <0.05 were considered significant.

RESULTS

The sample of transgender women consisted of 32 subjects including 7 young adults, 19 adults, and 6 middle-aged individuals. The mean age was 33.08 years old. The sample of cisgender women was composed of 7 young adults, 18 adults, and 3 middle-aged individuals with a mean age of 35.07 years old (see Figure 1 and Table 1) (DeCS, 2016). There was no statistically significant difference in age between the groups.

According to the GRBASI scale, there was a significant difference in the absence of roughness changes between transgender and cisgender women. The control group presented more cases of absence of roughness (18 cases, 64.29%; Fisher's Exact test, *P* = 0.031; Table 1 and Figure 2).

Regarding the evaluation of masculinity and femininity, transgender women exhibited significantly lower values (more masculine voices) when compared with cisgender individuals (Mann-Whitney test, *P* < 0.001; Table 1 and Figure 3). Furthermore, a higher frequency of male voices was observed in individuals who presented with F0 between 80 and 150 Hz (Mann-Whitney test, *P* < 0.001; Table 2).

Concerning F0, a greater number of transgender women showed F0 in the range of 80–150 Hz compared with controls (11 cases, 34.38%; chi-square test, *P* = 0.03), whereas the most cisgender women presented F0 in the range of 150–250 Hz (27 cases, 96.43%; chi-square test, *P* = 0.03; Table 2, Figure 4).

Regarding the vertical resonance focus, cisgender women had a significantly higher frequency of balanced resonance when compared with the transgender women (25 cases, 89.29%; Fisher's Exact test, *P* = 0.001; Table 2). Transgender women exhibited a significantly higher number of hypernasality (11 cases, 34.38%; Fisher's Exact test, *P* = 0.001; Table 2). When related to F0, for both groups, there was a higher frequency of vertical focus of altered resonance in individuals with F0 values between 80 and 150 Hz (8 cases, 44.44%; Table 3; Fisher's Exact test, *P* = 0.004). When related to masculinity and femininity, for both groups, in relation to the vertical resonance focus, the voices evaluated as more masculine presented altered focus of vertical resonance and lower F0 (Mann-Whitney test, *P* < 0.001; Table 4). Concerning the horizontal resonance focus, voices evaluated as more feminine presented a balanced resonance focus resonance and higher F0 (Mann-Whitney test, *P* < 0.002; Table 4). The group

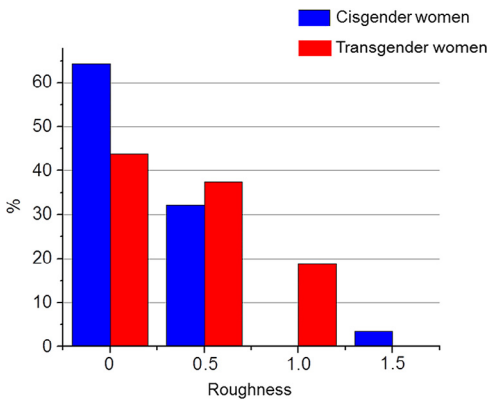

FIGURE 2. Degree of roughness in cisgender and transgender women.

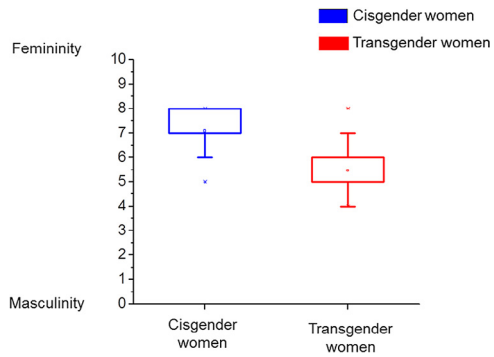

FIGURE 3. Masculinity and femininity in cases and controls.

TABLE 2.
F0 and Vertical Resonance Focus Results

Variables	Cisgender Women (n = 28) %	Transgender Women (n = 32) %	Total
Vertical resonance focus	**25 (89.29%)***	17 (53.13%)	42
Balanced			
Hypernasal	1 (3.57%)	**11 (34.38%)***	12
Hyponasal,	0	1 (3.13%)	1
Pharyngeal	1 (3.57%)	0	1
Laryngeal-pharyngeal	1 (3.57%)	0	1
Hypernasal + pharyngeal	0	3 (9.38%)	3
F0			
80–150 Hz	1 (3.57%)	**11 (34.38%)†**	12
150–250 Hz	**27 (96.43%)†**	21 (65.63%)	48

The results presented in bold and with asterisk presented significant statistical results.
* Fisher's Exact test: $P < 0.001$.
† Chi-square test: $\chi 2 = 8.86$; GL = 1; $P = 0.003$.

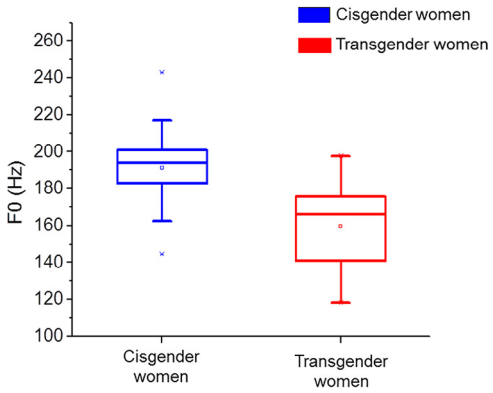

FIGURE 4. Masculinity and femininity in relation to F0.

of subjects presented voices evaluated as more masculine when the focus of vertical resonance was altered (Mann-Whitney test, $P = 0.025$; Table 5).

DISCUSSION

The production of a female voice with a male vocal organ may result in a perceptible tense voice quality, as well as in vocal fatigue or vocal fold trauma.[25] Aiming for a more feminine voice, transgender women sometimes perform vocal compensations, such as elevation of the larynx in speech.[9,12,25] This affirmation is in line with the results obtained in this study, which showed a higher rate of roughness in transgender women when compared with cisgender women (Table 1 and Figure 2). A great variety of vocal characteristics was observed among the transgender women; however, most of these women presented vocal hyperfunction as a result of feminization, which could explain the high occurrence of vocal complaints.[25]

The F0 increase is associated with a voice perceived as sounding more feminine; however, the F0 elevation is often insufficient for a voice to be recognized as female.[4,8,26] In a study performed with cisgender men and women and with transgender women without great variability in the intonation patterns between groups, it was found that transgender women who did not have their voices recognized as female presented a F0 lower than cisgender women and transgender women did who had their voices recognized as female.[27] In consonance with the previous study, research whose voice samples were subjected to perceptual-auditory evaluations and to acoustic analysis demonstrated that transgender women classified as having female voices had higher F0 values, less extensive descending intonations, and a higher percentage of ascending intonations than did transgender women categorized as having male voices.[27] The results of the present study are consistent with the findings of other studies in that transgender women evaluated with more feminine voices have higher F0 values. Thus, the presence of lower F0 was associated with the perception of a more masculine voice (Table 2; Figures 3 and 4).

Resonance characteristics, such as the formants' frequencies, are not only greater in women but are also an obvious gender mark.[26,28] It is known that compensations in speech, such as the greater labial stretch, alter the voice resonance and may make the voice more feminine.[28] Authors[9] found preliminary evidence to suggest that oral resonance therapy may be effective in increasing the femininity of voice in MtF transsexual clients' therapy with an increase in the use of lip spreading during speech and an increase in forward tongue carriage.

In the present study, the vertical focus of the resonance, mainly of the hypernasal type, was affected (Tables 4 and 5). In addition, the majority of the controls did not present alterations in vertical resonant focus, the voices with vertical resonant focus changes were evaluated as more masculine, and the majority of individuals with vertical focus of the resonance affected had F0 values in the range of 80–150 Hz (Tables 3–5). In the hypernasal voice, there is excessive use of the nasal cavity and contamination of the oral sounds by this resonance. In a discreet degree, it may reflect emotional changes, affectivity, or sensuality.[21] These results have shown that the pitch may also have been affected

TABLE 3.
F0 in Relation to the Vertical Resonance Focus (Balanced or Altered) for Both Groups

F0	Vertical Resonance Focus (Balanced) N (%)	Vertical Resonance Focus (Altered) N (%)	Total
80–150 Hz	4 (9.52%)	**8 (44.44%)***	12
150–250 Hz	**38 (90.48%)***	10 (55.56%)	48

The results presented in bold and with asterisk presented significant statistical results.
* Fisher's Exact test: $P = 0.004$.

TABLE 4.
Resonance Focus and Relation to Age, F0, Masculinity, and Femininity (All Sample)

	Variables	N	A	SD	Max	Min	*P*
Horizontal resonance focus balanced	Age	55	33.62	8.78	52	19.00	
	Masc/fem	55	6.36	1.13	8.00	4.00	
	F0	55	176.84	24.43	243.07	118.40	
Horizontal resonance focus anterior	Age	5	27.20	6.98	35.00	19.00	$P = 0.127$
	Masc/fem	5	4.60	0.55	5.00	4.00	$P = 0.002$*
	F0 (Hz)	5	147.43	25.06	178.06	121.95	$P = 0.027$*
Vertical resonance focus balanced	Age	42	33.45	8.91	48.00	20.00	
	Masc/fem	42	6.62	1.06	8.00	4.00	
	F0 (Hz)	42	179.70	21.68	217.03	118.40	
Vertical resonance focus altered	Age	18	32.22	8.65	52.00	19.00	$P = 0.594$
	Masc/fem	18	5.28	4.00	7.00	4.00	$P < 0.001$*
	F0 (Hz)	18	161.99	30.17	243.07	121.95	$P = 0.008$*

P value for the Mann-Whitney test for comparison of values between the 2 groups (balanced × anterior and balanced × altered).
* Statistically significant value.
Abbreviations: A, average; F0, fundamental frequency; Masc/fem, masculinity and femininity (0–10); Max, maximum value; Min, minimum value; N, number of subjects; SD, standard deviation.

by hypernasal resonance; in other words, this alteration may have generated a damping of the high frequencies, leaving the pitch lower. Therefore, the resonant focus is important for identifying gender and should be considered in speech therapy.

Study limitations

This study presents some limitations such as the performance of voice judgments by only 2 speech therapists. For future studies and confirmation of these findings, a greater number of specialist judges and lay judges should be used for the evaluation of the voices. In addition, the substitution of the GRBASI scale score by the analysis rule allows a more precise evaluation of each item, but it does not allow comparison of the results with those of other studies. The use of standardized scales, such as the Traditional Masculinity-Femininity scale, can also help elucidate issues related to voice and gender.[29]

To date, this is the only study that evaluated the relationship among F0, resonant focus, and degree of masculinity and femininity via perceptual-auditory analysis among transgender women. This area should be further studied to improve speech-language therapy. Finally, the transgender women evaluated had a greater perceptual effect voice (roughness) when compared with cisgender women. Among the transgender women, those with lower F0 values were rated as having more masculine voices, and the cases with resonance alterations had lower F0 values and were evaluated as having more masculine voices. This information may contribute to better therapy planning and vocal feminization surgery for transgender women.

TABLE 5.
Vertical Resonance Focus and Relation to Age, F0, Masculinity, and Femininity

	Variables	N	A	SD	Max	Min	*P*
Vertical resonance focus balanced (cases)	Age	17	34.94	9.49	48.00	21.00	$P = 0.438$
	Masc/fem	17	5.82	1.01	8.00	4.00	$P = 0.025$*
	F0	17	163.56	20.77	190.66	118.40	$P = 0.234$
Vertical resonance focus altered (cases)	Age	15	32.60	9.35	52.00	19.00	
	Masc/fem	15	5.07	0.80	7.00	4.00	
	F0 (Hz)	15	155.24	21.53	197.79	121.95	
Vertical resonance focus balanced (control group)	Age	25	32.44	8.53	48.00	20.00	$P = 0.628$
	Masc/fem	25	7.16	0.69	8.00	6.00	$P = 0.176$
	F0 (Hz)	25	190.67	14.33	217.03	162.50	$P = 0.683$
Vertical resonance focus altered (control group)	Age	3	30.33	4.16	35.00	27.00	
	Masc/fem	3	6.33	1.15	7.00	5.00	
	F0 (Hz)	3	195.72	49.44	243.07	144.42	

P value for the Mann-Whitney test for comparison of values between the 2 groups (balanced × anterior [cases] and balanced × altered [control group]).
* Statistically significant value.
Abbreviations: A, average; F0, fundamental frequency; Masc/fem, masculinity and femininity (0–10); Max, maximum value; Min, minimum value; N, number of subjects; SD, standard deviation.

CONCLUSION

The control group showed a significant absence of roughness. The MtF group of individuals showed altered vertical resonant focus, more masculine voices, and lower fundamental frequencies than the controls.

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