Long-Term Effects of Gender-Affirming Hormone Therapy from Adolescence to Adulthood on Voice

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SUMMARY: Objectives. The primary aim of this study was to evaluate vocal outcomes in adult transgender men and transgender women who initiated gonadal hormone suppression (GHS) and gender-affirming hormone therapy (GAHT) during adolescence. The secondary aim was to explore the influence of timing and type of GHS and voice interventions on vocal parameters.

Methods. In this cross-sectional study, 88 transgender men and 23 transgender women who had received GAHT for 5–10 years were compared with 12 cisgender men and 17 cisgender women. Voice recordings of a sustained vowel, reading a phonetically balanced text, and spontaneous speech were collected using Praat software. Fundamental frequency (f_o), voice intensity, and Acoustic Voice Quality Index (AVQI) were analyzed.

Results. Transgender men exhibited f_o values similar to cisgender men across all speech tasks. transgender women had significantly higher f_o than cisgender men but often significantly lower than cisgender women in the reading task and spontaneous speech. Transgender women had lower voice intensity than cisgender men, while similar to that of cisgender women. No significant differences were found in AVQI scores between groups, although a high proportion of participants in all groups presented very mild dysphonia. Transgender women who began GHS with GnRHa at earlier pubertal stages tended to have higher f_o than those who started later with cyproterone acetate. Phonosurgery appeared to increase f_o, while the impact of voice training was inconsistent.

Conclusion. Voice masculinization in transgender men who initiate GAHT during adolescence typically results in vocal characteristics comparable to those of cisgender men. In transgender women, earlier GHS may help preserve a more feminine voice, but complete alignment with cisgender women is not guaranteed (if this is the goal), especially in reading and spontaneous speech. These findings underscore the importance of early pubertal intervention and access to individualized voice care, including speech-language pathology support for trans persons.

Keywords: Gender-affirming hormone therapy– Puberty– Voice– Fundamentalfrequency.

Abbreviations: AG, affirmed gender– AVQI, Acoustic Voice Quality Index–f_o, fundamental frequency–GAHT, gender-affirming hormone therapy–GAVT, gender-affirming voice training–GHS, gonadal hormone suppression–GnRHa, Gonadotropin Releasing Hormone agonists–RFAB, registered female at birth– RMAB, registered male at birth– SPL,Sound Pressure Level– TGD,transgender and gender diverse.

INTRODUCTION

The human voice is widely regarded as one of the key modalities that contributes to the communication of gender as one of the dimensions of human diversity.[1] Although pitch has often been emphasized in this context, it is only one aspect of gendered voice perception. Typically, masculine voices have a lower pitch and feminine voices a higher one, but features such as resonance, intonation, and vocal quality also play important roles.[2,3] Many of these characteristics undergo significant changes during puberty, driven largely by the effects of sex hormones on the vocal folds and vocal tract, as evidenced by the presence of androgen, estrogen, and progesterone receptors in laryngeal tissue.[4] Pubertal changes in voice are more pronounced in boys, whose voices drop approximately one octave, compared to about one-third of an octave in girls.[5] In boys, this transformation, typically occurring at Tanner stages 3–4, is driven by testosterone, which induces lengthening and thickening of the intrinsic vocal fold muscles and enlargement of the vocal tract, contributing to lower fundamental frequency (f_o) and resonant frequency. In contrast, girls retain shorter vocal folds and vocal tract dimensions.[5,6] Nevertheless, hormonal fluctuations throughout the menstrual cycle influence female vocal quality. During the follicular phase, estrogens increase blood flow and tissue hydration, contributing to vocal fold edema. In the luteal phase, elevated progesterone levels decrease epithelial proliferation and increase mucus viscosity, reducing vibratory efficiency. These cyclic changes may lead to noticeable voice alterations in some women, including premenstrual dysphonia.[7]

Vocal changes experienced during puberty can be incongruent with gender identity in transgender and gender diverse (TGD) individuals; therefore, voice is often a relevant source of dysphoria for them.[8,9] In individuals

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registered male at birth (RMAB), testosterone-induced deepening of the voice during puberty can be difficult to alter, especially when gender-affirming hormone therapy (GAHT) is only initiated in adulthood.[1] Therefore, transgender women (TW) and non-binary individuals who desire a more feminine-sounding voice, often face challenges. This leads some of them to pursue gender-affirming voice training (GAVT) or phonosurgery.[10] Voice masculinization for transgender men or non-binary individuals aiming for a masculine-sounding voice is mostly achieved through GAHT with testosterone, causing a decrease in f_o.[11,12] However, voice changes induced by testosterone may not always align with the desires and expectations of transgender men or nonbinary individuals, which can lead them to seek GAVT to better match their vocal presentation with their gender identity.[13,14]

In recent years, gender clinics have reported increasing numbers of TGD adolescents.[15–17] For them, GAHT is often preceded by gonadal hormone suppression (GHS). GHS can be initiated from Tanner stage 2 onwards, with gonadotropin-releasing hormone agonists (GnRHa). If GHS is initiated at later stages, alternative medications, such as progestins for registered female at birth (RFAB) individuals or anti-androgens for those RMAB, may be used.[1,18] Since testosterone drives the pubertal vocal changes in RMAB individuals and voice breaks typically occur in mid-puberty, early GHS may theoretically preserve a more gender-congruent vocal profile. However, clinical data indicate that most TGD adolescents begin GHS at later pubertal stages, after key vocal changes may have already occurred.[15,19] Despite the growing number of TGD individuals receiving medical gender-affirming care since adolescence, little is known about the effects on vocal parameters.

In this study, we analyzed vocal characteristics of transgender men and transgender women who began GHS and GAHT in adolescence and had received GAHT for 5–10 years at the moment of the voice assessment, comparing them to cisgender men and women of comparable age as controls.

METHODS

This study was approved by the Ethics Committee of Ghent University Hospital (reference: B670201942449) and conducted in accordance with the principles of the Declaration of Helsinki. All participants provided written informed consent prior to participation. Recruitment occurred between September 2023 and December 2024.

Study population

All individuals who had initiated medical transition during adolescence within the Pediatric Gender Team at Ghent University Hospital and who had been receiving GAHT for a minimum of five years and a maximum of ten years at the time of the study visit were invited to participate in a comprehensive cross-sectional study, aiming to evaluate bone health, body composition, muscle strength, cardiovascular function, and voice characteristics. Of 231 eligible individuals (163 transgender men, 68 transgender women), 117 (91 transgender men, 26 transgender women) consented to participate in the study. Voice samples for this study were obtained from 111 participants (88 transgender men, 23 transgender women) who were native Dutch-speakers. Information about GHS was retrieved retrospectively from the clinical files.

A control group of 29 cisgender individuals (12 cisgender men, 17 cisgender women), all native Dutch speakers aged between 20 and 30 years, was also included. Controls were recruited to achieve an age-comparable sample rather than strict individual age-matching. We chose a broad recruitment window because voice characteristics are largely established after puberty and remain relatively stable during young adulthood.

Voice sample collection

Participants were instructed to produce a sustained vowel /a/ for at least 3 s, read a phonetically balanced text entitled "Papa en Marloes,"[20] and provide a spontaneous speech sample of at least 1 minute, at the habitual pitch and loudness. Recordings were made using a Samson C01U USB Studio Condenser Microphone (44.1 kHz sampling rate), connected to a Dell Latitude 5520 laptop running the acoustic analysis software Praat.[21] The mouth-to-microphone distance was consistently maintained at 15 cm, and a minimum signal-to-noise ratio (SNR) of 20 dB was required for all recordings. The calibration procedure of Maryn et al. was used to calibrate the microphone.[22] This consisted of comparing the dB intensity levels of the microphone and a sonometer after recording white noise, resulting in a calibration factor that can be used for acoustic analyses.

Acoustic analysis

For the f_o, the median and percentiles 5–95 and 25–75 were measured with Praat software, using the Analyze periodicity > To Pitch > Query "mean" and "quantile" functions. The median intensity (Sound Pressure Level, SPL) of each speech sample was calculated in Praat using "To Intensity > Query 'quantile'." To evaluate vocal quality, the Acoustic Voice Quality Index (AVQI) was used, which is an objective, multiparameter approach to quantify dysphonia severity on the basis of both sustained vowels and continuous speech.[23] The AVQI consists of a weighted combination of six time-domain (i.e., shimmer local [SL], shimmer local decibels [SLdB], and harmonics-to-noise ratio [HNR]), frequency-domain (i.e., general slope of the spectrum [slope] and tilt of the regression line through the spectrum [tilt]), and quefrency-domain (i.e., smoothed cepstral peak prominence [CPPs]) measures. The index is constructed as 2.571 (3.295 – 0.111 CPPs − 0.073 HNR − 0.213 SL + 2.789 SLdB − 0.032 slope + 0.077 tilt) and ranges from 0 to 10. A higher index indicates a worse vocal quality. The threshold score separating normophonic from dysphonic persons in Dutch is 2.95.

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the study population. Categorical variables

are presented as frequencies and percentages. Continuous variables are reported as means with standard deviations (± SD) for normally distributed data, or as medians with interquartile ranges (IQR) for non-normally distributed data. Group comparisons between TM or TW and the cisgender controls were performed using independent samples t-tests or Wilcoxon rank-sum tests, depending on data distribution. To account for multiple comparisons, *P* values were adjusted using the Bonferroni correction.

A sensitivity analysis was conducted for the group of transgender women by excluding individuals who had undergone voice interventions (i.e., phonosurgery or voice training). The remaining transgender women were then compared with cisgender women and cisgender men to assess whether results were consistent. This analysis was not performed in transgender men as only one participant had undergone voice training.

Statistical significance was defined as a two-sided P value < 0.05. All analyses were conducted using RStudio, version 4.4.3.

RESULTS

General information

Median age at enrollment was 23.4 (2.1) years in transgender men and 24.4 (2.4) years in transgender women. Among controls, cisgender men were enrolled at a median age of 27.5 (3.2) years, and cisgender women at 25.6 (4.7) years.

Two transgender women underwent glottoplasty before the study participations and four had had GAVT. These six transgender women were excluded from the sensitivity analysis reported later in this section. Only one transgender man had had GAVT; therefore, for the group of transgender men, the sensitivity analysis was not performed.

Information regarding GHS, GAHT, gonadectomy, smoking status, GAVT, and voice surgery is presented in Table 1.

As expected, cisgender controls had not undergone GHS or GAHT, nor had they received voice training. Regarding smoking status, only one cisgender woman reported being a smoker.

Table 1.
Baseline Characteristics of the Study Cohort

	Trans men (n=88)	Trans women (n=23)
At enrollment		
Age	23.4 (2.1)	24.4 (2.4)
Duration of GAHT (years)	6.0 (2.4)	6.3 (3.0)
Still on GHS (%)	4 (4.5%)	7 (30%)
Type of GAHT	Testosterone esters i.m.: 77 (87.5%) Testosterone undecanoate: 9 (10.2%) Testosterone gel: 2 (2.3%)	Estradiol valerate: 21 (91.3%) Estradiol gel: 2 (8.7%)
Gonadectomy (%)	60 (68.2%)	16 (69.6%)
Smoking status	Never: 45 (51.1%) Former: 10 (11.4%) Current: 30 (34.1%) Not available: 3 (3.4%)	Never: 11 (47.9%) Former: 5 (21.7%) Current: 7 (30.4%) Not available: 0
GAVT	1 (1.1%)	4 (17.4%)
Phonosurgery	0	2 (8.7%)
At start of GHS*		
Age	16.2 (2.3)	15.9 (2.7)
Tanner stage 2-3 (%)	5/83 (6%)	7/23 (30.4%)
Tanner stage 4-5 (%)	78/83 (94%)	16/23 (69.6%)
Post-menarche (%)	78/83 (94%)	NA
Testicular volume (%)	NA	< 12 mL: 7 (30.4%) 12-15 mL: 6 (26.1%) 15-20 mL: 6 (26.1%) 25 mL: 2 (8.7%) Not available: 2 (8.7%)
Type of medication (%)	GnRHa: 5 (5.7%) Progestins: 78 (88.6%) Oral contraceptive/none: 5 (5.7%)	GnRHa: 6 (26.1%) CPA: 17 (73.9%)
At start of GAHT		
Age	17.1 (1.6)	16.9 (2.1)
Type of medication	Testosterone esters i.m. as per protocol	Estradiol valerate as per protocol

CPA, cyproterone acetate; GHS, gonadal hormone suppression; GAHT, gender-affirming hormone treatment; GAVT, gender-affirming voice training; i.m., intramuscular; NA, not applicable. All participants were assuming ongoing GAH since 5-10 years.
Ages are expressed in years, as mean (± SD) or median (IQR) depending on the data distribution. *Tanner stage and menarche at GHS reported only for those who started GHS prior to GAHT (83 of 88).

Table 2.
Fundamental Frequency Parameters During Sustained Vowel (/a/) Production

Fundamental frequency	Cisgender women (CW)	Trans women (TW)	Trans men (TM)	Cisgender men (CM)	TW vs CW (p_{adj})	TW vs CM (p_{adj})	TM vs CW (p_{adj})	TM vs CM (p_{adj})
Median	197.5 (24.8)	189.0 (47.8)	103.6 (16.6)	100.7 (36.8)	0.226	*< 0.001*	*< 0.001*	> 1.00
pc5	193.7 (24.8)	174.2 (50.7)	100.4 (18.1)	99.8 (36.6)	0.142	*0.004*	*< 0.001*	0.774
pc25	196.1 (24.4)	179.6 (48.3)	103.0 (17.6)	100.4 (36.7)	0.238	*0.001*	*< 0.001*	0.544
pc75	198.6 (24.6)	189.7 (48.2)	104.2 (16.4)	101.3 (36.9)	0.238	*< 0.001*	*< 0.001*	> 1.00
pc95	201.3 (24.1)	190.7 (48.7)	105.8 (16.5)	102.3 (35.8)	0.214	*< 0.001*	*< 0.001*	> 1.00

Values are expressed as median (IQR) or mean (± SD), depending on the data distribution. *P* values have been adjusted according to Bonferroni method.

Table 3.
Fundamental Frequency Parameters During Reading of Standard Text ("Papa en Marloes")

Fundamental frequency	Cisgender women (CW)	Trans women (TW)	Trans men (TM)	Cisgender men (CM)	TW vs CW (p_{adj})	TW vs CM (p_{adj})	TM vs CW (p_{adj})	TM vs CM (p_{adj})
Median	196.7 (19.8)	166.8 (51.4)	107.4 (15.4)	103.0 (12.2)	*0.011*	*< 0.001*	*< 0.001*	> 1.00
pc5	112.9 (58.9)	113.5 (49.1)	85.8 (16.0)	81.1 (10.3)	> 1.00	*0.006*	*< 0.001*	> 1.00
pc25	175.8 (13.3)	147.9 (50.2)	97.4 (17.0)	92.9 (14.5)	*0.001*	*< 0.001*	*< 0.001*	> 1.00
pc75	213.8 (± 14.3)	184.5 (± 35.4)	117.3 (± 14.7)	121.5 (± 21.1)	*0.002*	*< 0.001*	*< 0.001*	> 1.00
pc95	252.2 (36.9)	230.7 (68.3)	134.1 (30.2)	156.2 (36.7)	0.063	*0.015*	*< 0.001*	0.058

Values are expressed as median (IQR) or mean (± SD), depending on the data distribution. *P* values have been adjusted according to Bonferroni method.

All voice samples had a SNR higher than 20 dB. The mean SNR was 33.8 (± 6.8), with a range of 21.2–54.4 dB.

FUNDAMENTAL FREQUENCY

Sustained vowel production

The median f_o and its 5th, 25th, 75th, and 95th percentiles for all groups are presented in Table 2. Group comparisons revealed that transgender men had significantly lower f_o values than cisgender women, and transgender women had significantly higher f_o values than cisgender men. However, when compared to their affirmed gender (AG), no significant differences were found: transgender men did not differ from cisgender men, and transgender women did not differ from cisgender women.

Reading task

The median f_o and its 5th, 25th, 75th, and 95th percentiles for all groups are presented in Table 3. Group comparisons revealed that transgender men had significantly lower f_o values than cisgender women, and transgender women had significantly higher f_o values than cisgender men. While transgender men did not differ significantly from cisgender men in any of the analyzed parameters, transgender women showed significantly lower median f_o, as well as lower 25th and 75th percentile values, compared to cisgender women. Graphical representation of group comparisons of median, 5th and 95th percentile is shown in Figure 1.

Spontaneous speech

The median f_o and its 5th, 25th, 75th, and 95th percentiles for all groups are presented in Table 4. Group comparisons showed that transgender men had significantly lower f_o values than cisgender women for all parameters. Transgender women had significantly higher f_o values than cisgender men with the exception of the 5th percentile. Transgender men did not differ significantly from cisgender men in any of the analyzed parameters, while transgender women showed significantly lower 25th, 75th and 95th percentile values, compared to cisgender women. Graphical representation of group comparisons of median, 5th and 95th percentile is shown in Figure 1.

Voice intensity (SPL) and Acoustic Voice Quality Index (AVQI)

Voice intensity (SPL) during sustained vowel (/a/) production, standard text reading, and spontaneous speech is presented in Table 5, along with the AVQI results. The only significant difference observed was in voice intensity during spontaneous speech, with transgender women exhibiting significantly lower intensity than cisgender men. The proportion of participants with AVQI scores greater than 2.95 did not differ between groups.

Sensitivity analysis

A sensitivity analysis was conducted in the cohort of transgender women after excluding 2 participants who had undergone phonosurgery and 4 who had received GAVT. Results are presented in Supplementary Tables 1 and 2. Contrary to expectations, the f_o parameters after exclusion of the above-mentioned participants tended to be higher than in the full cohort of transgender women. Importantly, information about GAVT could not be collected systematically, as most participants had received it outside our

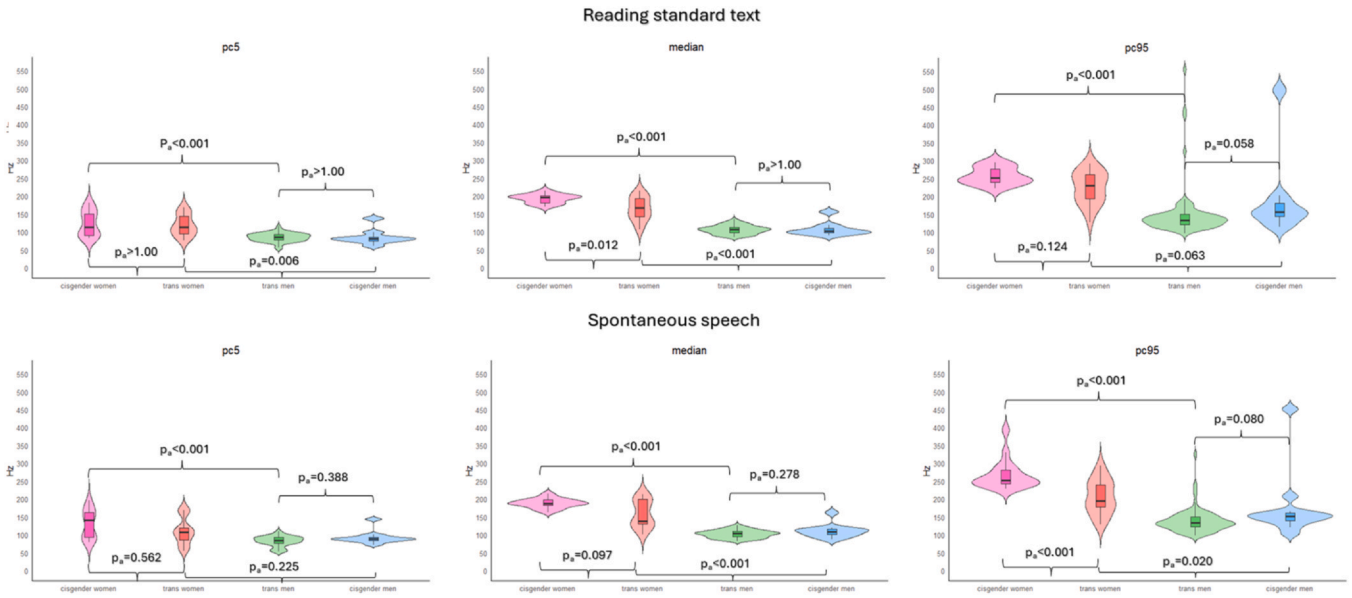

Figure 1. Fundamental frequency during reading and spontaneous speech: group comparison. p_a: p value adjusted (according to Bonferroni); pc, percentile.

Table 4.
Fundamental Frequency Parameters During Spontaneous Speech

Fundamental frequency	Cisgender women (CW)	Trans women (TW)	Trans men (TM)	Cisgender men (CM)	TW vs CW (p_{adj})	TW vs CM (p_{adj})	TM vs CW (p_{adj})	TM vs CM (p_{adj})
Median	188.0 (14.8)	138.5 (69.3)	103.5 (16.2)	109.5 (15.4)	0.097	*< 0.001*	*< 0.001*	0.278
pc5	141.7 (69.3)	106.5 (33.2)	84.5 (16.7)	89.0 (8.3)	0.562	0.225	*< 0.001*	0.388
pc25	175.5 (18.8)	128.7 (65.1)	97.2 (15.6)	101.0 (14.9)	*0.038*	*< 0.001*	*< 0.001*	0.518
pc75	208.6 (± 16.7)	175.7 (± 40.9)	111.8 (± 13.2)	121.4 (± 20.6)	*0.005*	*< 0.001*	*< 0.001*	0.280
pc95	252.6 (37.9)	194.9 (61.3)	133.6 (28.4)	152.5 (21.8)	*< 0.001*	*0.020*	*< 0.001*	0.080

Values are expressed as median (IQR) or mean (± SD), depending on the data distribution. p-values have been adjusted according to Bonferroni method.

Table 5.
Voice intensity and Acoustic Voice Quality Index (AVQI)

Fundamental frequency	Cisgender women (CW)	Trans women (TW)	Trans men (TM)	Cisgender men (CM)	TW vs CW (p_{adj})	TW vs CM (p_{adj})	TM vs CW (p_{adj})	TM vs CM (p_{adj})
Intensity SV	64.4 (± 4.8)	63.3 (± 8.4)	64.6 (± 8.0)	66.9 (± 6.6)	> 1.00	0.445	> 1.00	0.179
Intensity text	57.3 (± 3.7)	54.4 (± 5.2)	56.3 (± 6.9)	56.6 (± 4.5)	0.103	0.526	0.855	> 1.00
Intensity speech	55.8 (± 3.4)	53.4 (± 7.0)	55.8 (± 7.2)	59.5 (± 4.9)	0.370	*0.012*	> 1.00	0.063
AVQI	3.1 (1.2)	3.0 (1.2)	3.3 (1.3)	3.0 (0.6)	0.699	0.580	0.336	0.274
AVQI > 2.95	10/17 (58.8%)	11/23 (47.8%)	53/88 (60.2%)	5/12 (41.7%)	-	-	-	-

SV, sustained vowel. Fisher's exact test indicated no significant difference in the proportion of participants with AVQI > 2.95 across groups ($P = 0.915$).

center and did not recall the exact number of sessions nor the specific training received. Individual participant values are shown in Supplemental Figure 1.

Voice intensity and AVQI were consistent with the results from the full cohort of transgender women.

Influence of GHS medication and timing on fundamental frequency

The subgroup of participants receiving GHS through GnRHa, and therefore initiating treatment at the onset of puberty, is too small for formal statistical comparison. However, individual values for spontaneous speech f_o (median, 5th, and 95th percentiles) are shown in Figure 2. In transgender men, the range of f_o appeared similar regardless of the type and timing of GHS. In contrast, a different trend was observed in transgender women: while the 5th percentile values did not differ markedly between participants on cyproterone acetate and those on GnRHa, the median and 95th percentile values tended to be higher in those treated with GnRHa. However, some participants

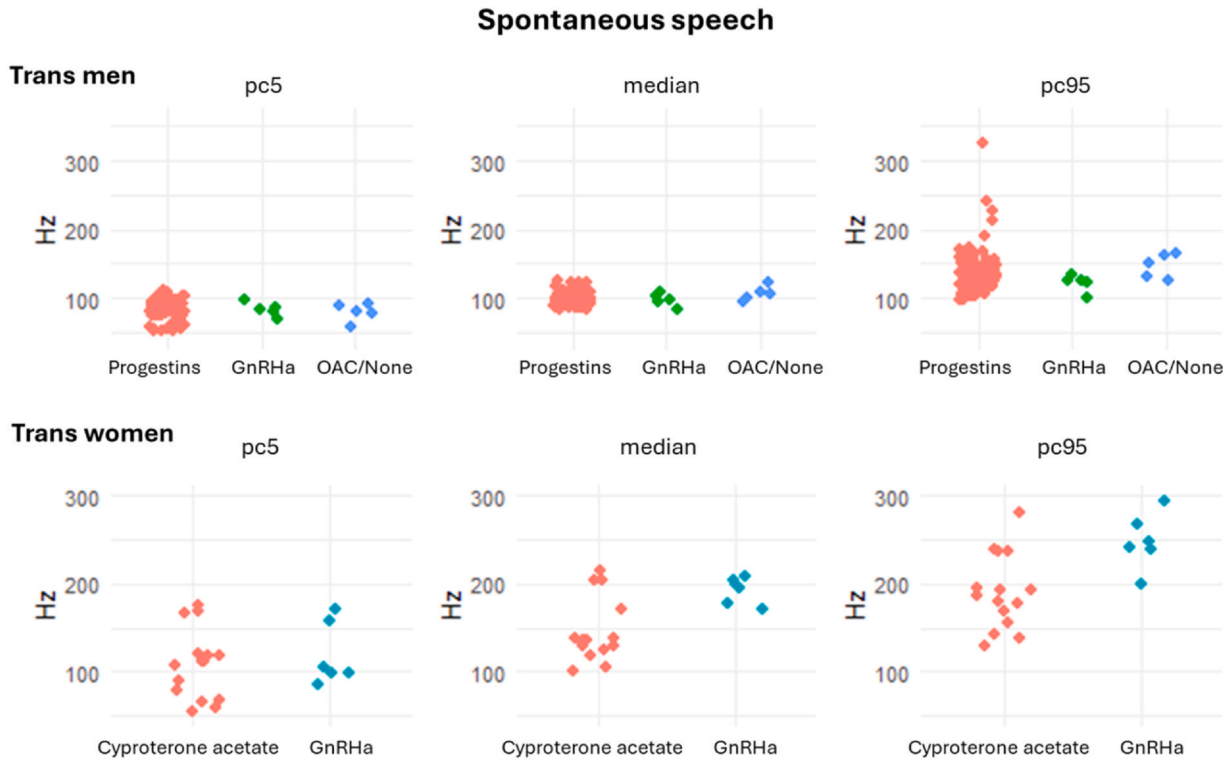

Figure 2. Fundamental frequency during spontaneous speech in trans men and trans women by type of gonadal hormone suppression. GnRHa, GnRH agonists; OAC, oral anticonceptional; pc, percentile.

on cyproterone acetate (thus starting GHS at later stages) also showed values within this higher range.

DISCUSSION

In this study, we examined the vocal characteristics of transgender men and transgender women who initiated GHS and GAHT during adolescence and had been undergoing GAHT for 5 to 10 years at the time of voice assessment. Their vocal outcomes were compared to those of cisgender men and cisgender women, serving as control groups.

Overall, for most of the analyzed parameters, the results of transgender men were more similar to those of cisgender men, whilst results of transgender women were intermediate. The median f_o during the reading task was lower in transgender women compared to cisgender women, but significantly higher than that of cisgender men and in the gender ambiguous zone of f_o. When evaluating spontaneous speech, differences in f_o were more pronounced, with transgender women exhibiting on average lower values than cisgender women. This may reflect the greater challenges some individuals face in maintaining pitch modulation strategies or gender-affirming vocal techniques during spontaneous speech, particularly when these strategies are self-developed or inconsistently applied.

At the individual level, glottoplasty appeared to have a clear impact on f_o, as the two participants who had undergone it showed f_o values in the higher range. In contrast, GAVT did not appear to exert a consistent influence on vocal outcomes. Specifically, the f_o values of transgender women who had received GAVT were within the lower range of those who did not receive any voice intervention. A key limitation of this subgroup analysis is that most transgender women who had undergone GAVT received it outside our center, often several years prior to study participation. As such, precise information about the duration and type of GAVT, as well as baseline data before these interventions, could not be systematically collected. Additionally, some participants may have discontinued the use of learned techniques over time.

Conversely, initiating GHS at the onset of puberty through GnRHa may help prevent the voice-deepening changes that typically occur during puberty, thereby contributing to a more feminine-sounding voice. Indeed, for both the median and 95th percentile of f_o, transgender women who received GnRHa tended to have higher values compared to those who began GHS later, and using cyproterone acetate. In line, all transgender women who underwent voice interventions belonged to the cyproterone acetate subgroup, thus had started GHS at later pubertal stages. However, longitudinal data collected from the start of GHS onwards are needed to better evaluate this aspect. It is important to underline that, in this study, the comparison between participants on cyproterone acetate and those on GnRHa indirectly reflects the timing of GHS initiation (late vs early), rather than the effect of the specific medication. In our center, GnRHa have been available for

use at later pubertal stages only since September 2022, following changes in reimbursement criteria,[15] while before they were reserved to TGD adolescents starting GHS in early puberty.

Our results align with previous findings. Schneider et al. presented longitudinal acoustic voice evaluations across four time points over a 20-month period in an 11-year-old transgender girl undergoing pubertal suppression with GnRHa. The f_o during vowel /a/ initially dropped by approximately 30 Hz during the first 17 months of treatment, but later rose again, ultimately remaining within a more feminine range. The study did not include a control group but offers some evidence of how early puberty suppression may influence vocal development in transgender youth.[24] Additionally, Dominguez-Riscart et al. conducted a cross-sectional study examining the relationship between the timing of GnRHa and voice-related outcomes in RMAB adolescents. They compared individuals who began treatment in Tanner stage 2 with those who started in Tanner stage 3 or higher. Results showed that early treatment was associated with a significantly higher f_o, on average 71.5 Hz higher. Importantly, the study identified a strong negative correlation between f_o and age at puberty suppression, indicating that earlier intervention may help preserve higher pitched, less masculinized voices.[25] However, as mentioned above, long-term follow-up voice outcomes are needed.

Regarding voice intensity, our findings showed that transgender women had lower values than cisgender men during spontaneous speech. This is consistent with existing literature showing that loudness differs between cisgender men and cisgender women.[26–28] While GAHT is not expected to affect vocal loudness, the reduced intensity observed in transgender women may reflect a behavioral adjustment. In fact, loudness is also known to influence gender perception as listeners often associate softer voices with femininity,[26–28] though it remains difficult to isolate its effects from other features such as breathiness.[29] As this is a cross-sectional study, we cannot determine whether reduced loudness in transgender women results from self-initiated changes, social adaptation, or other factors.

Finally, regarding the AVQI, the majority of participants in each group showed values above the normative cut-off for the Dutch language, indicating mild dysphonia. However, no significant differences in this prevalence were found across groups. The AVQI is a very sensitive multiparameter index; scores around 3 frequently reflect very mild dysphonia and can even occur in some healthy speakers.[30,31] However, it is important to remain attentive to changes in vocal quality, as early recognition allows individuals to seek timely support from a speech pathologist when needed.

Our results cannot be considered definitive given the small sample size, particularly for transgender women. This limitation, however, reflects real-world clinical practice, where the ratio of RFAB to RMAB adolescents accessing gender services is approximately 3:1, as shown both in our center[15] and in other European clinics.[16,17] The underlying reasons for this discrepancy remain unclear, although the sharp rise in TGD adolescents referred to gender services in recent years has been primarily driven by an increase in referrals of RFAB individuals. The control group was also relatively small, which may limit the generalizability of the findings.

Nonetheless, our study has several strengths: it is among the few to assess long-term voice outcomes in transgender men and transgender women who initiated GAHT during adolescence. We included both sustained vowels, a structured reading task, and spontaneous speech, providing a comprehensive assessment of voice in different communicative contexts. The inclusion of individual-level data allows for nuanced interpretation beyond group-level comparisons. Additionally, we examined the impact of early versus late initiation of GHS, offering preliminary insight into the potential protective role of early GHS on voice outcomes.

CONCLUSION

This study demonstrates that transgender men who begin GAHT during adolescence generally achieve vocal outcomes similar to those of cisgender men. In contrast, transgender women show distinct patterns compared to cisgender women, particularly during reading and spontaneous speech, although earlier access to GHS appears advantageous. Transgender women exhibited lower voice intensity (SPL) than cisgender men, while matching that of cisgender women. AVQI scores did not differ significantly between groups. These findings clarify how the timing and type of GHS, alongside subsequent voice interventions, shape long-term vocal parameters. They emphasize the clinical importance of early intervention and individualized care, while underscoring the need for larger, longitudinal studies to better understand diverse long-term vocal outcomes.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Ghent University Hospital (reference: B670201942449). All participants provided written informed consent prior to participation.

CRediT authorship contribution statement

Study conceptualization: SC, CL, MC, EDH. Funding acquisition: MC. Data acquisition: SC, DK, JV, GTS. Writing of the first draft: SC, CL. All authors approved the final version of the manuscript.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Martine Cools reports financial

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Not applicable.

Consent for publication

Not applicable.

Availability on data and material

The data underlying this article will be shared on reasonable request to the corresponding author.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jvoice.2026.01.048.

References

1. Coleman ERA, Bouman WP, Brown GR, et al. Standards of care for the health of transgender and gender diverse people, version 8. *Int J Transgend Health.* 2022;23:S1–S259.
2. Titze IR. Physiology of the female larynx. *J Acoust Soc Am.* 1987;82:S90–S91.
3. Davies S, Goldberg JM. Clinical aspects of transgender speech feminization and masculinization. *Int J Transgenderism.* 2006;9:167–196.
4. Kirgezen T, Sunter AV, Yigit O, Huq GE. Sex hormone receptor expression in the human vocal fold subunits. *J Voice.* 2017;31:476–482.
5. Zamponi V, Mazzilli R, Mazzilli F, Fantini M. Effect of sex hormones on human voice physiology: from childhood to senescence. *Hormones.* 2021;20:691–696.
6. Afsah O. Effects of hormonal changes on the human voice: a review. *Egyptian J Otolaryngol.* 2024;40:22.
7. Kadakia S, Carlson D, Sataloff R. The effect of hormones on the voice. *J Singing.* 2013;69:571–574.
8. Hancock AB, Krissinger J, Owen K. Voice perceptions and quality of life of transgender people. *J Voice.* 2011;25:553–558.
9. Dacakis G, Oates J, Douglas J. Beyond voice: perceptions of gender in male-to-female transsexuals. *Curr Opin Otolaryngol Head Neck Surg.* 2012;20:165–170.
10. Nolan IT, Morrison SD, Arowojolu O, et al. The role of voice therapy and phonosurgery in transgender vocal feminization. *J Craniofac Surg.* 2019;30:1368–1375.
11. Cosyns M, Van Borsel J, Wierckx K, et al. Voice in female-to-male transsexual persons after long-term androgen therapy. *Laryngoscope.* 2014;124:1409–1414.
12. Nygren, Nordenskjold A, Arver S, Sodersten M. Effects on voice fundamental frequency and satisfaction with voice in trans men during testosterone treatment-a longitudinal study. *J Voice.* 2016;30:766..e23-.e34.
13. Azul D. Transmasculine people's vocal situations: a critical review of gender-related discourses and empirical data. *Int J Lang Commun Disord.* 2015;50(1):31–47.
14. Papeleu T, Leyns C, Alighieri C, et al. Voice and communication in transmasculine individuals one year under testosterone therapy: a qualitative study. *J Voice.* 2024.
15. Ciancia S, Bruneel L, Van Schuylenbergh J, et al. The evolution of pediatric transgender healthcare in Flanders: trends in referrals, intakes and gender-affirming interventions over the last 15 years. *Int J Transgender Health.* 2025.
16. Wiepjes CM, Nota NM, de Blok CJM, et al. The Amsterdam Cohort of Gender Dysphoria Study (1972-2015): trends in prevalence, treatment, and regrets. *J Sex Med.* 2018;15(4):582–590.
17. Kaltiala R, Bergman H, Carmichael P, et al. Time trends in referrals to child and adolescent gender identity services: a study in four Nordic countries and in the UK. *Nord J Psychiatry.* 2020;74(1):40–44.
18. Hannema SE, Busiah K, Butler G, et al. Endocrine management of transgender and gender diverse adolescents: expert opinion of the ESPE Working Group on Gender Incongruence and the Endo-ERN main thematic group on Sexual Development and Maturation. *Horm Res Paediatr.* 2024:1–41.
19. van der Loos M, Klink DT, Hannema SE, et al. Children and adolescents in the Amsterdam Cohort of Gender Dysphoria: trends in diagnostic- and treatment trajectories during the first 20 years of the Dutch Protocol. *J Sex Med.* 2023;20:398–409.
20. Van de Weijer J.S.I. Papa en Marloes, 1991.
21. Boersma P. Praat, a system for doing phonetics by computer. *Glot Int.* 2001;5:341–345.
22. Maryn Y, Zarowski A. Calibration of clinical audio recording and analysis systems for sound intensity measurement. *Am J Speech Lang Pathol.* 2015;24:608–618.
23. Maryn Y, Corthals P, Van Cauwenberge P, et al. Toward improved ecological validity in the acoustic measurement of overall voice quality: combining continuous speech and sustained vowels. *J Voice.* 2010;24:540–555.
24. Schneider MA, Spritzer PM, Soll BMB, et al. Brain maturation, cognition and voice pattern in a gender dysphoria case under pubertal suppression. *Front Human Neurosci.* 2017;11:528.
25. Dominguez-Riscart J, Triviño-García A, Sanchez-Toscano E, et al. Voice self-perception and acoustic parameters in transgirls adolescent related to pubertal stage blockage. *Early Human Develop.* 2025;201:106190.
26. Leung Y, Oates J, Chan SP. Voice, articulation, and prosody contribute to listener perceptions of speaker gender: a systematic review and meta-analysis. *J Speech Lang Hear Res.* 2018;61:266–297.
27. Andrews ML, Schmidt CP. Gender presentation: perceptual and acoustical analyses of voice. *J Voice.* 1997;11:307–313.
28. Holmberg EB, Oates J, Dacakis G, Grant C. Phonetograms, aerodynamic measurements, self-evaluations, and auditory perceptual ratings of male-to-female transsexual voice. *J Voice.* 2010;24:511–522.
29. Titze IR. *Principles of Voice Production.* Englewood Cliffs, NJ: Prentice Hall; 1994.
30. Jayakumar T, Benoy JJ. Acoustic Voice Quality Index (AVQI) in the Measurement of voice quality: a systematic review and meta-analysis. *J Voice.* 2024;38:1055–1069.
31. Batthyany C, Maryn Y, Trauwaen I, et al. A case of specificity: how does the acoustic voice quality index perform in normophonic subjects? *Appl Sci.* 2019;9:2527.