# Transmasculine People's Voice Function: A Review of the Currently Available Evidence

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**Summary: Objectives.** This study aims to evaluate the currently available discursive and empirical data relating to those aspects of transmasculine people's vocal situations that are not primarily gender-related, to identify restrictions to voice function that have been observed in this population, and to make suggestions for future voice research and clinical practice.

**Methods.** We conducted a comprehensive review of the voice literature. Publications were identified by searching six electronic databases and bibliographies of relevant articles. Twenty-two publications met inclusion criteria. Discourses and empirical data were analyzed for factors and practices that impact on voice function and for indications of voice function-related problems in transmasculine people. The quality of the evidence was appraised.

**Results.** The extent and quality of studies investigating transmasculine people's voice function was found to be limited. There was mixed evidence to suggest that transmasculine people might experience restrictions to a range of domains of voice function, including vocal power, vocal control/stability, glottal function, pitch range/variability, vocal endurance, and voice quality.

**Conclusions.** More research into the different factors and practices affecting transmasculine people's voice function that takes account of a range of parameters of voice function and considers participants' self-evaluations is needed to establish how functional voice production can be best supported in this population.

**Key Words:** trans men–female-to-male transgender–female-to-male transsexual–voice treatment–testosterone treatment.

## INTRODUCTION

In the last 15 years, there has been a steady increase in publications in the voice literature concerned with gender-diverse people. In this paper, we use "gender diverse" as an overarching term that refers to people who do not identify with the gender assigned to them at birth and that comprises transsexual, transgender, and gender-nonconforming people.[1,2] We use "cisgender" to refer to people who identify with the gender assigned to them at birth.[2] "Vocal situation" is used as an overarching term comprising all aspects of voice production, including the anatomy and physiology of the speaker's or the singer's voice organ, their vocal behavior, the meanings others attribute to the speaker's or the singer's voice, and the cultural and environmental context in which voice production occurs (eg, [normative] understandings of vocal gender and voice function on which speakers and listeners draw, and vocal-loading factors). We use "voice function" as an overarching term similar to "vocal ability,"[3] which comprises the areas of assessment and treatment voice clinicians would consider with every voice client regardless of the client's subjective gender positioning and which are not primarily gender-related.

It is important to note that there is some overlap between gender-related and voice function-related aspects of a person's vocal situation. For instance, studies have shown that greater pitch range and pitch variability, lower vocal intensity, and breathy voice quality tend to be associated with female gender and would therefore be seen as desirable for gender-diverse people who would like to be heard and addressed as female.[4] By contrast, monotonous speech melody, smaller habitual and physiological vocal range, and higher vocal intensity tend to be associated with male gender and would therefore be seen as desirable for gender-diverse people who would like to be heard and addressed as male.[4,5] However, when evaluating these characteristics from a voice function perspective, limitations to pitch variability or vocal intensity and breathy voice quality could indicate difficulties with optimizing the configuration of the voice production system, which prevent the speaker from producing the most efficient vocal output.

Traditionally, the gender-diverse population is divided into two subgroups: transfeminine people, assigned male gender at birth; and transmasculine people, assigned female gender at birth. The latter subgroup is the target population of this review. In this article, by focusing on transmasculine people's voice function, we are exploring a topic area that has been exposed to a twofold neglect in the past. First, most publications exploring gender-diverse people's vocal situations are focused on transfeminine people, whereas transmasculine people have to date been underrepresented in the voice literature.[2,6] Second, most emphasis seems to have been placed on exploring and describing gender-related aspects of gender-diverse people's vocal situations, whereas their voice function has received less attention.

Accepted for publication May 6, 2016.

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Journal of Voice, Vol. 31, No. 2, pp. 261.e9–261.e23
0892-1997



http://dx.doi.org/10.1016/j.jvoice.2016.05.005

There are several reasons why we consider it important to examine the currently available evidence pertaining to transmasculine people's voice function. On the one hand, it has been claimed that transmasculine people's vocal situations can be regarded as unproblematic[7] and that transmasculine people do not require professional voice support,[8] but these assertions have not been sufficiently demonstrated. The rationale for this argument is commonly presented as follows. Transmasculine people do not experience voice-related difficulties in everyday encounters, because testosterone treatment lowers their pitch and increases their chances of being perceived and addressed as male. Contrary to this, voice feminization in transfeminine people does not occur as a result of estrogen treatment but is seen as complicated, requiring specialist intervention in the form of voice treatment or laryngeal surgery or both. This view seems to be supported by observations indicating that, in general, a lower number of transmasculine people compared with transfeminine people are referred to or seek professional voice support.[2] Hereby it is important to note, however, that it would be inaccurate to conclude that lower client numbers necessarily imply the absence of a problem. Indeed, a recent review of the voice literature investigating the current knowledge about the gender-related aspects of transmasculine people's vocal situations demonstrated that some transmasculine people (including those treated with testosterone) do experience problems with the vocal communication of gender and require or request professional voice support.[6]

On the other hand, it is our own clinical experience, if case history and voice assessment are carried out very carefully in transmasculine people who visit our clinics primarily to optimize their vocal gender presentation, a range of voice function-related symptoms might be revealed.[5]

In addition, just as is the case for cisgender people, gender-diverse people may be exposed to factors or engage in practices that compromise their voice function. Some of these factors and practices might be shared between cisgender and gender-diverse speakers (such as, smoking habits, diseases affecting voice, heavy vocal loading, background noise, poor room acoustics or air quality)[9]; others might be specific to the methods some gender-diverse people use to change their gender presentation. Examples of such "trans-specific"[2] factors or practices that might have an impact on voice function are behavioral modification of the voice production mechanism to feminize or masculinize the voice, laryngeal surgery to increase or lower pitch, or hormone treatment.

Testosterone has been demonstrated to lead to changes in vocal fold tissue[10] and to have deleterious effects on the voice function of cisgender women who have been exposed to high levels of androgens (eg, *via* exogenous administration of androgens or endogenous production of androgens in women with congenital adrenal hyperplasia).[11–16] The aspects of voice function that have been described as affected in this population are vocal stability, singing voice, vocal power, and voice quality. Based on the assumption that the anatomy and physiology of the voice organs of transmasculine people and cisgender women can be regarded as comparable before testosterone treatment, we are hypothesizing the possibility of restrictions to transmasculine people's voice function as a result of testosterone treatment, a supposition that requires careful investigation.

In light of these considerations and given that a review of the voice literature on the gender-related aspects of transmasculine people's vocal situations has already been conducted a short time ago,[6] the main aims of this review are to identify and categorize the current evidence related to voice function in transmasculine people, to identify restrictions to voice function that have been observed in this population, and to make suggestions for future voice research and clinical practice.

## METHODS

### Search methods, inclusion, and exclusion criteria

We conducted a comprehensive search of six electronic databases (Medline, PubMed, Embase, PsycINFO, CINAHL, and Scopus) without restriction on language and publication date, in October and again in December 2015. The date of the last search was 23 December 2015. Because gender diversity and voice are topic areas that are discussed at the intersections of medical and social sciences, we selected databases that covered publications in both of these areas of inquiry. We chose general search terms for the database search to avoid excluding studies prematurely. We conducted keyword and subject-heading searches at first individually and then combined the search terms in the following manner: (transsex* OR transgend* OR gender dysphor* OR gender identity disord* OR gender divers* OR transmasculine) AND (voice OR vocal OR phonat* OR voice disord* OR dysphon*).

Publications were considered for inclusion if they were concerned with the notion of voice in the material sense (ie, voice as sound), they focused on gender-diverse people including transmasculine people, and they were concerned with transmasculine people's voice function. Publications were excluded if they were solely concerned with the notion of voice in the metaphorical sense (ie, voice as political representation) or were solely focused on transfeminine people.

In addition, studies that were limited to exploring average speaking fundamental frequency (F0), formant frequencies, gender attribution to voice, or satisfaction with vocal gender presentation were classed as having a sole focus on gender-related aspects and were excluded from this review. Studies exploring areas of voice production that can be investigated from both a gender and a voice function perspective (such as, voice quality and pitch range) were included in this review even if the study authors did not consider voice function in their own evaluations. Bibliographies of review and empirical articles were also searched for additional studies.

To acknowledge findings from previous studies indicating that transmasculine people do not necessarily identify as unambiguously male or wish to be perceived and addressed as male by others,[17,18] we will use the singular "they" as a gender-neutral pronoun in the remainder of this paper when referring to research participants whose subjective gender positioning or desired gender attribution was not reported in the studies under review.

### Review foci

First, we classified the publications included in the review according to study design criteria within The Joanna Briggs Institute

hierarchy of evidence[19] and appraised the quality of the evidence pertaining to the current research questions. We chose the Joanna Briggs classification of levels of evidence because it is inclusive of expert opinion papers and distinguishes between different types of observational studies. In addition, this hierarchy of evidence has been used by other authors investigating the evidence base in the area of gender diversity and voice.[20] Second, we identified accounts and empirical data in which voice function in transmasculine people was described, measured, or discussed. Third, we identified factors and practices in the studies under review that are known to have an impact on voice function or that were associated with voice function by the study authors. Fourth, we categorized the aspects of voice function that were addressed. Fifth, we evaluated accounts and empirical data indicating restrictions to voice function.

Classifications of levels of evidence, identifications of factors/practices, and domains were initially proposed by the first author for discussion in the team of coauthors. Amendments were made until agreement was reached on all classifications presented in this paper.

## RESULTS

The initial searches identified 258 papers. Following application of the inclusion criteria to titles and abstracts, we retrieved a total of 41 publications and considered these for further analysis. Of these, we excluded 25 (61%) because they solely considered gender-related aspects of transmasculine people's vocal situations. Sixteen publications remained. We identified six additional publications through searching the bibliographies of the 41 publications mentioned before to give 22 publications included in the review. Because two publications reported findings from two separate studies, we identified 24 different studies in the 22 publications under review (Figure 1).

### Quality of the evidence

Following The Joanna Briggs Institute hierarchy of evidence,[19] we classified 10 studies[2,4,21a–28] (40%) as "expert opinion" (evidence level 5); these will be referred to as "expert opinion papers" in the remainder of this article. Of the 10 expert opinion papers, eight were peer-reviewed journal articles and two were chapters from edited collections bringing together contributions from specialists working in the area of gender diversity and voice. Of the remaining 14 studies, we classified five as "cross-sectional studies"[29–33a] (evidence level 4b), four as "case series"[5,33b–35] (evidence level 4c), and five as "case reports"[21b,36–39] (evidence level 4d). These 14 studies comprise the "primary research studies" referred to in the remainder of this article (Table 1).

We classified all primary research studies included in the review as observational descriptive studies. Ten primary research studies (71%) had a sample size of no more than 20 participants. The sample sizes per study design were distributed as follows: longitudinal case reports (n = 1), longitudinal case series (n = 2, n = 50, n = 53, n = 712), and cross-sectional studies (n = 12, n = 14, n = 16, n = 20, n = 38) (Table 2). Further aspects of the quality of the evidence will be reported and discussed below.

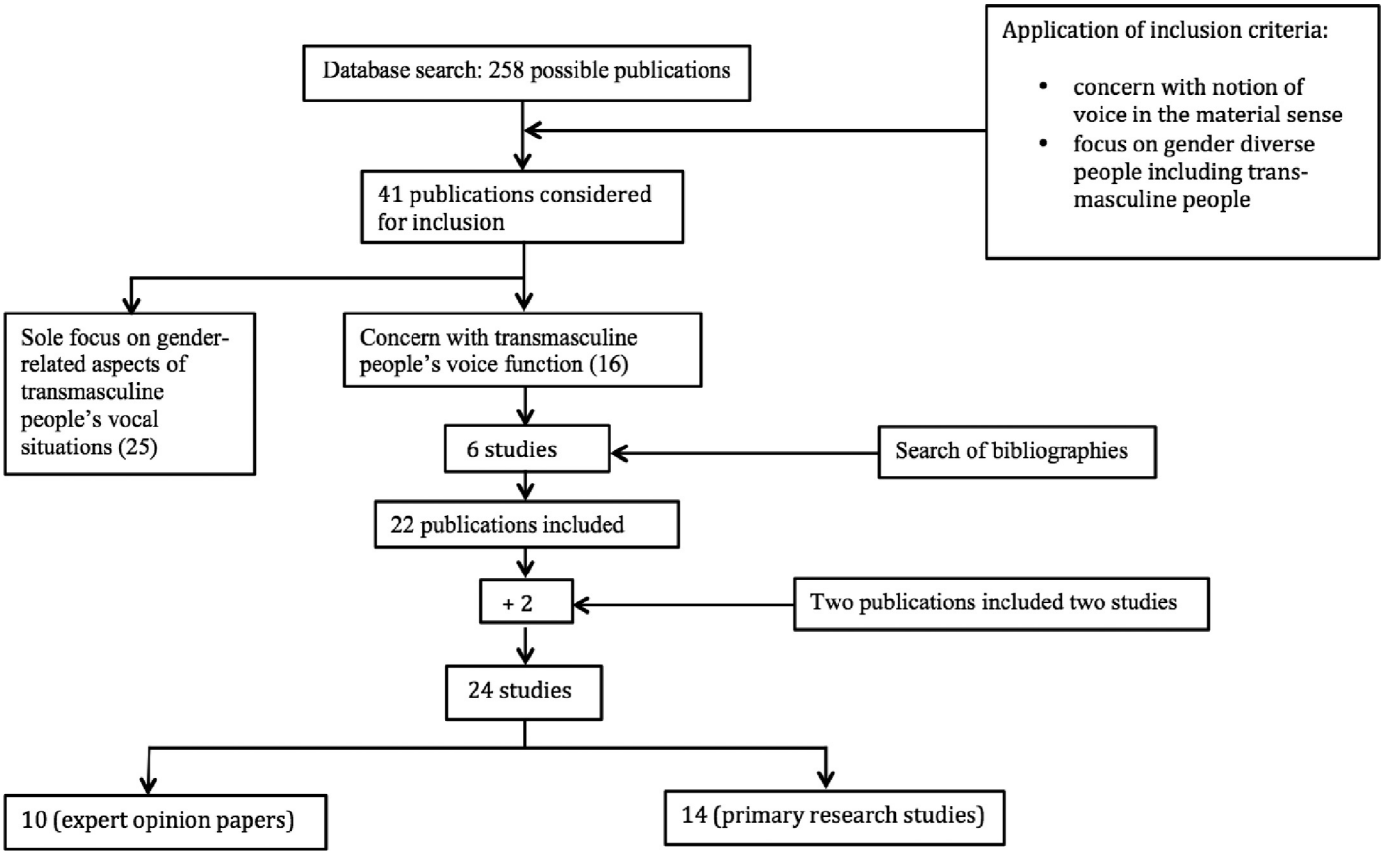


**FIGURE 1.** Literature search flow diagram.

**TABLE 1.**
**Study designs and levels of evidence (The Joanna Briggs Institute)[19]**

| | Observational–Descriptive Studies | | | |
|---|---|---|---|---|
| Study design | Cross-sectional studies | Case series | Case reports | Expert opinion |
| Level of evidence | 4b | 4c | 4d | 5 |
| Reference | Cosyns et al[29]<br>Neuschaefer-Rube[30]<br>Scheidt et al[31]<br>T'Sjoen et al[32]<br>**Van Borsel et al[33a] | Gooren and Giltay[34]<br>Nygren et al[5]<br>**Van Borsel et al[33b]<br>Wierckx et al[35] | **Adler et al[21b]<br>Damrose[36]<br>Kojima et al[37]<br>Söderpalm et al[38]<br>Yanagi et al[39] | **Adler et al[21a]<br>Azul[22]<br>Davies et al[2]<br>Neuschaefer-Rube et al[23]<br>Oates and Dacakis[4]<br>Parker[24]<br>Schüchner[25]<br>Thornton[26]<br>Van Borsel and Baeck[27]<br>Wylie et al[28] |

*Notes:* Publications marked with two asterisks (**) report on two studies with different designs[(a,b)].

## Factors or practices associated with transmasculine people's voice function

We identified 12 different factors or practices in the expert opinion papers that are known to have an impact on voice function or that were associated with voice function by the study authors. Eight of these factors or practices (67%) were also considered in primary research studies (Table 3). As a rule, authors of primary research studies focused their investigation on one factor or practice that was presented as predominantly affecting participants' vocal situations. In five primary research studies[30,34–36,38] (36%), only information pertaining to this main factor or practice was provided (Table 2). In the remaining nine studies[5,21b,29,31–33a,b,37,39] (64%), one or more additional factors or practices were mentioned (Table 2).

### *Hormone treatment*

Hormone treatment was addressed in all 10 expert opinion papers[2,4,21a–28] and in 12 primary research studies[5,21b,29–36,39] (86%) (Table 3). In three of the 12 primary research studies with participants treated with testosterone, the authors reported the duration of hormone treatment only.[21b,30,33a] In one study, the authors reported the method of hormone administration only.[32] In another study, the authors reported the method of administration and duration of hormone treatment but reported no other details.[31] In one study, type of testosterone, dosage, and method of administration were reported but not the duration of the treatment.[34] For six studies (43%), the complete details of the treatment regimens were given (Table 3).[5,29,33b,35,36,39] Of these, three studies reported the results of testosterone treatment administered intramuscularly,[35,36,39] one reported on treatment given *via* the oral route,[33b] and two reported on groups of transmasculine people who were treated *via* different methods of hormone administration (intramuscular, oral, transdermal).[5,29] In addition, participants of individual studies were treated with a variety of types of testosterone, including testosterone undecanoate, testosterone enanthate, testosterone gel, and mixtures of testosterone esters. Authors of four studies reported average group results for their participants who were not all treated with the same type of testosterone and/or method of hormone administration.[5,29,32,35] The duration of testosterone treatment varied between participants of different studies. For four studies for which only average group results were reported, the duration of testosterone treatment varied between participants.[29,32,33a,34]

### *Self-guided attempts at changing vocal situation*

A range of approaches transmasculine people may use to change their vocal situation and that were deemed to have an effect on voice function were addressed in the literature under review: smoking habits, self-guided changes to voice use, changes to outward appearance, chest binding, changes to posture, and alcohol consumption (Table 3).

*Smoking habits.* Smoking habits were addressed in two expert opinion papers[2,23] (20%) and six primary research studies[29,32,33a,b,37,39] (43%) (Table 3). Authors of two expert opinion papers[2,23] and one primary research study[33b] suggested that transmasculine people might take up or increase smoking as a method to change vocal gender presentation (in terms of voice quality or pitch). For three primary research studies,[29,32,33a] smoking habits were reported as a percentage of participants who were smokers but individual data were not provided. Therefore, it was not possible to distinguish between results for participants who were exposed only to the main factor explored in these studies (testosterone treatment) and results for those who engaged in smoking in addition to testosterone treatment.

In Kojima et al's[37] study of the effects of thyroplasty type III surgery on voice, the sole participant was a smoker who had smoked 15 cigarettes per day for 18 years. In Van Borsel et al's[33b] study of the effects of testosterone treatment on voice, one of the two participants was a smoker. In Yanagi et al's[39] study of the effects of testosterone treatment on voice, the sole participant had smoked for 4 years but had given up on smoking 3 years before the study. Implications of smoking habits for voice function were not reported or discussed in any of the primary research studies considering this practice.

*Self-guided changes to voice use.* Changes to voice use initiated and guided by transmasculine people themselves without

**TABLE 2.**
**Research Designs and Measures in Primary Research Studies**

| | | Factors Affecting Voice Function | | Domains of Voice Function | | | |
|---|---|---|---|---|---|---|---|
| Reference | Study Design (Sample Size) | Main Factor | Additional Factors | Voice Quality | Pitch Range/ Variability | Vocal Power | Other |
| Cosyns et al[29] | Cross-sectional study (n = 38) | HT: IM, O, TD (C) | SH | Jitter [%], shimmer [dB] | Pitch variation [Hz/s] | | |
| Damrose[36] | Longitudinal case report (n = 1) | HT: IM (C) | | Shimmer [%], noise-to-harmonics ratio, voice turbulence index | Pitch range | | Glottal function |
| Gooren and Giltay[34] | Longitudinal case series (n = 712) | HT: IM (T, DO, M) | | PE | | | |
| Neuschaefer-Rube[30] | Cross-sectional study (n = 12) | HT (D) | | PE | | | Glottal function |
| Nygren et al[5] | Longitudinal case series (n = 50)* | HT: IM, TD (C) | VT, PS | SE | Speech range profile (SRP)<br>Voice range profile (VRP) | SRP Leq [dB], VRP max SPL [dB], SE | Vocal endurance (SE)<br>Vocal stability (SE) |
| Scheidt et al[31] | Cross-sectional study (n = 14)* | HT: IM (M, D) | VT | PE, SE<br>Göttingen Hoarseness Diagram | VRP | VRP max SPL [dB]<br>VRP SPL range [dB], SE | MPT [s] |
| T'Sjoen et al[32] | Cross-sectional study (n = 20) | HT: IM, O (M) | SH | | | | VHI |
| Van Borsel et al[33a] | Cross-sectional study (n = 16) | HT (D) | VT, SH, SGVC | | | | Vocal endurance (SE) |
| Van Borsel et al[33b] | Longitudinal case series (n = 2) | HT: O (C) | SH | Jitter [%], shimmer [%] | Pitch range (VRP) | | |
| Wierckx et al[35] | Longitudinal case series (n = 53) | HT: IM (C) | | | | | Vocal stability (SE) |
| Yanagi et al[39] | Longitudinal case report (n = 1) | HT: IM (C) | SH, SGVC, ME | | Pitch range | | Glottal function<br>Vocal control (SE)<br>Singing voice (SE)<br>VHI |
| Adler et al[21b] | Longitudinal case report (n = 1) | LS: TP III | HT (D), VT | | Pitch range, SE, PE | SE, PE | Pitch variability (SE, PE) |
| Kojima et al[37] | Longitudinal case report (n = 1) | LS: TP III | SH, PS | PE, SE jitter [%], shimmer [%], signal to noise ratio [dB] | | | Glottal function |
| Söderpalm et al[38] | Longitudinal case report (n = 1) | VT | | | | | Vocal endurance (SE)<br>Vocal stability (SE) |

* Because of missing data for some parameters, sample sizes varied for different aspects of these studies.
*Abbreviations:* (C), complete details of hormone treatment regimen reported; (D), duration of hormone treatment reported; (DO), dosage of hormone treatment reported; (M), method of hormone administration reported; (T), type of testosterone reported; HT, hormone treatment; IM, intramuscular application; Leq, equivalent continuous sound level; LS, laryngeal surgery; ME, mastectomy; MPT, maximum phonation time; no entry, not examined; O, oral application; PE, perceptual evaluation; PS, psychosocial situation; SE, self-evaluation; SGVC, self-guided voice change; SH, smoking habits; SPL, sound pressure level; TD, transdermal application; TP III, thyroplasty type III; VHI, Voice Handicap Index; VT, voice therapy.

**TABLE 3.**
**Number (and Percentage) of Papers that Included Factors or Practices Associated With Transmasculine People's Voice Function**

| Factor or Practice | Primary Research Studies (N = 14) | Expert Opinion Papers (n = 10) |
|---|---|---|
| Hormone treatment | 12 (86%) | 10 (100%) |
| Self-guided attempts at changing vocal situation | | |
| Smoking habits | 6 (43%) | 2 (20%) |
| Self-guided changes to voice use | 2 (14%) | 3 (30%) |
| Changes to outward appearance | 1 (7%) | 1 (10%) |
| Chest binding | | 3 (30%) |
| Changes to posture (Slouching) | | 2 (20%) |
| Alcohol consumption | | 1 (10%) |
| Professional voice support | 5 (36%) | 8 (80%) |
| Psychosocial situation | 3 (21%) | 2 (20%) |
| Laryngeal surgery | 2 (14%) | 4 (40%) |
| Mastectomy | 1 (7%) | 1 (10%) |
| Anatomy and physiology of voice organ | | 4 (40%) |

the involvement of voice professionals were discussed in three expert opinion papers[21a,b,23] (30%) and investigated in two primary research studies[33a,39] (14%) (Table 3). Commentators agreed that the use of excessive muscle tension during voice production to achieve or maintain a more masculine vocal presentation posed a risk to transmasculine people's voice function. The following aspects of voice use were identified as detrimental for voice function: excessive pressure on the larynx to produce a lower pitch,[21a,23] harsh glottal attacks to maintain a lower pitch,[21a,22] imitation of other voice, and speech features or behaviors that are stereotypically associated with masculinity and that contradict the principles of functional voice production (such as, monotonous intonation, limited jaw opening to lower formant frequencies, rough voice quality, backward tongue positioning, ventricular fold adduction or phonation).[22,23] Thirty-eight percent of participants in Van Borsel et al's[33a] survey with 16 transmasculine people reported that they had tried to change their voice before the start of hormone therapy mainly by attempting to speak at a lower pitch level. The participant of Yanagi et al's[39] study had reportedly lowered their speaking F0 to avoid voice breaks. Further implications of self-guided changes to voice use for these participants' voice function were not reported or discussed.

*Changes to outward appearance.* Authors of one expert opinion paper[23] (10%) suggested that changes to transmasculine people's outward appearance to improve passing as a member of the gender grouping to which they feel they belong might have positive implications for muscle tension, posture, and phonation. The participant of Kojima et al's[37] study of the effects of thyroplasty type III surgery on voice did not wish to be treated with chest or genital surgery or testosterone but had tried to reduce their feelings of discomfort with their gender by dressing like a man. Implications for this participant's voice function were not reported or discussed.

*Chest binding.* Transmasculine people's attempts at hiding their breasts and creating a more masculine-looking chest contour *via* the use of compressive clothing or bandages were discussed in three expert opinion papers[2,21a,23] (30%). Commentators agreed that this practice might negatively impact on a range of aspects of voice function, including muscle tension, posture, respiration, breath support for voice, phonation, and physical well-being.

*Changes to posture (slouching).* Transmasculine people's attempts at hiding their breasts by bending their shoulders forward were addressed in two expert opinion papers[21a,23] (20%). Commentators agreed that this practice limits optimal postural support for efficient respiration and voice production and has negative implications for muscle tension and phonation.

*Alcohol consumption.* Authors of one expert opinion paper[23] (10%) suggested that some transmasculine people might increase their alcohol consumption to modify their voice quality as a method to change their vocal gender presentation.

### *Professional voice support*

Professional voice support to improve voice function was addressed in eight expert opinion papers[2,21a–24,26–28] (80%) and in five primary research studies[5,21a,31,33a,38] (36%) (Table 3). Authors of expert opinion papers recommended assessment of voice function and counseling or treatment of restrictions to voice function. Adler et al[21a] described a recommended approach to treating muscle tension dysphonic behaviors in transmasculine people and advocated for combining a gradual increase in hormone intake with diaphragmatic breathing, gentle vocal exercises, and performance adjustments for transmasculine singers.

In Nygren et al's[5] study with 50 participants treated with testosterone, all participants received information about vocal hygiene and recommendations on how to prevent vocal fatigue. Twelve participants (24%) had received voice treatment during the study period because of a range of voice function-related voice complaints. The number of therapy sessions varied between one and five (mean: 3.2). The therapy was based on the accent method and aimed at reducing vocal fatigue, instability, and hyperfunction (U. Nygren, personal communication). Information about the results was not provided.

Authors of two primary research studies reported on the effects of voice treatment on the voice function of one participant. In Söderpalm et al,[38] voice treatment based on the principles of the accent method was used to address vocal instability and fatigue in one participant. The absence or presence of co-intervention was not clearly reported in this study. In Adler et al,[21b] voice treatment comprising mainly pushing exercises was used to address limitations to pitch variability and vocal power in one

transmasculine person who had been treated with testosterone and with thyroplasty type III.

Authors of two primary research studies investigated the need for voice therapy in addition to hormone therapy as expressed by participants or identified by researchers. In Scheidt et al's[31] study with 14 participants, 64% wished for professional voice support and 79% were judged by the researchers to be in need of voice treatment. In Van Borsel et al's[33a] survey with 16 participants, 31% indicated an interest in having further voice surgery or therapy in addition to hormone treatment.

### *Psychosocial situation*

Transmasculine people's psychosocial situations were addressed in two expert opinion papers[21a,23] (20%) and three primary research studies[5,37,39] (21%) (Table 3). Authors of the expert opinion papers suggested that transmasculine people's psychosocial situation (such as, the degree of distress they experience in relation to difficulties with communicating the gender to which they feel they belong, or the degree to which they are accepted and respected in their social circles) might affect their voice function. Authors of one primary research study considered the following psychosocial reasons in their explanations of restrictions to voice function they had found in their group of participants: Among others, lack of confidence regarding the voice might have led to low average sound pressure levels, and resistance to producing voice in high frequencies might have contributed to small average vocal ranges compared with vocally healthy Swedish and Australian men.[5]

The participant of Kojima et al's[37] study had reportedly experienced emotional distress when questioned about their gender during conversations at work. Yanagi et al[39] reported the following details for the emotional subscale of the Voice Handicap Index (VHI) their participant had completed before and after 143 days of hormone treatment: There were improvements in the items "I am less outgoing because of my voice problem," "My voice makes me feel handicapped," and "I am ashamed of my voice problem," but there was a deterioration in the item "I am tense when talking with others because of my voice." Details about whether the participants' voice function was seen as affected by psychosocial factors were not provided for the two latter studies.

### *Laryngeal surgery*

Laryngeal surgery was addressed in four expert opinion papers[2,24,27,28] (40%) and examined in two primary research studies[21b,37] (14%) (Table 3). All of these papers made reference to thyroplasty type III directed at lowering voice pitch.

### *Mastectomy*

Authors of one expert opinion paper[23] (10%) suggested that chest surgery would have a positive impact on transmasculine people's voice function because they would no longer need to hide their breasts and therefore be able to avoid the limitations to functional voice production associated with chest binding and slouching. Yanagi et al[39] reported that their participant had undergone mastectomy before starting testosterone treatment. Implications for this participant's voice function were not reported or discussed.

### *Anatomy and physiology of voice organ*

The properties and dimensions of transmasculine people's voice organs were addressed in four expert opinion papers[21a–23,25] (40%); however, none of the primary research studies included in the review reported empirical data to support or refute the comments and claims made (Table 3). Commentators agreed that testosterone treatment in adult transmasculine people leads to changes in the anatomy and physiology of voice organs that are neither directly comparable with the changes cisgender people experience during puberty nor to those experienced by cisgender people assigned female gender at birth who are treated with testosterone for gynecological reasons.[22,23]

In comparison with that of cisgender people, commentators described the anatomy of transmasculine people's voice organs in negative terms: "chest and lungs . . . in comparison to those of the average biological man,"[21a(p161)] larynges are small and "not properly descended, but . . . somewhere in between adult male and female positions."[21a(p163)] For transmasculine people who are treated with testosterone, commentators described a configuration that Adler et al[21a] have termed "entrapped FTM [female-to-male] vocality"[(p162)]: There may be an increase in vocal fold mass but no proof so far of increase in vocal fold length because it could not be demonstrated that testosterone leads to a growth of the laryngeal framework.[23,25] As a result, the thickened vocal folds may "become entrapped within a less than adequately enlarged larynx."[21a(p165)]

## Parameters of voice function and analysis of presence or absence of voice problems

We classified the parameters of transmasculine people's voice function that were addressed in the literature under review into 10 domains and identified the measures that were used in primary research studies to examine these domains (Table 2). In addition, we classified restrictions to voice function that were identified in expert opinion papers or primary research studies into 10 problem areas. Authors of expert opinion papers described restrictions in nine domains of voice function; data from primary research studies indicated restrictions in eight domains (Table 4). In cases in which this was possible, we compared the results from different studies with each other and evaluated them against norm values to establish the clinical significance of the restrictions to voice function that had been identified.

### *Voice quality*

Transmasculine people's voice quality was addressed in four expert opinion papers[4,21a,22,25] (40%) and examined in eight primary research studies[5,29–31,33b,34,36,37] (57%). Authors of all four expert opinion papers identified restrictions in this domain (Table 4). Problems described included coarsening of the voice and hoarse, rough, or brittle voice quality as a result of hormone treatment or self-guided changes to voice use.

Data to assess the problem area "restrictions to voice quality" were provided in eight primary research studies. This domain was explored with various acoustical measures, perceptual evaluation, and participants' self-evaluation (Table 2). In six of the primary research studies[5,30,31,34,36,37] (75%), a restriction to

**TABLE 4.**
**Number (and Percentage) of Papers in which Study Authors Identified Restrictions to Voice Function**

| Domains of Voice Function Reported to be Restricted | Primary Research Studies | Expert Opinion Papers |
|---|---|---|
| Voice quality | 6/8 (75%) | 4/4 (100%) |
| Pitch range/variability | 6/7 (86%) | 5/5 (100%) |
| Vocal control/stability | 4/4 (100%) | 3/3 (100%) |
| Vocal power | 3/3 (100%) | 5/5 (100%) |
| Vocal endurance | 3/3 (100%) | 1/1 (100%) |
| Glottal function | 2/4 (50%) | |
| Singing voice (other than pitch range) | 1/1 (100%) | 1/2 (50%) |
| Respiration | | 3/3 (100%) |
| Muscle tension/posture | | 1/1 (100%) |
| Voice function not further specified | 2/4 (50%) | 1/1 (100%) |

voice quality was observed for all or some of the participants (Table 4).

Gooren and Giltay[34] reviewed their publications on the effects of testosterone treatment on 712 transmasculine people treated at their clinic over 9 years and reported that in almost all participants a "coarsening" of the voice occurred in the first 6–12 weeks of hormone treatment. Details about the method of assessment, a definition of the term "coarsening," or an indication of whether the change in voice quality was interpreted as a restriction to voice function were not provided. For these reasons, this study will not be included in the summary of study results in the domain of voice quality.

Cosyns et al[29] found no statistically significant differences between acoustic measures of voice quality (jitter and shimmer) for transmasculine participants treated with testosterone and heterosexual biological male controls. Individual data were not provided for this study; therefore, an exact number of participants being affected or unaffected by a restriction to voice quality could not be determined (Table 5). For the two participants of

**TABLE 5.**
**Number of Participants per Sample size Observed in each Study to Have Problems With Voice Quality, Pitch Range/Variability, and Vocal Power**

| Reference (Study Type, Main Factor Explored) | Problems With Voice Quality | | Limited Pitch Range/Variability | | Problems With Vocal Power | |
|---|---|---|---|---|---|---|
| | Observed/ Sample Size | Measures | Observed/ Sample Size | Measures | Observed/ Sample Size | Measures |
| Cosyns et al[29] (CS, HT) | –/38 | Jitter, Shimmer | –/38 | Pitch variation | | |
| Van Borsel et al[33b] (LT, HT) | 0/2 | Jitter, Shimmer | 2/2[†] | Pitch range VRP | | |
| Nygren et al[5,*] (LT, HT) | 9/50 | SE | 11/36[†] | Pitch range VRP | 36/36 | SRP Leq < 72.2 dB, Max SPL VRP < 109.3 dB, SE |
| Neuschaefer-Rube[30]/Scheidt et al[31,*] (CS, HT) | 12/14 | PE, SE, Göttingen Hoarseness Diagram | 14/14[†] **4/14** | Pitch range VRP | 14/14 | SE, SPL shouting < 93.3 dB, Max SPL VRP < 96.5 dB, SPL range VRP < 46.5 dB |
| Damrose[36] (LT, HT) | 1/1 | Shimmer, NHR, VTI | 1/1[†] **1/1** | Pitch range | | |
| Yanagi et al[39] (LT, HT) | | | 1/1[†] | Pitch range | | |
| Adler et al[21b] (LT, LS) | | | 1/1[†] **1/1** | Pitch range | 1/1 | SE, PE |
| Kojima et al[37] (LT, LS) | 1/1 | SNR, Jitter, Shimmer, SE, PE | | | | |
| Total | 23/106 (22%) | | 30/93[†] (32%) 6/93 (6%) | | 51/51 (100%) | |

*Notes:* Boldfaced data = noticeable restriction to pitch range according to Schultz-Coulon's[42] reference value.
* Sample sizes varied for different parts of this study.
† Restriction to pitch range according to Hallin et al's[40] and Sanchez et al's[41] reference values.
*Abbreviations:* –, number of participants affected or unaffected by voice problem not determinable; CS, cross-sectional study; HT, hormone treatment; Leq, equivalent continuous sound level; LS, laryngeal surgery; LT, longitudinal study; NHR, noise-to-harmonics ratio; PE, perceptual evaluation; SE, self-evaluation; SNR, signal-to-noise ratio; SPL, sound pressure level; SRP, speech range profile; VRP, voice range profile; VTI, voice turbulence index.

Van Borsel et al's study,[33b] jitter and shimmer measures did not change during the first 12 months of testosterone treatment (Table 5).

Nygren et al[5] reported that six (12%) of their 50 participants treated with testosterone complained about strained voice quality and hoarseness, whereas three (6%) complained about strained voice quality only (U. Nygren, personal communication) (Table 5). These nine participants had received voice therapy because of those complaints.

Neuschaefer-Rube[30] and Scheidt et al[31] reported on the same multidimensional cross-sectional study with a group of 14 transmasculine participants (all but one treated with testosterone). Voice quality was examined *via* perceptual evaluation, the participants' self-evaluation, and acoustical evaluation of voice samples (Göttingen Hoarseness Diagram). Twelve participants (86%) presented with restrictions to voice quality as measured by the reference values for one or more of the evaluation methods used; for two participants (14%), restrictions to voice quality were not observed (Table 5).

For Damrose's[36] participant, acoustical measures of shimmer, noise-to-harmonics ratio, and voice turbulence index increased during the first 16 months of hormone treatment, indicating a potential restriction to voice quality (Table 5). The author did not compare these results with norm values, which makes it difficult to determine their clinical significance.

Kojima et al[37] reported decreased signal-to-noise ratio, increased jitter, and increased shimmer for one participant who had been treated with thyroplasty type III, indicating a potential restriction to voice quality (Table 5). The authors did not compare their results with norm values but reported that according to the participant's self-evaluation and the researchers' perceptual evaluation, no restriction to voice quality was observed.

In summary, according to the results of the currently available studies that provided enough detail to be evaluated (total sample size of 106 participants), indications of restrictions to voice quality were found for a minority of 23 participants (22%) (Table 5). However, given that the authors of two studies[29,34] with large sample sizes did not provide enough detail to enable a calculation of the number of participants being affected by a restriction to voice quality, it cannot be ruled out that the number of participants having experienced problems in this domain was much higher.

### *Pitch range/variability*

Transmasculine people's phonational frequency range in speaking and singing, and their ability to vary their pitch in speaking was addressed in five expert opinion papers[2,21a,22,25,27] (50%) and examined in seven primary research studies[5,21b,29,31,33b,36,39] (50%). Authors of all five expert opinion papers identified indications of restrictions in this domain (Table 4). Problems described included restriction of phonational frequency range with a loss in the high tones as a result of hormone treatment, monotonous intonation as a result of self-guided attempts at voice masculinization, and difficulty with producing a higher pitch as a result of laryngeal surgery. Davies et al[2] made reference to an unpublished study with transmasculine people treated with testosterone in which some participants experienced a small decline in pitch range (3–4 semitones [ST]) after 1 year of hormone treatment and others a widening of more than an octave.

Data to assess the problem area "limited pitch range/variability" were provided in seven primary research studies (Table 4). This domain was explored with various approaches to establishing participants' phonational frequency range, a measure of pitch variation, and *via* participants' self-evaluations or researchers' perceptual evaluations (Table 2). Two of the primary research studies were cross-sectional studies[29,31] and the remaining five were longitudinal studies.[5,21b,33b,36,39] In six studies,[5,29,31,33b,36,39] the effects of testosterone on voice were explored as the main factor; in one,[21b] the effects of laryngeal surgery were explored as the main factor . In six primary research studies[5,21b,31,33b,36,39] (86%), authors identified a restriction to pitch range or variability for all or some of the participants (Table 4).

Cosyns et al[29] found no statistically significant differences between the group average of pitch variation for 38 transmasculine participants treated with testosterone compared with heterosexual biological male controls. Individual data were not provided for this study; therefore, an exact number of participants being affected or unaffected by a restriction to pitch variability could not be determined (Table 5). Nygren et al[5] reported no restrictions to the group average of voice range profile (VRP) pitch range for 36 participants during the first 12 months of hormone treatment, but when analyzing individual data, a large variation was found and is reported below (U. Nygren, personal communication).

Scheidt et al[31] did not report pitch range measurements for their 14 participants but identified four participants (29%) who had been treated with testosterone for shorter than 12 months whose VRP pitch range was less than 18 ST. Data for the remaining 10 participants (71%) exceeded this value. Authors of the four remaining longitudinal studies[21b,33b,36,39] (total sample size = 5) reported restrictions to pitch range for all participants (Table 5).

To enable a comparison between the results of the five longitudinal studies, we extracted min F0 and max F0 before and during (or after) intervention and evaluated the min F0, max F0, and pitch range changes in hertz and ST (Table 6). The data for the Nygren et al study[5] were provided by the study authors. The data show a wide variation of results across studies. For all studies, max F0 and min F0 decreased. In the Nygren et al study[5] with a large pitch range variation, it was found that the range increased for 23 persons (range 0.2–15.6 ST), decreased for 12 persons (range 0.6–6.9 ST), and was unchanged for one person.

For two studies[5,33b] with a total sample size of 37 participants, the gain in min F0 exceeded the loss in max F0 so that the pitch range increased (by 0.3–3.4 ST) (Table 6). This increase was revealed only when using the logarithmic ST scale to calculate data but remained undetected when using the linear hertz scale. The finding of an increased pitch range stands in contrast to Van Borsel et al's[33b] own interpretations; the authors did not convert hertz data to ST and saw their participants' pitch ranges as "seriously reduced as a result of the hormone therapy."(p434) For the remaining three studies[21b,36,39] with a total sample size of three participants, the loss in max F0 exceeded the gain in min F0 so that the pitch range decreased (by 1.6–15.0 ST) (Table 6).

**TABLE 6.**
**Change in F0 Minimum, Maximum, and Range Reported in Longitudinal Design Studies**

| Reference (Sample Size, Main Factor Explored) | Before Intervention | | | During/After Intervention | | | Evaluation of Change | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min F0 | Max F0 | Pitch Range | Min F0 | Max F0 | Pitch Range | Min F0 | Max F0 | Pitch Range |
| Van Borsel et al[33b] (n = 1 (P1), HT: 17 m) | 165 Hz | 800 Hz | 635 Hz<br>27.3 ST | 105 Hz | 525 Hz | 420 Hz<br>27.9 ST | −60 Hz<br>−7.8 ST | −275 Hz<br>−7.3 ST | −215 Hz<br>**+0.6 ST** |
| Van Borsel et al[33b] (n = 1 (P2), HT: 13 m) | 125 Hz | 525 Hz | 400 Hz<br>24.8 ST | 82 Hz | 350 Hz | 268 Hz<br>25.1 ST | −43 Hz<br>−7.3 ST | −175 Hz<br>−7.0 ST | −132 Hz<br>**+0.3 ST** |
| Nygren et al[5,*] (n = 36, HT: 12 m) | 132 Hz (SD 23) | 944 Hz[†] (SD 279) | 808 Hz[†] (SD 277)<br>33.8 ST (SD 5.5) | 79 Hz (SD 10) | 733 Hz (SD 203) | 654 Hz (SD 202)<br>38.0 ST (SD 5.1) | −53 Hz (SD 23)<br>−8.7 ST (SD 3.2) | −206 Hz[†] (SD 273)<br>−4.2 ST (SD 5.4) | −132 Hz[†] (SD 290)<br>**+3.4ST** (SD 6.3) |
| Damrose[36] (n = 1, HT: 12 m) | 140 Hz | 338 Hz | 198 Hz<br>15.3 ST | 91 Hz | 201 Hz | 110 Hz<br>13.7 ST | −49 Hz<br>−7.5 ST | −137 Hz<br>−9.0 ST | −88 Hz<br>−1.6 ST |
| Yanagi et al[39] (n = 1, HT: 4.5 m) | 138 Hz | 1046 Hz | 908 Hz<br>35.1 ST | 82 Hz | 392 Hz | 310 Hz<br>27.1 ST | −56 Hz<br>−9.0 ST | −654 Hz<br>−17.0 ST | −598 Hz<br>−8.0 ST |
| Adler et al[21b] (n = 1, LS) | 104 Hz | 554 Hz | 450 Hz<br>29.0 ST | 93 Hz | 208 Hz | 115 Hz<br>13.9 ST | −11 Hz<br>−1.9 ST | −346 Hz<br>−17.0 ST | −335 Hz<br>−15.0 ST |

*Notes:* Data in boldface indicate increase in pitch range.
* Data for the Nygren et al study[5] included in this table were provided by the study authors.
† One missing data.
*Abbreviations:* HT, hormone treatment (duration of hormone treatment in months [m]); LS, laryngeal surgery; P1, participant 1; P2, participant 2; SD, standard deviation; ST, semitones (method hertz-to-semitone conversion: http://www2.ling.su.se/staff/hartmut/umrechnung.htm).

Evaluating study results against norm values proved difficult for several reasons. In some studies examining pitch range, standardized recording procedures were used[5,31,33b]; in others, the recording procedures were not further specified.[21b,36,39] In one study, participants were explicitly instructed to expand their pitch range during the recording and measures were taken repeatedly.[5] As has been shown in several studies, different approaches to eliciting participants' pitch range may lead to different results.[40] In addition, authors did not agree whether to evaluate pitch ranges on the basis of the hertz scale or the perceptually more relevant ST scale, which reference values to use, and how to distinguish between insignificant day-to-day fluctuations and results that indicate a restriction to pitch range that would require clinical intervention (see also Ref. 2).

Authors[5,31] cited three different reference values for VRP pitch ranges: 40.6 ST (±4.41) (Hallin et al[40]), 40.04 ST (±4.33) (Sanchez et al[41]), and 18 ST (Schultz-Coulon[42]). The mean value for 36 participants in Nygren et al's study[5] was located within one standard deviation (SD) of Hallin et al's[40] and Sanchez et al's[41] reference data and was therefore counted as unrestricted after 1 year of testosterone treatment. The interindividual variation was large and showed that 11 of the 36 persons had a restricted range (more than one SD below the reference values in Hallin et al[40]), whereas 25 had a nonrestricted range. Two of those actually had a larger range (more than one SD above the reference value) (U. Nygren, personal communication) (Table 5). The results of all five participants in the remaining longitudinal studies[21b,33b,36,39] and the results of all 14 participants of Scheidt et al's[31] cross-sectional study (confirmed by study authors in personal communication) were located below one SD of Hallin et al's[40] and Sanchez et al's[41] reference values and therefore counted as restricted (total sample size: 19) (Table 5). Measured by Schultz-Coulon's[42] reference value, the results of two participants in two longitudinal studies[21b,36] and of four participants of Scheidt et al's[31] cross-sectional study were found to be noticeably restricted (total sample size: 6) (Table 5).

In summary, according to the results of the currently available studies with a total sample size of 93 participants, restrictions to pitch range or variability were found for 30 participants (32%) according to reference values by Hallin et al[40] and Sanchez et al[41] and for six participants (6%) according to reference values provided by Schultz-Coulon[42] (Table 5). However, given that Cosyns et al,[29] with a large sample size, did not provide individual data to enable a calculation of the number of participants being affected by a restriction to pitch range/variability, it cannot be ruled out that the number of participants having experienced problems in this domain was higher.

### *Vocal control/stability*

We defined vocal control or stability as a domain of voice function comprising comments or empirical data pertaining to the capacity or lack of capacity to control and stably produce any aspect of voice function. Transmasculine people's vocal control and stability was explored in three expert opinion papers[21a,26,28] (30%) and in four primary research studies[5,35,38,39] (29%) that reported on participants' self-evaluations. Authors of all three expert opinion papers identified indications of restrictions in this domain

as a result of hormone treatment (Table 4). Data to assess the problem area "restrictions to vocal control or stability" were provided in four primary research studies.[5,35,38,39] In all of these studies, a restriction to this domain of voice function was observed for all or some of the participants (Table 4).

Söderpalm et al[38] reported that vocal stability had increased for one participant who had received voice treatment. In Nygren et al's[5] study with 50 participants treated with testosterone, five (10%) had received voice therapy because of self-reported vocal instability. In Wierckx et al's[35] study with 53 participants treated with testosterone, the percentage of participants reporting voice instability increased from about 15% to more than 60% during the first 12 months of hormone treatment. The participant of Yanagi et al's[39] study complained of voice breaks during conversation and when speaking loudly on day 48 of their testosterone treatment. On day 71, they complained of difficulties with controlling volume, and on day 143, they still complained of anxiety about voice breaks and reported deliberately lowering their speaking F0 to avoid these.

In summary, according to the results of the currently available studies with a total sample size of 105 participants, indications of restrictions to vocal control or stability were found for at least 39 (37%) participants.

### *Vocal power*

We defined vocal power as a domain of voice function comprising comments or empirical data pertaining to the perceived ability to project the voice, perceived/measured vocal intensity, and intensity ranges, respectively. Transmasculine people's vocal power was explored in five expert opinion papers[21a,22,24,25,27] (50%) and in three primary research studies[5,21b,31] (21%). Authors of all five expert opinion papers identified indications of restrictions in this domain (Table 4). Problems described included weak voice, limited volume range or lack of the voice's capacity to carry over distances as a result of hormone treatment, laryngeal surgery, or self-guided changes to voice use. Data to assess the problem area "limited vocal power" were provided in three primary research studies.[5,21b,31] In all of these studies, a restriction to vocal power was observed for all or some of the participants (Table 4).

During the first year of testosterone treatment, Nygren et al[5] could not find any significant changes in the mean group value of the equivalent continuous sound level (Leq) measured from the speech range profile (SRP) (70.4 dB before treatment and 70.8 dB after 12 months). No significant changes were found for the mean group value of max sound pressure level (SPL) measured from the VRP (96.9 dB initially and 97.3 dB after 12 months) either. However, these values were lower than the reference values for vocally healthy Swedish men as reported by Hallin et al[40] (SRP Leq: 72.2 dB [±2.14]; max SPL VRP: 109.3 dB [±1.77]). Group results for max SPL VRP were located more than two SDs below the reference value and results for SRP Leq were located within one SD reported for the reference data.

When analyzing individual data from participants during the first 12 months of hormone treatment, we found that 13 out of 34 had SRP Leq values more than one SD below the reference value, and for two participants, SRP Leq values were more than one SD higher than the reference values (U. Nygren, personal communication). For 36 participants, VRP max SPL was located lower than the reference values; for 35 participants more than two SDs below and for one more than one SD below (U. Nygren, personal communication). Four out of 36 participants (11%) in the Nygren et al study[5] reported difficulties projecting their voice. Thirty-six participants (100%) presented with restrictions to vocal power as measured by one or more of the evaluation methods used in this study (U. Nygren, personal communication) (Table 5).

Scheidt et al[31] reported individual data in comparison with norm values for 14 transmasculine participants (all but one treated with testosterone) for the following aspects of vocal power: self-reported difficulties with vocal power, SPL shouting (<93.3 dB), max SPL VRP (<96.5 dB), and SPL range VRP (<46.5 dB). All 14 participants presented with restrictions to vocal power as measured by one or more of the evaluation methods used (Table 5). Although both studies used the same mouth-to-microphone distance (30 cm) for the VRP max SPL measures (personal communication, study authors), the reference value for VRP max SPL used by Scheidt et al[31] (96.5 dB) was considerably lower than the reference value used in the Nygren et al study (109.3 dB).[5] Adler et al[21b] reported a weak voice (as assessed by the participant's self-evaluation and the researchers' perceptual evaluations) for one participant after thyroplasty type III (Table 5).

In summary, according to the results of the currently available studies with a total sample size of 51 participants, indications of restrictions to vocal power were found for 51 participants (100%) (Table 5).

### *Vocal endurance*

We defined vocal endurance as a domain of voice function comprising comments or empirical data pertaining to perceptions of vocal fatigue or strain when speaking as reported by the participants. Transmasculine people's vocal endurance was explored in one expert opinion paper[25] (10%) and in three primary research studies[5,33a,38] (21%) that reported on participants' self-evaluations. The author of the expert opinion paper commented that transmasculine people treated with testosterone might experience vocal fatigue (Table 4). Data to assess the problem area "restrictions to vocal endurance" were provided in three primary research studies.[5,33a,38] In all of these studies, restriction to vocal endurance was observed for all or some of the participants (Table 4).

Söderpalm et al[38] reported that vocal fatigue had disappeared for one participant who had received voice treatment. In Nygren et al's[5] study with 50 participants treated with testosterone, nine (18%) had received voice therapy because of self-reported vocal fatigue. Significant changes had not been found in this study for mean group results of self-ratings for the survey item "I get tired in my throat/voice or hoarse when speaking" during the first 2 years of testosterone treatment, but the authors reported that individual ratings had varied considerably. When analyzing individual data, we found 10 (20%) of the participants rated high values (more than 5 on a seven-point equal-appearing scale) for the item "I get tired in my throat/voice or hoarse when speaking" after 12 months of testosterone treatment. Three of those 10 participants had also received voice

**TABLE 7.**
**Number (and Percentage) of Participants Reported to Have Problems With Glottal Function in a Group of 12 Transmasculine People Treated With Testosterone (Neuschaefer-Rube)[30]**

| Indications of Restrictions to Glottal Function | Number and Percentage of Participants (n = 12) |
|---|---|
| Vocal fold (VF) erythema | 5 (42%) |
| Excessive secretions | 5 (42%) |
| Edema VF edge | 2 (17%) |
| Ventricular fold constriction | 6 (50%) |
| Incomplete glottal closure | 6 (50%) |
| Reduced amplitude of VF vibration | 2 (17%) |
| Enlarged amplitude of VF vibration | 1 (8%) |
| Reduced mucosal wave | 3 (25%) |
| Enlarged mucosal wave | 2 (17%) |
| Irregular phase symmetry of vocal fold vibration | 1 (8%) |

therapy because of self-reported vocal fatigue. Altogether, 16 participants (32%) in the Nygren et al study[5] presented with indications of restrictions to vocal endurance (U. Nygren, personal communication). Van Borsel et al[33a] reported the results of a survey with 16 participants treated with testosterone. One participant (6%) was not satisfied with their voice because it strained them too much to speak at a low pitch level.

In summary, according to the results of the currently available studies with a total sample size of 67 participants, indications of restrictions to vocal endurance were found for 18 participants (27%).

### *Glottal function*

We defined glottal function as those aspects of laryngeal function that can be observed and evaluated *via* laryngoscopy. Transmasculine people's glottal function was explored in four primary research studies[30,36,37,39] (29%). In two of these studies,[30,37] restrictions to glottal function were observed for all or some of the participants (Table 4).

The participants of two case reports presented with unimpaired glottal function after having been treated with testosterone for 16 months[36] and 143 days,[39] respectively. Kojima et al[37] reported vocal fold edema, shortened vocal folds, and change in vocal fold tension for one participant who had been treated with thyroplasty type III. Neuschaefer-Rube[30] reported the results of laryngovideostroboscopic examinations for 12 participants who had been treated with testosterone during 2.5 months–9.3 years (mean: 22.6 months). Indications for restrictions to glottal function with regard to the different aspects that had been examined were found for between 8% and 50% of participants (Table 7).

### *Singing voice*

Transmasculine people's singing voice (other than pitch range) was explored in two expert opinion papers[21a,27] (20%) and in one primary research study[39] (7%) that reported on the participant's self-evaluation (Table 4). Van Borsel and Baeck[27] identified restrictions to singing voice (not further specified) as a possible side effect of testosterone treatment. Adler et al[21a] reported on successful attempts to maximize singing ability and singing voice quality for transmasculine people who had completed a voice training program in which gradual testosterone intake was combined with diaphragmatic breathing, gentle vocal exercising, and singing performance adjustments. Yanagi et al[39] reported difficulty producing falsetto voice for one participant who had been treated with testosterone for 143 days.

### *Respiration*

Authors of three expert opinion papers[2,21a,23] identified possible restrictions to transmasculine people's respiration (including, accumulated fatigue in the lungs, shortness of breath, inadequate breath support for voicing) as a result of chest binding, slouching, or hormone treatment (Table 4).

### *Muscle tension/posture*

Authors of one expert opinion paper[23] identified possible restrictions to transmasculine people's muscle tension and posture as a result of chest binding, slouching, or self-guided changes to voice use (Table 4). The same authors anticipated a positive impact on these aspects of voice function for transmasculine people who manage to adapt their outward appearance in a way that supports their passing as a member of the gender grouping to which they feel they belong.

### *Voice function not further specified*

Scheidt et al[31] reported maximum phonation times shorter than 15 seconds for five of 14 participants (36%) (all but one treated with testosterone). The maximum phonation times for the remaining nine participants (64%) exceeded this value. The reference value of 15 seconds to distinguish restricted from unrestricted voice function has been suggested Hirano et al.[43]

Neuschaefer-Rube et al[23] warned of the potential risk of irreversible changes to voice function and the incapacity to work for occupational voice users treated with testosterone. This concern was not supported by findings of two primary research studies with transmasculine people treated with testosterone. Damrose's[36] participant was reportedly capable of continuing full-time work as an attorney and performing successfully as a jazz and pop singer after having been treated with testosterone for 16 months. T'Sjoen et al[32] found very low mean group scores for the functional, emotional, physical, and total score of the VHI for 20 transmasculine people treated with testosterone. When compared with Jacobson et al's[44] reference values, no perceived voice-related handicap could be found for this group.

Yanagi et al[39] reported changes to VHI scores for one participant during the first 143 days of hormone treatment. The VHI total score increased from 31 to 35, the physical subscale increased from 6 to 14, the emotional subscale decreased from 12 to 8, and there were no changes for the functional subscale (13 on both time points). When compared with Jacobson et al's[44] mean reference values for self-perceptions of mild, moderate, and severe voice impairment, the participants' ratings at day 143 of hormone treatment for total score, physical, and emotional

subscale indicated mild impairment, and for the functional subscale, moderate impairment.

## DISCUSSION

This review demonstrated that transmasculine people's voice function is a topic area that is currently still underrepresented in the voice literature. Our database search revealed a small number of studies that have investigated transmasculine people's vocal situations and an imbalance in terms of the number of publications exclusively concerned with transmasculine people's vocal gender presentation compared with their voice function.

The comparison between the two different sets of articles that were analyzed illustrated that the research has yet to catch up on examining the variety and details of issues that have been raised in expert opinion papers. The overall quality of primary research studies was judged to be poor with study designs ranked at the bottom of evidence hierarchies. Small sample sizes, lack of detail about methods used to instruct participants and record voice samples, failure to provide individual data, and failure to specify normative values were found to limit interpretability and comparability of results and generalizability of findings.

In contrast to claims in the voice literature according to which transmasculine people's vocal situations can be regarded as unproblematic and voice treatment for this population can be seen as unnecessary, the review revealed clear indications that transmasculine people might experience restrictions to their voice function in a range of domains, and a substantial number of participants in several studies were found to request, require, or have received professional voice support to address problems with voice function.

These findings taken together indicate that the currently available evidence base for clinical practice to support functional voice production in transmasculine people is weak. To enable the development of an evidence-based approach to comprehensive clinical care for this population, it is therefore of paramount importance that more voice research that addresses gender- and voice function-related aspects of transmasculine people's vocal situations be conducted in the future.

### Factors or practices associated with transmasculine people's voice function

Our analysis revealed that a range of factors or practices might have an impact on transmasculine people's voice function. Hormone treatment is the only factor that has been explored in the majority of primary research studies included in this review. The other factors or practices that have been associated with transmasculine people's voice function in expert opinion papers have received scarce or no attention in primary research studies.

Given the inconsistent amount of detail provided, the diversity of hormone treatment regimens used, and the varying duration of hormone treatment per participant in the studies under review, the factor testosterone treatment cannot be considered as comparable for participants of different studies or even, in some cases, for participants of the same study. Therefore, the options of summarizing the evidence pertaining to this factor are limited.

There were clear indications in the literature under review that some transmasculine people require voice treatment, and suggestions were made that professional voice support would be beneficial for improving transmasculine people's voice function. However, the currently available evidence for the effectiveness of voice treatment with transmasculine people is thin. Only two studies[21b,38] reported successful treatment of restrictions to selected domains of voice function, but authors did not provide any empirical data to support these claims. In addition, approaches to voice treatment with transmasculine people were not well described, which makes it difficult to replicate studies and findings.

The literature search revealed merely two case reports[21b,37] that explored the effects of laryngeal surgery on transmasculine people's voice function. These studies considered only a few domains of voice function, and the results for one study[21b] were confounded by co-intervention effects (the participant underwent hormone treatment, laryngeal surgery, and voice treatment), which further limited the evidence base pertaining to this factor.

The evidence for the impact of the remaining factors or practices on transmasculine people's voice function (self-guided attempts at changing vocal situation, psychosocial situation, mastectomy, and anatomy and physiology of transmasculine people's voice organs) is currently located at expert opinion level. The comments and claims made will need to be explored in empirical studies before firm conclusions about their clinical relevance can be drawn. Psychosocial factors are known to have an impact on voice function irrespective of the speaker's subjective gender positioning (see, eg, Baker[45]). In gender-diverse people, it is particularly important to investigate this area because this population might experience various forms of distress arising from how they feel about their gender-diverse status or how this status is responded to by the people they encounter in addition to other psychosocial issues that are not gender specific (see, eg, Bockting et al,[46] and Boza and Nicholson Perry[47]).

We recommend that the interaction between the different factors and practices discussed in this review and transmasculine people's voice function should be further explored in future research. The research effort could prioritize the identification of factors and practices that expand or improve voice function in transmasculine people (facilitators) and those that restrict it (barriers). Future models for voice counseling and treatment could then be directed at fostering facilitators and avoiding or limiting barriers to voice function in transmasculine people.

While the currently available evidence base is too limited to enable clinicians to provide specific advice to transmasculine people, we suggest that the general principles of voice care comprising factors and practices that are specific to transmasculine people and those that pertain to all voice users should be explored and discussed as part of voice assessment and counseling with every transmasculine person seeking professional support.

### Parameters of voice function and analysis of presence or absence of voice problems in transmasculine people

Pitch range/variability and voice quality are the only domains of transmasculine people's voice function that have been

explored in a substantial number of primary research studies included in this review. The other domains have received scarce or no attention in primary research studies.

In general, the methods study authors have used to explore the different domains of voice function and the measures reported have not been consistent across studies, which made it difficult to compare the results between studies and contributed to the overall low level of evidence per domain. It was not in all cases possible to determine the number of participants having been affected by function-related voice problems. In cases in which restrictions to voice function or numerical worsening of results during or after an intervention were reported, conclusions about the clinical relevance of these findings were difficult to draw because information about recording methods and reference values used to evaluate data were either missing or inconsistent between studies.

For example, the procedures to establish participants' pitch ranges and the reference values to evaluate results can vary considerably. The reference values for VRPs reported in Hallin et al[40] and Sanchez et al[41] are comparable and compatible with the Nygren et al[5] study because all three studies used the same recording procedures and instructions to the participants. However, the reference values reported by Schultz-Coulon[42] and the results reported in the other studies investigating pitch range[21b,31,33b,36,39] were probably obtained in a different way and were considerably lower than those reported in the abovementioned studies.[5,40,41] Therefore, we suggest that guidelines used for recording and evaluating parameters of voice function need to be described in detail to enable comparisons between studies, reliable and valid evaluation of results, and conclusions about clinical relevance of findings.

In addition, restrictions to acoustical measurements of voice features did not always match participants' self-perceptions or did not necessarily imply limitations to the participants' voice-related activities and participation. Consequently, future research with transmasculine people needs to consider transmasculine people's self-evaluations of all aspects of their vocal situations in addition to clinician-centered and impairment-focused empirical data.

Findings from the review further indicated that the methods some transmasculine people use to change their gender presentation (including, testosterone treatment, laryngeal surgery, chest binding, and changes to posture) might imply changes in the anatomy and physiology of their voice organs and other parts of their voice-related bodily conduct. This means that the biological or behavioral components of transmasculine people's voice production need to be conceptualized as specific to the methods they have used to change their gender presentation rather than as generally comparable with those of cisgender women or men. This argument raises the question of whether it is appropriate to evaluate transmasculine people's voice function on the basis of existing normative ranges that apply to cisgender people or whether normative ranges need to be developed that are specific to transmasculine people's vocal situations and that are based on transmasculine people as the reference group.

## CONCLUSIONS

More careful research into the different factors and practices affecting transmasculine people's voice function needs to be conducted so that transmasculine people can be provided with reliable advice about the likelihood and nature of voice problems they may experience and be offered treatment that is suitable to facilitate functional voice production for all situations in which they need to use their voice.

## Acknowledgments

This research was supported under La Trobe University's Research Focus Area - Building Healthy Communities 2016 Publication - enabling funding scheme. The authors would like to thank two anonymous reviewers for their constructive comments and suggestions for improving this paper.

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