Exogenous Testosterone and the Transgender Singing Voice: A 30-Month Case Study

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Journal of Singing, March/April 2022
Volume 78, No. 4, pp. 441–455
https://doi.org/10.53830/YKWM3774

OBJECTIVES AND BACKGROUND

While transgender voices have received more scholarly attention recently, there remains very little research on singing, with most scholarship focused on speaking. This literature also focuses on the voices of transfeminine people (those assigned male at birth who identify as women/with a feminine identity), rather than people who are transmasculine (assigned female at birth and identify as men/with a masculine identity) or have another gender identity.[1] This article is the first rigorous, scientific description of the timing and nature of the singing voice changes of an assigned female singer taking testosterone. It bridges gaps between performing arts pedagogy and medical/clinical perspectives, including both perceptual and clinical voice measures and assessing the relationship between hormone levels and voice changes. It includes illustrative audio recordings of the singer's changing voice and pushes traditional boundaries of voice research by considering the singer's embodied, emotional experience of their voice.

Gender Identity Terms

In this article, the term "transgender" is used for people whose sex assigned at birth (typically determined by biological characteristics like reproductive organs or chromosomes) does not align in traditional ways with their gender identity (sense of themselves as a man, woman, or something else). For example, a person who was assigned female at birth and identifies as a man would be considered transgender. This use of transgender includes people whose gender identity is nonbinary, meaning they do not identify as either, or entirely, a man or a woman. There is disagreement about whether nonbinary identities should be included under the transgender umbrella, but in this article, they are. The term "cisgender" is used for people whose assigned sex and gender identity align in traditional ways. For example, a person assigned female at birth who identifies as a woman would be considered cisgender.

Current Understanding of Exogenous Testosterone's Impact on the Voice

People assigned male and those assigned female produce both estrogen and testosterone throughout their lives.[2] Before puberty, children of all sexes have relatively low levels of both hormones. During puberty, estrogen increases

in people assigned female, as does testosterone in those assigned male.[3] In some ways, the physiological changes in people assigned female who take testosterone are similar to those in cisgender boys during puberty. In cisgender boys, in addition to overall increases in height and muscle mass, increased testosterone during puberty causes the larynx to grow, the vocal folds to lengthen and thicken, and the vocal tract to lengthen, leading to lower pitch.[4] When adults assigned female take testosterone, their voices go through similar changes, but because they are already adults, they do not grow taller, and their laryngeal cartilages, which are more ossified than those of an adolescent, are not believed to grow.[5] These differences between the impacts of endogenous testosterone (originating inside the body) on cisgender boys and exogenous testosterone (originating outside the body) on persons assigned female necessitate further investigation.

Numerous studies on the transgender voice have been published over the last several years, but Block contests "there is relatively little data (at the writing of this chapter, around 100 speakers) on the changes exogenous testosterone brings about in transmasculine speakers."[6] While limited, this research shows that, contrary to early assumptions that exogenous testosterone unproblematically "masculinizes" voices, it can lead to many vocal problems, including restrictions in pitch range and variability, limited vocal stability, power, and endurance, and self-reported dissatisfaction with the voice.[7] Some of the research on speaking touches on changes to singing voices (for example, see Damrose, Van Borsel and Baeck, and Cler),[8] but findings on the singing voice in these studies are minimal.

A handful of publications focus more explicitly on singing. Constansis, considered the foundational study in the area, hypothesizes that while exogenous testosterone causes the vocal folds of adults assigned female to thicken and lengthen, their larynges do not grow and are not as flexible as those of cisgender boys.[9] The lack of laryngeal growth and flexibility is because testosterone was started in adulthood, when laryngeal cartilages have typically begun to ossify and when height increases are not expected.[10] Constansis uses the term "entrapped vocality" to describe the hoarseness, lack of control and color, and limited power that he contends is caused by "the encasing of [growing vocal folds] in an established laryngeal structure."[11] He also hypothesized that starting on a low dose of testosterone and slowly increasing to a maintenance dose, giving more time for delicate vocal structures to adjust, would lead to fewer vocal problems than more quickly proceeding to a maintenance dose. The study included Constansis himself, a classically trained professional singer, and fifteen other singers. Singers that started on a lower dose of testosterone and transitioned more gradually and those under forty years old when they began taking testosterone experienced fewer singing problems.

In the last five years, several more anecdotal descriptions of singing voice changes with exogenous testosterone have been published.[12] Because data collection, analysis, and findings are not well documented in Constansis or the other publications on singing, it is difficult to draw firm conclusions. Still, some general patterns do emerge.[13] With exogenous testosterone, overall singing range gets lower and vocal instability, hoarseness, and weakness occur as the range shifts. Singers often lose access to the higher part of their range early on and must relearn how to access it. In some singers, range constriction and quality issues improve over time, but in others, the problems persist. While these formally published descriptions are useful additions to experiences informally shared by trans singers in person and online, there is a clear need for a methodologically rigorous assessment of how the assigned female singing voice changes with exogenous testosterone. This project addresses that need.

METHODS

The lead investigator/lead author, Ari Agha, is also the individual whose voice change is described in this project. With a Ph.D. in sociology, expertise in gender theory and social science research methods, and over a decade leading empirical research in academic, government, and nonprofit settings, Agha was well suited for the dual role of researcher and participant. Agha identifies as nonbinary, uses they/them pronouns, and was 39 years old at the inception of testosterone therapy. They are a high intensity (5 hours/week) choral singer in select amateur and semiprofessional ensembles. Before this project, they had only sporadic private voice study, most recently in the late 1990s when acquiring a minor in

music. Perceptual assessments of the voice are primarily provided by the second author, Laura Hynes (she/her). Hynes is an associate professor of voice at the University of Calgary, who has a DMA in voice performance and 20 years of professional performance experience in addition to 15 years of teaching experience.

Context of the Study

Agha had been studying private voice with Hynes for six months before the start of the project. To ensure a clean baseline, data collection began before hormone therapy was started. Voice lessons between Hynes and Agha continued for 30 months after starting testosterone. In addition to vocalized warm-ups and repertoire, Agha sang the traditional Shaker hymn, "Simple Gifts," every six to eight weeks throughout the study to allow comparison of voice characteristics in the context of a song. The piece was familiar, had a range of one octave, was easy to transpose, and the lyrics resonated with Agha, also making it a good fit for the performance creation project that accompanied the research. (For more information on the performance creation, see www.keyoft.com.)

Agha's singing goal was to maintain a healthy voice. They were not seeking to achieve a traditionally "masculine" range or timbre. Quite the opposite, while they knew a shift down in their range was likely unavoidable, Agha worried about losing access to head voice and the tone becoming more breathy and less resonant. Given the risk of voice damage, Agha considered a broad range of resources in 2015–2016, when they were planning their gender transition. Constansis[14] and Sims[15] were the most relevant formal resources available at the time. Another valuable source of information was informal statements from transgender singers who shared their experiences with singing voice changes, some of which appear in written format (for example, see Riverdale).[16] Best practices in vocal health and pedagogy that are relevant to all singers were also considered. In consultation with Agha's endocrinologist and Hynes, the following approach was used:

1. Agha planned to take 12 months to bring testosterone levels within the typical range for cisgender men.[17] Agha intended to do this this by starting on a low dose and gradually increasing to a maintenance dose, instead of achieving a maintenance dose shortly after starting.[18]
2. Hynes and Agha followed established practices of good vocal hygiene and pedagogy, intending for Agha to continue singing throughout the transition, provided there were no indications of excessive vocal strain. Anecdotal evidence shows that it is not uncommon for transgender singers using exogenous testosterone to completely stop singing during their transition for several reasons, including physical discomfort and vocal fatigue, vocal instability and hoarseness, constriction of range, and emotional distress (for example, Riverdale).[19]
3. Voice lessons with Hynes continued throughout the study. Key to facilitating a healthy transition was Hynes's expertise in understanding the voice and her ability to identify and address technical challenges that arose or were exacerbated during the transition.

Data Collection

Following are more details on the data collected in the study: perceptual and clinical measures of the voice, hormone dosage and blood serum levels, and Agha's perspective on the emotional, embodied experience of the voice change.

Perceptual measures of singing voice

Hynes provided perceptual evaluations of Agha's voice. Instances of Agha describing their own voice are indicated. Voice lessons occurred approximately once per week for 30 months, less frequently in summer months. Every six to eight weeks, Agha sang "Simple Gifts" in voice lessons. All lessons were video/audio recorded. At each lesson, Hynes documented, in writing, the top and bottom notes of Agha's range, transition areas, and other observations about vocal quality. Recorded sessions were referenced when needed to verify written records.

Clinical measures of voice

Agha sought support from a speech language pathologist (SLP) to ensure healthy speaking voice use. Information from those sessions supplements perceptual voice measures. Additional information includes fundamental frequency in conversation and reading and visualization of the vocal folds through flexible laryngoscopy with stroboscopy.

Measures of hormones

Unlike prior research, hormone levels were tracked to assess Agha's relationship to singing voice changes. Hormone measures include the dosage of exogenous testosterone and blood serum levels of total testosterone,

free testosterone and estradiol (a measure of estrogen). Blood serum levels were measured approximately every three months as part of regular medical monitoring.

Measures of Agha's emotional, embodied experience of voice change

Agha used several approaches to document their voice change experience: informal written journal entries, essays/blog posts, and video blogs. Agha used an open ended/unstructured approach, recording thoughts, feelings, reflections, and experiences as often as desired. There were a total of nine written journal entries, three essays/blogs, and 12 video reflections. Agha manually coded reflections identifying themes that arose from the content.

RESULTS

This section begins with a detailed description of when and how Agha's singing voice changed. Next, information about potential connections between hormones and voice changes are explored. Then, learnings from supplemental clinical data on voice changes are summarized, followed by an exploration of Agha's emotional, embodied experience of living with a changing voice.

Timing and Nature of Changes in Singing Voice

This investigation assesses changes in total and functional singing range, timbre, register transitions, and registration strategies. The highest and lowest notes in a singer's range can change for many reasons that have nothing to do with hormones or permanent physiological changes, including fatigue, dehydration, and stress, so caution is warranted in attributing significance to small changes. It is also important to note that at least three different factors can explain changes to Agha's singing voice in this study: (1) physiological changes brought about by exogenous testosterone; (2) time/experience singing with these physiological changes; and (3) changes to technique from lessons and practice. These factors overlap and interact in complex ways. Vocal changes should not be solely attributed to testosterone.

Comparison: pre-testosterone and 30 months with testosterone

Before beginning testosterone, Agha's total range was C_3 to C_6, with a functional range from $F^{\#}_3$ to A_5. They were a choral alto singing almost exclusively in head voice, employing mix and chest voice only while descending below the staff, around B_3 and below. Head voice *passaggio* began around $C^{\#}_5$. Voice quality was reedy, bright, straight tone, and clear with some occasional breathiness.

After 30 months of taking testosterone, Agha's total range had shifted a fourth lower, from G_2 to G_5, with a functional range of B_2 to F_5. Agha's head voice *passaggio* descended to around B_4, and a chest-head voice *passaggio* at E_4 emerged as the primary vocal transition event. Head voice quality gained richness and vocal weight through the transition, with a coarse edge developing at the very top of the range. While still primarily using straight tone, their voice was generally fuller, with an emergent brassiness throughout, a significantly increased reliance on chest voice production, and some pressed phonation in the lower part of the range.

Process of change over time

Figure 1 shows the total range (highest and lowest notes) before beginning testosterone and for 30 months with testosterone. The first notable change in range began after five months with testosterone, with the addition of three half steps down in the lower range. Three weeks later, Agha's highest note was between a half step and whole step lower, and a pronounced break emerged at $A^{\flat}_3$ as they descended into chest voice. This break occurred at the beginning of a prolonged period of vocal instability and fatigue. The top and bottom of their range continued to shift downward very gradually in an almost parallel fashion. Unlike other published studies,[20] as well as informal anecdotes shared by transgender singers, Agha did not experience a dramatic loss of head voice at any point during the transition. By 14 months, range shift had settled, though development of the lower voice was still in process.

Agha's singing goal was to maintain a healthy voice rather than achieve a traditionally "masculine" sound, and they expressed concern about losing access to the head voice. Because of this goal and concern, lessons included ongoing attention to head voice, chest voice, and mix. Head voice was regularly exercised through vocalization and repertoire. Chest voice was explored and developed concurrently, at first primarily through vocalization, and eventually with the addition of lower

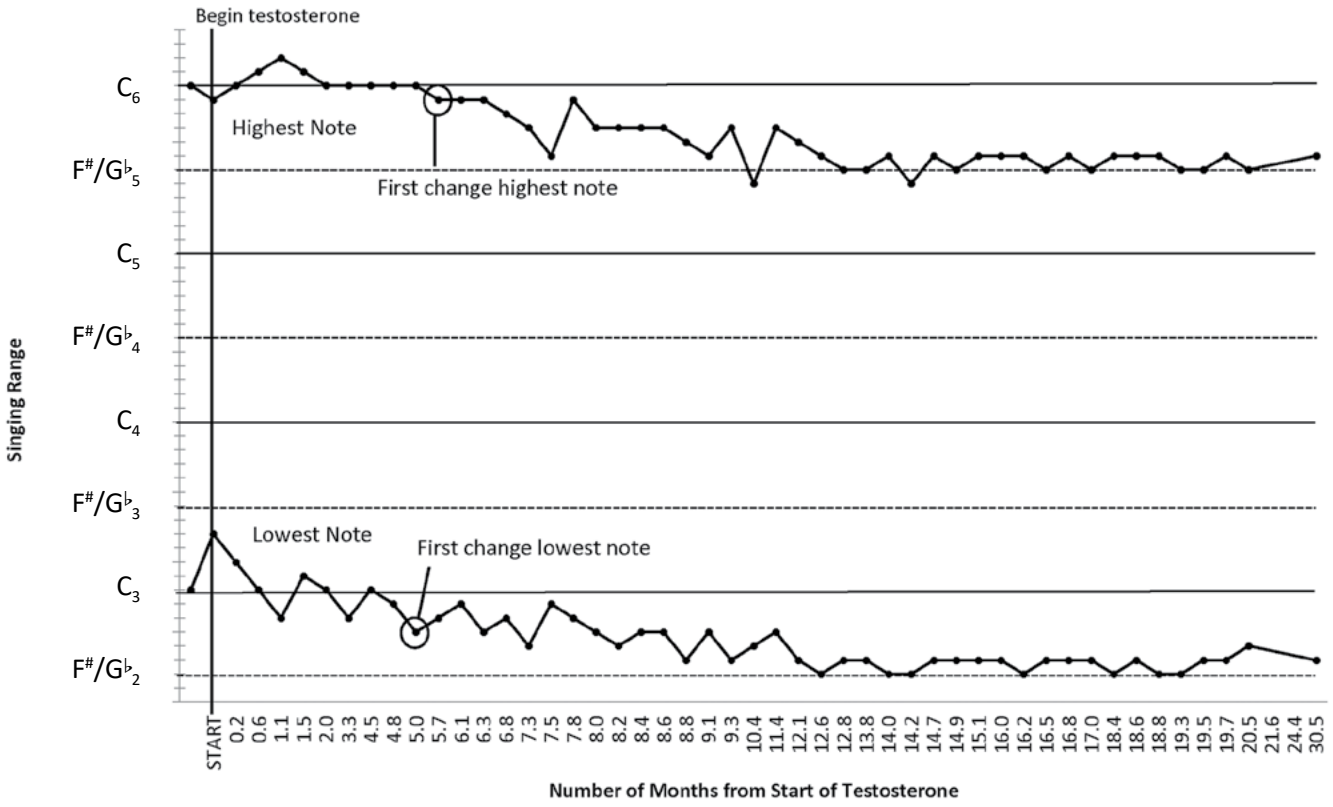

Figure 1. **Singing range over time.**

repertoire, including the transposition of "Simple Gifts" into lower keys. Though range, timbre, and registration strategies changed over the study, Agha generally maintained ease and clarity in head voice, and the tone gained richness and vocal weight. While they retained access to head voice throughout, by 6.8 months, the uppermost part of this range took on a slightly more strained and noisy falsetto-like quality. As new low notes emerged, the tone was initially growly and of limited functionality. For instance, while Agha could produce lower sounds upon gaining three half-steps at the bottom of the range (B_2, $B^{\flat}_2$, and A_2) at month five, they were not yet functional for repertoire. Eventually, though, the tone became more stable in low chest voice, and by the end of the study, Agha's functional range extended to B_2.

A critical factor in Agha's voice change was increased vocal fatigue and decreased stamina while speaking and singing, beginning five months after starting testosterone and continuing throughout the study. Some of this can likely be attributed to the change of registration, from relying almost exclusively on head voice mechanism to sustaining extended periods of chest voice/mixed register use in singing. The shift in technique and fatigue likely contributed to additional pressed phonation in the speaking voice and in the lowest singing notes, and a worsening of laryngeal elevation and excess breath pressure while singing, which were already present. Combined, these factors led to strain and a "shout" quality from A_3 to E_4, and difficulty navigating the sensation of "turning over" through the unsettled chest *passaggio*.[21] Agha described feeling excessive phlegm and an urge to cough and noted fatigue was especially apparent in long choir rehearsals. To address fatigue, Agha made sure to properly warm up the voice on their own before choral rehearsal, took frequent breaks from singing in choral rehearsal (such as avoiding repeated lines), and used straw phonation water therapy as a cool down afterward. At 20 months, Agha's voice and technique had stabilized enough to comfortably work up to E_4 in chest voice. By 24 months, upper chest voice use was stabilizing and would become more consistently accessible in the following months.

TABLE 1. Illustrative examples of "Simple Gifts."*

	Months with Testosterone			
Key	Pre	8.4	9.2	28.4
D (highest, range A_3 to A_4)	🔊			🔊
A (middle, range: E_3 to E_4)		🔊		
F (lowest, range: C_3 to C_4)			🔊	🔊

**Listen to this recording at https://www.nats.org/Journal_of_Singing_Multimedia_.html.*

"Simple Gifts" over time

Tracking Agha's singing of the song "Simple Gifts" provided another perspective on their voice change. Agha could sing the song in several different keys at each recording, but identifying which key best suited their changing voice offered important insights. Suitability was based on vocal stability, tone quality, and ease. The most suitable key reflected, essentially, the best working tessitura at any given time. (Table 1 includes audio clips to illustrate Agha's voice in different keys at different times.) [22] Before beginning testosterone, Agha sang "Simple Gifts" most comfortably in the key of D (range: A_3 to A_4), using head voice. At 8.4 months, the key of A (down a fourth, range: E_3 to E_4) was a better match for supporting their technical progress. The song was still primarily sung in head voice and mix due to considerable vocal instability in chest voice. In particular, Agha noted encroaching tension in the uppermost part of their head voice. Even while they felt more power and capacity in chest voice, they had less ease, stability, and control there, with frequent cracking. In choral rehearsals, they were most comfortable switching between alto and tenor parts to reduce strain, as either voice part on its own sat in a tessitura that exacerbated either tension or instability.

At 9.2 months, the key of A was still the best fit, but "Simple Gifts" was also recorded lower again, this time in F (range: C_3 to C_4) to allow Agha to experiment with different parts of the range. Even though the key was lower, they still sang primarily using head voice and mix, opting for the ease and stability there over chest voice alone, which remained unstable. As Agha became accustomed to the sensation of singing in chest voice, it was easier to shift fully into that register, even though it was still unstable. A capacity for chest/head mix developed gradually. By 28.4 months, they were still refining control in their chest voice while singing "Simple Gifts" in F (range: C_3 to C_4), but with far more stability and ease than before. At that time, "Simple Gifts" was also recorded in D (the original key, in head voice), which was still the most stable and clear. By the end of the study, 30 months, head voice production remained more stable and consistent overall, but F was the better key for Agha's changing voice and technique.

Hormone Dosage and Levels and Changes in Singing Voice

Information about testosterone dosage and levels is shared to understand how they may relate to voice changes. This information should *not* be considered a recommendation or guideline for others transitioning with exogenous testosterone. Agha had a positive relationship with an endocrinologist and strongly advocated for their goals of maintaining a healthy singing voice and transitioning gradually. All decisions about testosterone dosage were made together by Agha and the endocrinologist.

Agha took testosterone cypionate (brand name, Depo-Testosterone, manufactured by Pfizer Injectables), 100 mg/ml, administered via intramuscular injection. They started taking 1.0 ml every two weeks, which the endocrinologist described as a low starting dose.[23] At 7.5 months, the dosage was decreased to 0.75 ml, but frequency was increased from every two weeks to every week, meaning Agha was receiving a higher overall dosage. At 24.5 months, the dosage was decreased to 0.70 ml every week. Testosterone dosage is often the first factor considered when taking stock of testosterone-related changes. Because of variation in how bodies process the hormone, dosage on its own is of limited value. Considering blood serum levels adds substantially to understanding how testosterone impacts the body.

Blood serum levels of estrogen and testosterone were measured approximately every three months as part of regular medical monitoring. Measures were taken at trough, shortly before the next administration of testosterone was due. Estradiol reflects estrogen levels. Both total testosterone and free testosterone were collected, but total testosterone is reported.[24]

As stated previously, Agha's plan for hormone therapy was to bring blood serum levels of testosterone within

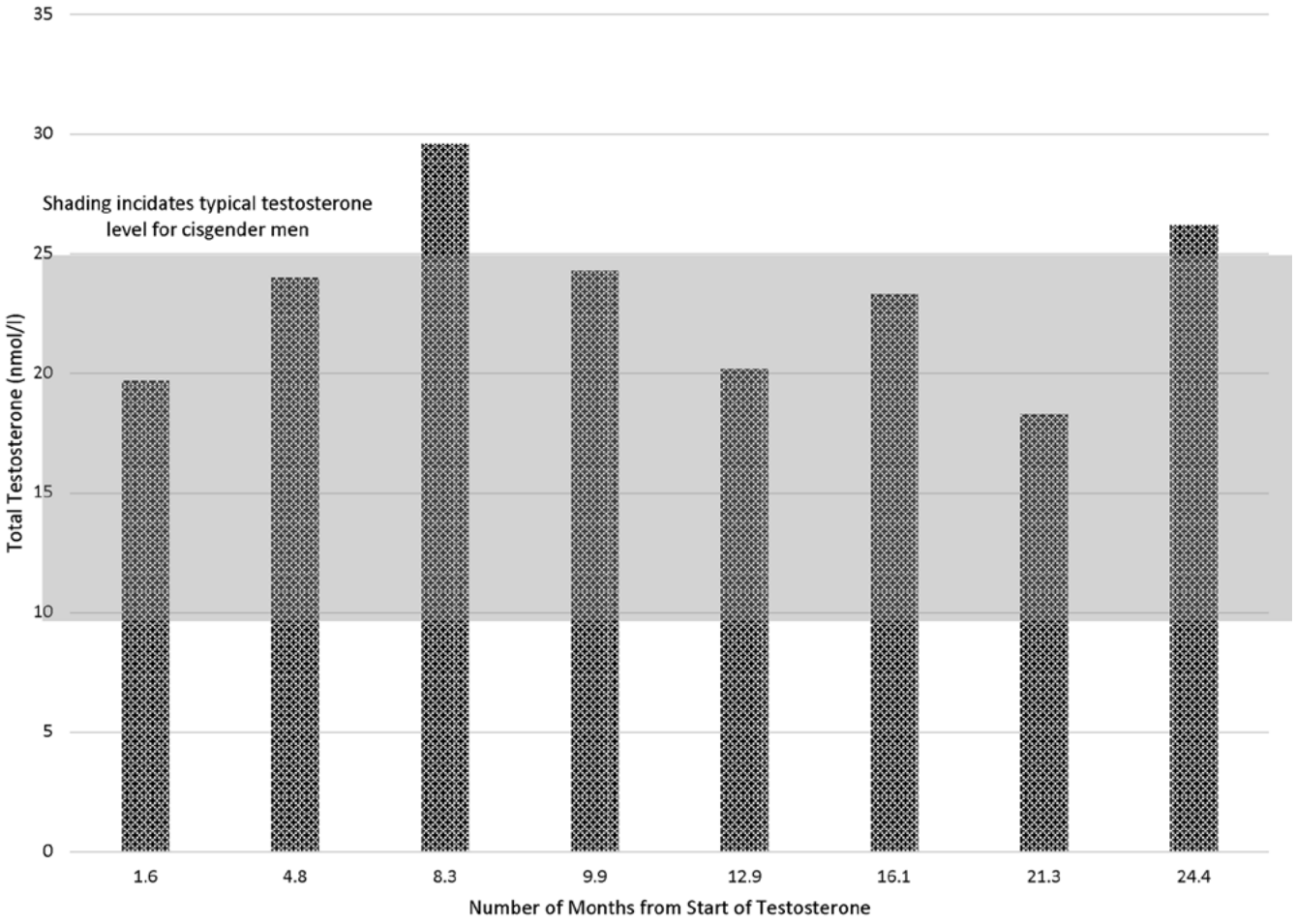

Figure 2. Total Testosterone blood serum over time.

the typical range for cisgender men over the course of 12 months. Blood serum levels were not recorded before starting to take testosterone. Figures 2 and 3 show blood serum levels of total testosterone and estradiol with columns, while the cisgender male level of each hormone is indicated, for reference, with a grey shaded box.[25] Figure 2 shows that total testosterone was within or somewhat above the cisgender male range (10 to 25 nmol/L) beginning with the first blood test, 1.6 months after starting testosterone, and throughout the study. Figure 3, on the other hand, shows that estradiol levels remained above cisgender male levels (48 to 154 pmol/L) until 9.9 months and remained in the higher end of or slightly above the typical cisgender male range throughout the study.

Figure 4 combines Figure 2, top and bottom of singing range, with Figure 3, total testosterone blood serum. The horizontal lines show the top and bottom of the singing range and refer to the left axis. The columns show total testosterone level and refer to the right axis. The shaded box indicates the cisgender male range of testosterone (10 to 25 nmol/L) for reference. By starting with a low dose of testosterone, it was not expected that blood serum levels would be within the cisgender male range so quickly. This quick arrival at the cisgender male range caused some concern that voice changes may occur rapidly. Even though testosterone levels were within cisgender male range from very early in the study, changes in singing range did not begin until five months after starting testosterone and continued changing until 14 months after starting testosterone. In addition to being within cisgender male levels from early on, total testosterone levels did not vary significantly over the study, with all but one measure being between 18.3

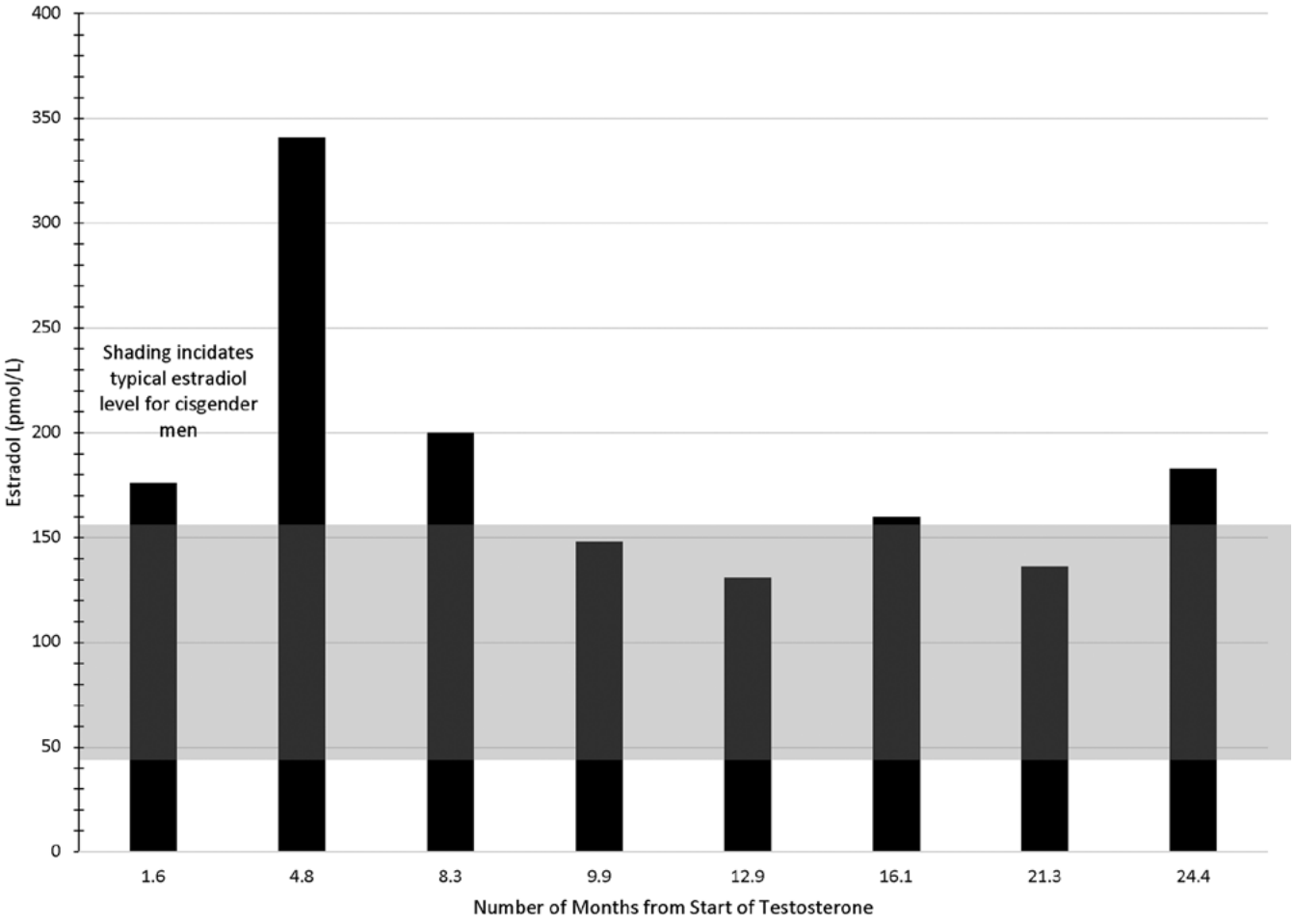

Figure 3. Estradiol blood serum over time.

nmol/L and 26.2 nmol/L. This lack of variation made drawing connections between testosterone levels and voice changes empirically challenging.

Because estradiol levels typically decrease over time with exogenous testosterone, the potential intervening impact of estradiol was not anticipated.[26] Although empirical research is lacking, the persistence of estradiol at the higher end of or slightly above the typical cisgender male range throughout the study may have contributed to the gradual nature of the decline and continued access to head voice; this topic warrants further investigation.

Supplemental Clinical Information

Two additional sources of clinical information supplement these findings. While the focus of this study is the singing voice, Table 2 includes data on fundamental frequency in reading and conversation from four time points: before starting testosterone, 13.0 months, 14.2 months, and 16.0 months with testosterone. Pre-testosterone measures indicate Agha's mean fundamental frequency on reading task, 180 Hz, was within typical cisgender-female range, 180 Hz to 220 Hz.[27] All three post-testosterone measures indicate Agha's speaking voice was within typical cisgender male range, 100 Hz to 140 Hz.[28]

Three flexible laryngeal stroboscopies were conducted, one before starting testosterone, a second after 8.5 months with testosterone, and a third after 34 months with testosterone. In the pre-testosterone and 34 month videos, the larynx was open with fully visualized vocal folds from the anterior commissure to the posterior glottis and only very mild type III muscle tension pattern (MTP) on phonation (initially described

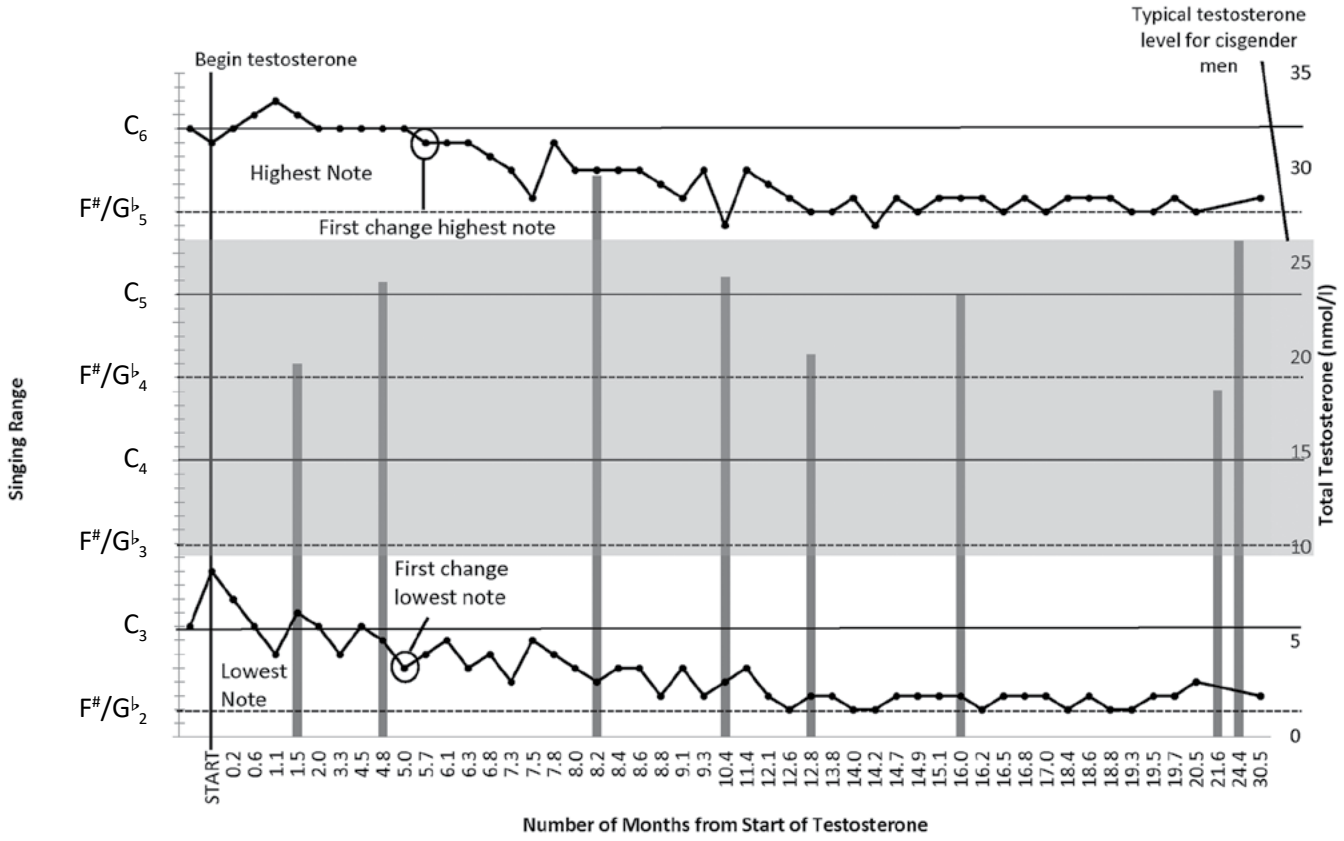

Figure 4. Singing range over time and total testosterone blood serum.

TABLE 2. Fundamental frequency.

	Months with Testosterone			
	Pre	13.0	14.2	16.0
Mean reading rainbow passage	180 Hz	132 Hz	137 Hz	135 Hz
Range reading rainbow passage	n/a	111 – 275 Hz	n/a	n/a
Mean conversation	n/a	117Hz	119 Hz	117 Hz
Range conversation	n/a	109 – 286 Hz	n/a	n/a

by Morrison and Rammage).[29] In contrast, the 8.5 month video shows increased type III MTP and the addition of mild type II MTP. This clinical assessment of increased tension mirrors and validates the increased vocal instability observed in lessons.

From visual inspection, the true vocal folds appeared fuller at 34 months than they did in pre-testosterone assessment. The width of the vocal folds, defined as the distance from the free edge to the arcuate line at the midpoint between the anterior commissure and vocal process, and referenced to the length of the vocal folds, defined by the distance from the anterior commissure to the vocal process, was calculated in a normal respiratory cycle with modal phonation using the ratio of width to length to control for different scope position and magnification effect. Using this method, the vocal fold width to length ratios were 0.24 pre-testosterone, 0.32 at 8.5 months, and 0.41 at 34 months, indicating

that the vocal folds thickened and became heavier with time, confirming the visual inspection. While the literature has long assumed that exogenous testosterone leads to thicker vocal folds, this is among the first studies to document this change.

Agha's Emotional, Embodied Experience of Voice Change

So far, the focus has been on describing how Agha's voice changed. This section shifts attention to how Agha *felt* as their voice was changing, using journal entries, blogs/essays, and video reflections as data sources. Agha's experiences should not be assumed to be typical of or broadly applicable to other people who transition with exogenous testosterone. This description can provide some examples of one transgender person's experiences and highlight the importance of paying attention not just to the qualities of the voice but also to the singer's experiences.

Uncertainty

Agha began testosterone therapy at age 39, well into adulthood. Singing had been a source of joy and fulfillment throughout their life. While their livelihood did not rely on their ability to sing, the potential that their singing voice could be irreversibly damaged was the greatest fear when deciding whether to take testosterone. Reflecting this concern, uncertainty featured prominently across all data sources beginning before they started taking testosterone and continuing throughout the study. See this excerpt from a video reflection (the ensuing quotations from video reflections are edited for clarity):

> I'm uncertain about what this process of changing is going to be like. I'm uncertain of what it's going to be like for my voice to be different from what it was before, even though I, of course, want it to be different. That's why I'm doing this. I'm uncertain about what I'm going to end up sounding like. I'm uncertain about what that's going to feel like for me, in my body. I'm uncertain about how I will feel about my voice, how I will connect with my voice, and if it will still feel like mine.

Complex responses to change

The first change in Agha's singing voice happened after five months when their lowest note shifted down (see Figure 1). Agha had chosen to transition gradually. While, objectively, five months is not very long, Agha was both eager and anxious in the time between starting testosterone and their first voice change. When that first change happened, they were overjoyed and relieved.

> It is February 8, 2017, and my range has finally changed, it appears! This is really happening! It feels super, freaking exciting and rewarding and like "Ahhhhh!" finally, something is happening, it's awesome, it's just awesome. It's a tiny change, but it's a real change. It is such a relief that things are actually starting to change.

While their immediate reaction was positive, the value they place on singing and the uncertainty of how testosterone would impact their voice made things more complicated. Not long after their singing voice began changing, Agha shared:

> It's exciting that things are changing, and that's great, and at the same time, it's like, "Oh my god, things are changing!" I want them to change, and at the same time, it's frightening that they're changing.

Losing head voice was troubling to Agha. This concern was a combination of worry about losing access to the higher part of the range altogether and about the timbre of the upper part of the range becoming more breathy and less resonant. This excerpt is from after a discussion Agha and Hynes had about the expected shift from primarily singing in head voice to primarily singing in chest voice.

> That idea of losing my head voice makes me bereft. It makes me sad, and it makes me scared to not be able to experience that anymore. There's a part of me that almost can't understand what that means. That is how I sing, I sing in my head voice, that's what I do, so to do something different to sing, I don't know, it's hard to imagine.

As described previously, Agha retained access to much of the upper part of the range throughout the study. They reflect on the experience of continuing to sing alto after a particularly poignant choir rehearsal of G. Gabrielli's "Hodie Christus Natus Est" (1615).

> It felt really good, in my body, to produce those sounds . . . With all of the ways my voice has been changing, it was reassuring that I'm still singing alto . . . I felt this

> connection with my voice and with what my voice has always been.

While they were preoccupied with concerns about the upper part of the range and curious about a deepening of the range, they were less focused on how the tone of the lower range might be different. Noticing the increased power and shift in resonance was exciting.

> It felt really good to sing in my chest voice today. The sound was expansive. It's not just that I can sing louder than I used to. I think it's the resonance that's different. It felt really awesome. I felt empowered. It is a very different sound than I was making a year ago when singing in this part of my range, and I really like it.

Vocal fatigue and instability

Agha's increased vocal fatigue and instability began around the same time their singing voice began to change, persisted throughout the study, and caused Agha substantial distress. In a blog post, they write:

> I try never to push my voice beyond what is comfortable. This is much easier said than done, though, because I love to sing. I want to sing. In (choir) rehearsal, I'm surrounded by singing voices, and it's frustrating to have to stop for a while or hold back.[30]

Before beginning testosterone, Agha paid little attention to register transitions. Continuing to do so became more difficult as those transitions became unstable. "I have a lot of instability, especially in the lower *passaggio*, my voice is cracking and squeaking, and it's disconcerting to not know what sound is going to come out when I try to sing." This uncertainty about their voice was especially troubling in auditions when they were competing with adult singers while their voice was still quite unstable.

> I felt frustrated, annoyed, and angry. I was also self-conscious. I mean, I'm an adult singer, and I'm having to deal with this change in my voice . . . unlike cisgender folks who went through this transition many years, if not decades, ago [when they experienced puberty].

This section provides some examples of how Agha felt as their voice was changing. For ease of understanding, themes were grouped into three categories, but Agha's lived experience was complex, multifaceted, and malleable. Singers and teachers are encouraged to allow space for the emotional aspects of living with a changing voice and to consider how these factors can influence vocal development.

DISCUSSION

This project advances research on transgender singing voice transition in several ways. It brings together performing arts pedagogy and medical/clinical perspectives, including both perceptual and clinical voice measures and assessing the relationship between hormone levels and voice changes. It includes audio recordings, providing valuable illustrations of Agha's voice at several points during the transition. By describing Agha's embodied, emotional experience of living with a changing voice, it highlights the need to consider the person behind the voice, in addition to the qualities of the voice. Methodologically, it adds to the literature by beginning data collection before testosterone was started and repeatedly measuring the voice over the course of thirty months.

While the project was rigorous and carefully planned, it is still a case study. There is no "control singer" who did not take testosterone, a second experimental singer who used a different approach to transition with which to compare Agha's experience. Case study evidence cannot be used to demonstrate causal relationships, but it does provide a thorough, detailed description of one person's experience, test methods to document this type of voice change, and set the stage for additional case studies. This section uses current scientific understanding to make sense of Agha's voice change, understanding that some explanations may need to be adjusted or dropped as scientific knowledge evolves.

The parallel nature of the shift down in Agha's total range and their continuous access to head voice throughout the transition was substantially different than other published studies,[31] as well as informal anecdotes shared by transgender singers, which show a dramatic loss of head voice followed by gradually improved access to this range. Two factors may help to explain this outcome. First, Agha felt a strong emotional connection to the head voice and worried about losing access to the higher parts of their range. Because of this, and given its stability and familiarity, lessons intentionally focused

on regular exercise of the head voice, which may have contributed to Agha maintaining access to it throughout the transition. In addition, despite starting on a low dose of testosterone, Agha's blood serum level of testosterone was within the reference range for cisgender men from 1.6 months after starting. Even with this quick arrival at cisgender male testosterone levels, Agha's singing voice did not begin changing until five months after initiation. The continuation of estrogen at the high end of or above cisgender male levels throughout the study may also have contributed to the gradual and parallel nature of changes. These unexpected findings regarding hormone levels do not suggest that starting on a low dose of testosterone and increasing gradually is unwarranted or that monitoring blood serum levels of hormones is unnecessary. They show that it is important to allow time for voice changes to occur and that it is worth considering the possibility that estrogen may intervene in the impact of exogenous testosterone.

The lowering of range is often the primary focus in testosterone-related voice transition, but this study shows substantial changes in two other areas: timbre in both head and chest voice and which registration mode was primarily used. Beginning with timbre, over the study Agha's head voice gained richness and weight, while the chest voice became fuller and brassier, with some pressed phonation. Regarding registration, Agha shifted from primarily singing in head voice to primarily singing in chest voice. This shift to greater reliance on chest voice was accompanied by vocal instability (documented in singing lessons and with increased type III MTP and the addition of mild type II MTP in stroboscopies). This shift required adjustments to technique and coordination. After a lifetime of attachment to and experience singing as an alto, developing these skills was an ongoing process that developed slowly and required dedicated effort in lessons and practice.

Agha's experience fits with the reduced stamina and vocal fatigue that has been documented in research on the impact of exogenous testosterone on both speaking and singing.[32] Agha's vocal fatigue emerged after five months taking testosterone, and it persisted throughout the study. This issue impacted multiple facets of Agha's life. Their voice was often tired after a workday with typical vocal load. In lessons, Hynes remained attuned to indicators of vocal fatigue and adjusted as needed. Low stamina was especially noticeable in choral rehearsals. Before transition, Agha did not tire from a typical choral rehearsal (2.5 hours), but stamina decreased substantially shortly after range changes started. By the end of the study, vocal stamina had begun improving.

Another important contribution of this study is the focus, not just on how Agha's voice changed but also on their emotional and embodied experience of going through a voice change. What is most important about Agha's experience of voice change is that it was not a simple story of moving from unhappy to happy. After a lifetime of deriving great joy from singing, the potential of voice damage made their experience of voice transition complicated. They understood that the singing voice would change with testosterone therapy, and while they eagerly anticipated and celebrated changes, changes also caused worry and anxiety. Agha was grateful to have maintained access to head voice. Discovering new power in chest voice was exciting, but vocal instability and the slow process of adjusting technique were frustrating. Long-lasting vocal fatigue was especially challenging as it impacted multiple facets of their singing: choral singing, solo singing, voice lessons, and at home practice.

Since Agha began taking testosterone in 2016, there has been some growth in information about these kinds of voice changes; however, singers transitioning with exogenous testosterone today still have little certainty about outcomes. Creating space for a range of emotions and responses to voice changes is vital in supporting singers going through a gender transition. One way to do this is by continuously centering the student in the voice studio and understanding that the student's experience of their voice, their goals, and their concerns, can shift and change over time.

RECOMMENDATIONS FOR FUTURE RESEARCH

This section begins with recommendations for how to create research teams that will enable rigorous, comprehensive scholarship on this topic, then shifts to methodological and knowledge circulation recommendations.

Research partnerships between voice teachers, voice scientists, and singers are necessary for a thorough understanding of transgender voice change. If the singer's perspective is left out, a critical component will be miss-

ing. The present project's partnership between singer and voice teacher originated with the singer (Agha) who was already a skilled and experienced researcher. Partnerships with singers can take many different forms (for example, see Cler et al.).[33] A singer does not need specialized training to be a productive research partner. It is common for transgender people to document their gender transitions in writing, video, and audio, and share this documentation online as a resource for others considering gender transition. These grassroots efforts highlight the resilience of the transgender community in the face of formal scholarship that is limited in both quantity and quality. Rather than dismissing these grassroots efforts as "unscientific," voice teachers and scientists can partner with transgender singers to formalize and systematize a method that is already familiar to them. For more guidance, see literature on community-based participatory research and similar methodologies. For a unique combination of knowledge and experience, the reader is referred to a recent study by Graham and Glasner.[34] Graham is a professional transgender singer and teacher, who brings performance and teaching experience together with training in voice science to document his own voice transition.

In addition to partnering directly with singers, voice teachers and voice scientists can benefit by collaborating with professionals in other fields. Working with speech language pathologists (SLPs) will expand the pool of training and experience brought to the work.[35] It will also facilitate more comprehensive support for both speaking and singing changes in people taking testosterone. To avoid perpetuating harmful assumptions about transgender people, researchers working on transgender voice transition need a solid understanding of the basics of gender theory. It is crucial that this understanding go beyond using accurate terminology. Scholars of transgender voice transition need to understand foundational concepts like social construction, biological essentialism, and differences between assigned sex and gender. Researchers lacking this background or who are in the process of learning this literature can collaborate with women's and gender studies scholars.

Turning to methodological considerations, given how little is known about the impacts of exogenous testosterone on singing, the field would benefit from additional carefully planned case studies of one or a few singers that track changes for 18 months or more (especially if a gradual approach to transition is taken), include multiple data sources, and assess connections with hormone levels. Documenting the singer's experiences with voice change can also provide valuable insights. These studies will broaden understanding of the ways singing voices change with exogenous testosterone and suggest patterns to explore as similarities and differences in individual experiences emerge with more findings published.

Future case studies would benefit from collecting information for multiple data points before starting testosterone to establish pre-testosterone norms more thoroughly. A great deal could be learned by supplementing perceptual measures of singing voice changes with acoustic analysis. Tracking whether vocal tract length changes with exogenous testosterone to ascertain whether the Cler et al. finding of growth in the vocal tract is typical could have important implications for technical approaches for transitioning singers.[36]

Peer review and scholarly publication are important means of ensuring rigor and disseminating knowledge, but they also make information inaccessible to a broad swath of the population. Even with open access, the language and style used in academic publications can be a barrier to understanding. To make information on exogenous testosterone and singing more easily accessible, researchers, in addition to publishing in academic journals, are encouraged to post in plain language overviews of their work in free, online forums while abiding by copyright regulations.

This article is the most rigorous scientific description to date of the singing voice change of an assigned female singer taking testosterone. In addition to clearly articulating the nature and timing of changes to Agha's singing voice, offering illustrative audio examples of Agha's changing voice, providing new information on potential connections between voice changes and testosterone and estrogen, and additional insights from clinical data, the article demonstrates that Agha's experience of going through a voice change was complex and multilayered. Singing throughout the vocal transition and working with a skilled and compassionate teacher helped ensure that Agha could continue singing in a healthy way and that they learned the skills needed as their anatomy and physiology changed.

ACKNOWLEDGEMENTS

This article draws on research supported by the Social Sciences and Humanities Research Council of Canada. The authors wish to thank several people at Alberta Health Services/Calgary Voice Program. They thank Dr. Derrick Randall for visual and measurement analysis of stroboscopy data, Meri Andreassen (Speech Language Pathologist) for clinical support and support with collection of Calgary-based clinical information, and Calgary Voice Program administrative staff for coordinating services. Ari, especially, thanks Dr. Buki Ajala and staff at LMC Calgary for empowering them to be an informed decision maker in their gender transition, providing excellent medical care, and coordinating services. The authors thank Laurie Grisham (Speech Language Pathologist) and Dr. Jeffrey Baker at Benefits Therapy Centre (Great Falls, Montana) for collection of pre-testosterone clinical information. Finally, the authors thank Emily Greenleaf for feedback and perspective, and Dr. Timothy Shantz (University of Alberta) for perceptual data collection and manuscript feedback. Ari, especially, thanks him for his support and inclusive leadership.

NOTES

1. David Azul et al., "Transmasculine People's Voice Function: A Review of the Currently Available Evidence," *Journal of Voice* 31, no. 2 (March 2017): 261.e9–261.e23; https://doi.org/10.1016/j.jvoice.2016.05.005.
2. Intersex is a third category of assigned sex in which genitalia, hormones, internal anatomy, and chromosomes differ from the usual two ways that human bodies develop (InterACT: https://interactadvocates.org/faq/). Testosterone and estrogen production in intersex people may align with patterns in people assigned male or assigned female, or be different from both.
3. Sara A. DiVall and Carolina DiBlasi, "The Endocrinology of Puberty," in Antonio Belfiore and Derek LeRoith, eds., *Principles of Endocrinology and Hormone Action* (Cham, Switzerland: Springer, 2018), 626–658.
4. Sameep Kadakia, Dave Carlson, and Robert T Sataloff, "The Effect of Hormones on the Voice," *Journal of Singing* 69, no. 5 (May/June 2013): 4. K. V. S. Kumar et al., "Voice and Endocrinology," *Indian Journal of Endocrinology and Metabolism* 20, no. 5 (2016): 590–594; https://doi.org/10.4103/2230–8210.190523. Alessandro Ilacqua, Davide Francomano, and Antonio Aversa, "The Physiology of the Testis," in Carolina DiBlasi and Derek LeRoith, eds., *Principles of Endocrinology and Hormone Action* (Cham, Switzerland: Springer, 2018), 455–491.
5. Muralidhar Mupparapu and Anitha Vuppalapati, "Ossification of Laryngeal Cartilages on Lateral Cephalometric Radiographs," *The Angle Orthodontist* 75, no. 2 (March 1, 2005): 196–201; https://doi.org/10.1043/0003–3219(2005)075<0192:OOLCOL>2.0.CO;2.
6. Christie Block, Viktoria G. Papp, and Richard Kenneth Adler, "Transmasculine Voice and Communication," in Richard Kenneth Adler, Sandy Hirsch, and Jack Pickering, eds., *Voice and Communication Therapy for the Transgender/Gender Diverse Client: A Comprehensive Clinical Guide*, 3rd edition (San Diego, CA: Plural Publishing, 2019), 145.
7. Azul et al. Block, Papp, and Adler. Aaron Ziegler et al., "Effectiveness of Testosterone Therapy for Masculinizing Voice in Transgender Patients: A Meta-Analytic Review," *International Journal of Transgenderism* 19, no. 1 (January 2, 2018): 25–45; https://doi.org/10.1080/15532739.2017.1411857.
8. Edward J. Damrose, "Quantifying the Impact of Androgen Therapy on the Female Larynx," *Auris, Nasus, Larynx* 36, no. 1 (February 2009): 110–12; https://doi.org/10.1016/j.anl.2008.03.002. John Van Borsel and Heidi Baeck, "The Voice in Transsexuals," *Revista de Logopedia, Foniatría y Audiología* 34, no. 1 (January 1, 2014): 40–48; https://doi.org/10.1016/j.rlfa.2013.04.007. Gabriel J. Cler et al., "Longitudinal Case Study of Transgender Voice Changes Under Testosterone Hormone Therapy," *Journal of Voice* 34, no. 5 (April 13, 2019); https://doi.org/10.1016/j.jvoice.2019.03.006.
9. Alexandros N. Constansis, "The Changing Female-To-Male (FTM) Voice," *Radical Musicology* 3 (2008); http://www.radical-musicology.org.uk/2008/Constansis.htm.
10. Mupparapu and Vuppalapati.
11. Constansis, paragraph 4.
12. Alexandros N. Constansis and Aglaia Foteinou, "Case Study of a Performance-Active Changing Trans* Male Singing Voice," *Voice and Speech Review* 11, no. 2 (May 4, 2017): 154–175; https://doi.org/10.1080/23268263.2017.1383555. Brian Manternach et al., "Teaching Transgender Singers. Part 1: The Voice Teachers' Perspectives," *Journal of Singing* 74, no. 1 (September/October 2017): 83–88. Brian Manternach, "Teaching Transgender Singers. Part 2: The Singers' Perspectives," *Journal of Singing* 74, no. 2 (November/December 2017): 209–214. Loraine Sims, "Teaching Lucas: A Transgender Student's Vocal Journey from Soprano to Tenor," *Journal of Singing* 73, no. 4 (March/April 2017): 367. Liz Jackson Hearns and Brian Kremer, *The Singing Teacher's Guide to Transgender Voices* (San Diego, CA: Plural Publishing Inc, 2018). Anita Kozan, Sandra Hammond, and Jack Pickering, "The Singing Voice," in Adler, Hirsch, and Pickering, 291–335.

13. Constansis.
14. Ibid.
15. Sims.
16. Joshua Riverdale, "Testosterone and the FTM Singing Voice," *TransGuys.Com* (blog), December 28, 2009; http://transguys.com/features/testosterone-ftm-singing. Eli Conley, "Transgender Men, Testosterone, and Singing—Some Advice," *Eli Conley* (blog), February 11, 2013; http://www.eliconley.com/1/post/2013/02/transgender-men-testosterone-and-singing-some-advice.html.
17. Proceeding more quickly to a maintenance dose may be preferred among those who prioritize more rapidly relieving discomfort from misgendering. Teachers are encouraged to respect student choices about the pace at which to transition.
18. Given this goal, this research cannot speak to the effects of microdosing, or taking a low dose of testosterone over a prolonged period of time.
19. Riverdale.
20. Constansis. Sims, "Teaching Lucas."
21. Kenneth Bozeman, *Practical Vocal Acoustics: Pedagogic Applications for Teachers and Singers* (Hillsdale, NY: Pendragon Press, 2013).
22. Audio clips are available in the table and at: https://www.nats.org/Journal_of_Singing_Multimedia_.html.
23. Clinical opinion on dosage varies; see, World Professional Association for Transgender Health, "Standards of Care for the Health of Transsexual, Transgender, and Gender-Conforming People (7th Version)," 2012; https://www.wpath.org/publications/soc.
24. Clinical opinions on the accuracy and reliability of total and free testosterone vary. Total testosterone is reported, as recommended in the British Columbia guidelines for transgender endocrine therapy (World Professional Association for Transgender Health). Findings did not vary when using free testosterone.
25. Tests were conducted by Alberta Precision Laboratories, "Alberta Precision Laboratories | Lab Services"; https://www.albertahealthservices.ca/webapps/labservices/indexAPL.asp?zoneid=1&SearchText=&submit=Submit+Query&upperTest=-1&lowerTest=-1 (accessed March 11, 2021), and the laboratory's reference ranges were used.
26. Kelly J. Chan et al., "Estrogen Levels Do Not Rise With Testosterone Treatment For Transgender Men," *Endocrine Practice: Official Journal of the American College of Endocrinology and the American Association of Clinical Endocrinologists* 24, no. 4 (April 2018): 329–33; https://doi.org/10.4158/EP-2017–0203.
27. Shelagh Davies, "Training the Transgender Singer: Finding the Voice Inside," *Independent Voices—National Association of Teachers of Singing*, Spring 2016; https://www.nats.org/_Library/Independent_Voices_Articles/training_transgender_singer-10-2016.pdf.
28. Davies.
29. Murray D. Morrison and Linda A. Rammage, "Muscle Misuse VoiceDisorders: Description and Classification," *Acta Oto-Laryngologica* 113, no. 3 (1993): 428–434.
30. Ari Agha, "Singing in the Cracks*," *Genderqueer Me—Ari Agha* (blog), April 21, 2018; http://www.genderqueerme.com/2/post/2018/04/singing-in-the-cracks.html (accessed May 7, 2021).
31. Constansis. Sims.
32. Azul et al. Constansis. Sims.
33. Cler et al.
34. Felix Graham and Joshua Glasner, "Fundamentally Speaking (And Singing): A Longitudinal Single-Case Study of a Professional Transmasculine Singer During Hormone Replacement Therapy," 50th Annual Symposium: Care of the Professional Voice (Voice Foundation, Online, June 6, 2021); https://voicefoundation.org/.
35. Adler, Hirsch, and Pickering. Danielle Cozart Steele, "Speech-Language Pathologists with a Vocal Music Background: Exploring Impact on the Training of the Transgender Voice," *Theatre, Dance and Performance Training* 10, no. 3 (September 2, 2019): 373–391; https://doi.org/10.1080/19443927.2019.1640781.
36. Cler et al.

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