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Marta Assumpção de Andrada e Silva² Upper high notes: auditory-perceptual
analysis of voice and self-reporting among
professional sopranos*Superagudos: análise perceptivo-auditiva da
voz e autorrelato em sopranos profissionais*

Keywords

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ABSTRACT

Purpose: To describe the emission of upper high notes by professional sopranos by means of the auditory-perceptual evaluation of the singers' voices and self-reports. **Methods:** Five professional sopranos performed an excerpt from a Bellini opera which involved the emission of an upper high note. The auditory-perceptual evaluation was carried out by three speech-language therapists and three singing teachers, who considered brightness, loudness, metal quality, vibrato, breathiness, and resonance on a visual-analytical scale, based on each singer's emission of high notes. After the recording, the singers were asked to answer a proprioceptive questionnaire on the physical sensations that they had as they emitted upper high notes. An inferential analysis of the data from the auditory-perceptual evaluation was conducted, and the singers' self-reports were summarized and then orthographically transcribed. **Results:** In the auditory-perceptual analysis, the emission of upper high notes was characterized according to the presence of brightness, loudness, metal quality, vibrato, and anterior resonance, as perceived by speech-language therapists and singing teachers. In the proprioceptive report, all singers reported laryngeal elevation and a need to use respiratory support in order to emit upper high notes. **Conclusion:** Upper high notes are characterized by a bright vocal emission, enhanced loudness, with a metallic quality and vibrato, little or no breathiness, accompanied by a sensation of laryngeal elevation and a need for respiratory support.

RESUMO

Objetivo: Descrever a emissão de superagudos em sopranos profissionais por meio da avaliação perceptivo-auditiva da voz e do autorrelato das cantoras. **Método:** Cinco sopranos profissionais executaram o trecho de uma ópera de Bellini no qual havia a emissão de uma nota superaguda. A avaliação perceptivo-auditiva foi realizada por seis avaliadores (três fonoaudiólogos e três professores de canto) que consideraram brilho, *loudness*, metal, vibrato, sopro e ressonância em uma escala visual-analítica, tendo como base a emissão aguda de cada uma das cantoras. Após a gravação, as cantoras responderam a um questionário proprioceptivo sobre as sensações físicas durante a produção dos superagudos. Foi realizada uma análise inferencial dos dados da avaliação perceptivo-auditiva e transcrição ortográfica resumida do autorrelato das cantoras. **Resultados:** Na análise perceptivo-auditiva, a emissão superaguda foi caracterizada por presença de brilho, *loudness*, metal, vibrato e ressonância anteriorizada percebida por fonoaudiólogos e professores de canto. No relato proprioceptivo, todas as cantoras referiram elevação de laringe e necessidade de utilização do apoio respiratório para emitir a nota superaguda. **Conclusão:** Os superagudos foram caracterizados por uma emissão vocal brilhante, *loudness* aumentada, metálica, com vibrato, com pouca ou nenhuma sopro, com sensação de elevação da laringe e necessidade de apoio respiratório.

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INTRODUCTION

Studying the emission of upper high notes, widely used by sopranos, constitutes a challenge in the study of voice due to the lack of a precise definition thereof. It is common for singers to use the term upper high (or super high) when referring to notes higher than the usual upper limit in a soprano's vocal range, *i.e.* C5 ($\approx 1,050$ Hz). In fact, some studies suggest that notes higher than C5 are considered upper high⁽¹⁻³⁾. In the absence of a definition, we have chosen to adopt the terminology used by singers.

Historically, it is believed that the personal proximity between singers and composers may have contributed to upper high notes being written, thereby formalizing this type of emission in classical singing⁽⁴⁾. The character Queen of the Night from the opera "The Magic Flute", which Mozart wrote to one of his wives⁽⁴⁾, is an example of this feature. Such practice was consolidated in *Bel Canto* during Romanticism by composers such as Bellini, Rossini, and Donizetti⁽⁴⁾.

Other doubts about this type of emission involve the production mechanism and the variability in vocal quality among professional and amateur singers⁽²⁾. In addition to confusion as to upper high notes and whistle vocal register (whistle) or flute register, the lack of objective information and the divergences among singers and voice scientists contribute to a lack of consensus on the subject. Some authors believe that such type of emission has acoustic characteristics and source-filter adjustments that characterize vocal registers⁽⁵⁾ already known as: flute (flageolet), whistle, or bell registers⁽²⁾. Voice quality, however, can be breathy and small⁽⁶⁾, similar to the sound of a flute (*fluty*)⁽⁷⁾, or strong and bright^(1,6), depending on the vocal training of the singer. Thus, some studies have attempted to correlate the concept of vocal register with the emission of upper high notes^(2,7). For singers, on the other hand, the whistle or flute registers are not intense enough to fill a concert hall, and this would make it impossible to use upper high notes when delivering a performance to the audience.

In addition to engaging in artistic activities, many Brazilian singers also work as singing teachers⁽⁸⁾ and therefore seek theoretical information to help them build their students' voices up⁽⁹⁾, based on elements other than their empirical experience with singing. Thus, knowing more details about upper high notes should provide singers with practical support for guiding their own vocal production and that of their students. Also, singing professionals (speech therapists, singing teachers, and otorhinolaryngologists) will have useful information to rely on in order to deal with complaints related to the emission of upper high notes.

Although the number of publications on the emission of upper high notes has increased since 2010, there are no studies investigating the singer's self-perception during such emission. Research in this field explores acoustic phenomena and vocal tract adjustments related to the emission of upper high notes^(1,2,7,10), disregarding the individual perception of the singer producing them.

Therefore, taking into account the emission of upper high notes as the basis of a soprano's vocal emission, the objective of this study was to describe the emission of upper high notes by professional sopranos by means of the auditory-perceptual evaluation of the singers' voices as conducted by speech therapists and singing teachers and self-reports as made by the singers.

METHODS

This is a descriptive study based on the analysis of quantitative and qualitative data, and it was approved by the Research Ethics Committee at Faculty of Medical Sciences of Santa Casa de São Paulo committee opinion number 107/10.

Five professional sopranos voluntarily participated in the research following an invitation made by the researchers to their personal contacts. All of them volunteered to participate in the research because they considered the emission of upper high notes a controversial and necessary topic in the vocal pedagogy of a soprano receiving training. As inclusion criteria, the soprano had to have had music as her professional activity for at least 5 years, be able to emit the upper high note chosen for this research (D5, $\approx 1,175$ Hz) comfortably in public performances, and have no complaints relating to her vocal or general health at the time of the recording. All singers signed a voluntary Informed Consent Form (ICF).

The chosen musical excerpt (Bellini's duet *Fini, me lassa* opera *I Puritani* Vincenzo) contained an upper high note (D5, $\approx 1,175$ Hz) preceded by a high note (A4, ≈ 880 Hz), emitted with the vowels /a/ and /e/, respectively, as shown in Figure 1. This excerpt was chosen because it represents the professional reality of a light lyric or lyric coloratura soprano⁽⁴⁾, who must be being capable of emitting high and upper high notes, repeatedly and with any vowel. Furthermore, the high note served as a comparison parameter in the auditory-perceptual evaluation and was considered as the soprano's basal emission.

Prior to recording, the participant performed vocal warm-up for 10 minutes. She then was asked to take a standing position at a fixed distance from the pedestal on which the microphone was propped (at a 40 cm distance from the singer's mouth and at a 45° angle in order to avoid distortions due to the intensity of the voice in the lyric singing). To ensure that distance, a wooden slat affixed parallel to and laterally to the microphone body was used. The voices were recorded at 44.1 kHz sampling frequency directly by the software *Audacity* 1.3.12-beta (Unicode), on a Dell computer, Windows XP, sound card *Soundblaster* 2.1. The microphone used was a *Shure*® *SM 58*, unidirectional dynamic (cardioid) microphone. The recordings collected contained the excerpt from the duet *Fini, me lassa* presented to the singer through supra-aural headphones and a *HYUNDAI* MP3 player, model *HY231N/2GB*, so that there was no change in the height of the notes in the musical excerpt.

After recording the voice, a semi-directed interview was conducted with the soprano about upper high notes. The interview contained three open-ended questions that investigated the soprano's sensations during the emission of upper high notes:

- 1) During the emission of upper high notes, what are the sensations in your body?
- 2) During the emission of upper high notes, is there any laryngeal movement? How?
- 3) Is there a need to perform any "adjustments" in order to make the emission of upper high notes possible?

This interview was conducted according to the Consolidated Criteria for Reporting Qualitative Research (COREQ) proposed by Tong et al.⁽¹¹⁾, which takes into consideration the personal characteristics of the interviewer, his/her personal relationship

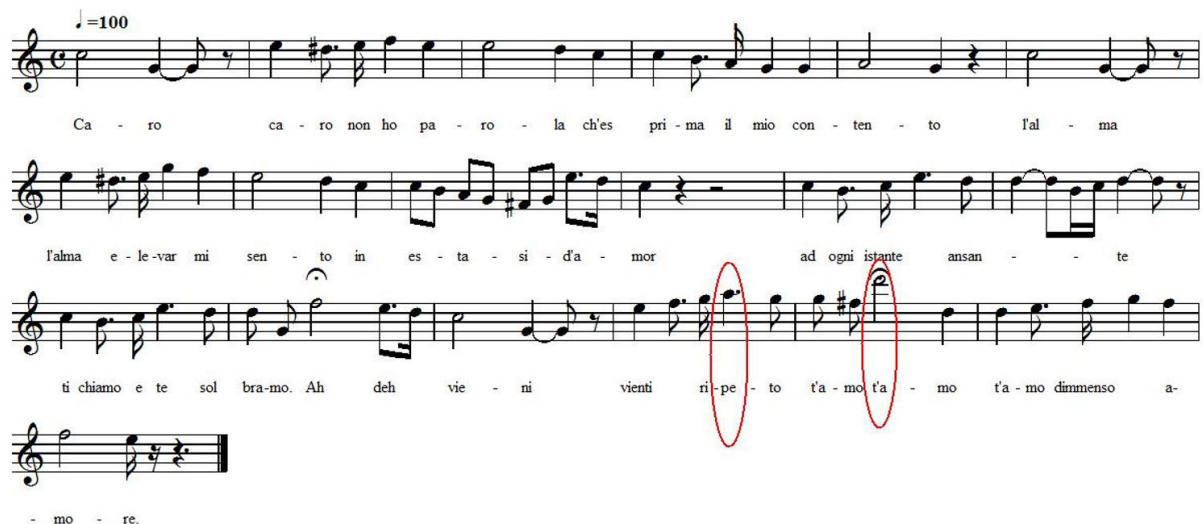


Figure 1. Excerpt from duet *Fini, me lassa* from the opera *I Puritani* by Vincenzo Bellini. The highlighted notes correspond to the high note (A4, \approx 880 Hz) and the super high note (D5, \approx 1,175 Hz)

with the research subjects, study design, participant selection, collection procedures, data analysis, and result reporting. At the time of collection, the interviewer was a Speech Therapy student and a professional male classical singer. He had a professional relationship with all participants in this research and invited them either in person or by telephone to participate in the study. The subjects were intentionally selected so as to ensure that the recruited sopranos would be capable of emitting the above mentioned upper high note. The interview lasted between five and ten minutes and was recorded with the same equipment used for voice recording. The interviews were analyzed using the content analysis technique after the orthographic transcription had been made with the aid of Microsoft® Word for Mac (version 16.17) and the main quotes transcribed, thereby yielding the results of this research.

Following voice recording, the researchers selected the sung excerpts and recorded them onto six Compact Discs (CDs) which were then delivered to three speech therapists and three singing teachers, all of whom had at least three years of experience with lyric singers. The evaluators were given evaluation instructions and a visual-analytical scale so that they could assign grades from 0 to 10 to the following aspects: brightness, loudness, metal quality, vibrato, and breathiness, where 0 represented the complete absence of these aspects in the sung excerpt and 10 was the maximum value for each one of them according to each evaluator's subjectivity, without any formal definition having been presented to them. With regard to resonance, however, the assessment was made relative to the position of the voice on the horizontal axis, so that 0 was equivalent to a more anterior (anteriorized) resonance position, whereas 10 referred to a more posterior position. These six aspects were considered as part of a common vocabulary for speech and language teachers when developing this evaluation instrument considered; they are also considered by the sopranos as appropriate parameters for evaluating the quality of the singing voice. Vocal tract adjustments such as mouth opening and tongue and larynx position were not considered in this instrument. Since the auditory-perceptual analysis of the voice can serve as a guide in the vocal improvement of a professional singer or one still receiving training⁽¹²⁾, this instrument was

developed to direct the analysis while the concepts underlying those aspects would not need to be presented to participants. hence, each evaluator judged the soprano's voice according to their previous experience with the singing voice. Also, the sopranos' self-perception results were not taken into consideration when developing this instrument. All evaluators were instructed to use pens of different colors to analyze high and upper high emissions and were allowed to listen to them as many times as they thought necessary.

The scores given by speech therapists and singing teachers for each vocal emission were tabulated using Microsoft® Excel for Mac (version 16.17) and analyzed with the help of IBM® SPSS Statistics, version 23. The Kolmogorov-Smirnov test was used for evaluating the normal distribution of data and, based on it, it was decided to use non-parametric tests for analyzing quantitative data: the Wilcoxon test for continuous variables (brightness, loudness, metal quality, vibrato, and breathiness), the Marginal Homogeneity test for the nominal variable (resonance), and the Kappa coefficient for comparing the evaluations from speech therapists and singing teachers. In all tests, $\alpha = 0.05$ and a 95% confidence interval were considered. When analyzing the singers' self-reports, excerpts of their interviews were transcribed in the form of quotes so as to yield the final results of this study.

RESULTS

The participants in this study had a mean age and standard deviation (SD) of 31.40 (\pm 1.74) years and, on average, 6.40 (\pm 1.96) years of experience as professional singers. The singers referred to themselves as light lyric sopranos (S1 and S4) or lyric coloratura sopranos (S2, S3, and S5). The sample data are described in Table 1.

When comparing the emission of an upper high note with that of a high note, speech therapists assigned statistically significant higher scores to loudness ($p = 0.00$), metal quality ($p = 0.00$), and vibrato ($p = 0.00$). In this group, the emission of upper high notes was considered brighter, less breathy, and as having an anterior resonance. Singing teachers described the emission

of upper high notes as bright ($p = 0.00$), having high loudness ($p = 0.01$), being metallic ($p = 0.00$), having vibrato ($p = 0.00$), and being less breathy ($p = 0.00$); they also considered this type of emission as having an anterior resonance. When comparing the evaluation of the two groups of professionals, an agreement is found between them both with respect to brightness ($p = 0.41$), loudness ($p = 0.15$), and vibrato ($p = 0.15$) in the emission of high notes; and loudness ($p = 0.68$) and resonance ($p = 0.97$) in the emission of upper high notes. For all other parameters, the two groups differed as to the auditory perception of sung emissions ($\kappa \leq 0.01$). Table 2 shows the description and comparison of evaluations for the two groups.

The semi-directed interview investigated aspects relating to the emission of upper high notes: the first question addressed body sensations; the second explored sensations of laryngeal

movement; and the third, more non-specific, inquired about any adjustments that were needed for singing the upper high note. Among the answers to the first question, there were reports of “support and sustaining the air” (S1), “deeper breathing” (S2), wider opening of the mouth (S3), positioning of the voice (S4), and also descriptions unrelated to the vocal emission itself (S5). In the second question, all the singers described laryngeal elevation for emitting the upper acute note. In the third question, all the singers reported feeling a need for more effective respiratory support in order for them to be able to properly emit the upper high note. Regarding the vocabulary used by sopranos, some used a more technical vocabulary based on vocal physiology (S1 and S2), whereas others were less technical in describing vocal production. Chart 1 shows the orthographic transcription of the self-reports from the five participants.

Table 1. Characterization of the sample as to participants' age, time of professional experience, and self-reported vocal subclassification

	S1	S2	S3	S4	S5	Mean (\pm SD)
Age (years)	30	34	33	30	30	31.40 (\pm 1.74)
Self-reported vocal subclassification	Light-lyric	lyric-coloratura	lyric-coloratura	Light-lyric	lyric-coloratura	
Time of Professional Experience (years)	10	7	5	5	5	6.40 (\pm 1.96)

Captions: SD = standard deviation; S1 = subject 1; S2 = subject 2; S3 = subject 3; S4 = subject 4; S5 = subject 5

Table 2. Mean grades assigned to each of the parameters evaluated by three speech therapists (SpTh) and three singing teachers (SiTe) and comparison of the evaluations of the two groups (SpTh X SiTe)

		SpTh					SiTe					SpTh X SiTe	
		Min	Max	Mean	SD	p value	Min	Max	Mean	SD	p value	p value	
Brightness	A	4.0	9.0	6.5	1.5	0.37 ^a	2.0	8.0	5.8	1.7	0.00 ^a	-0.01 ^c	
	UH	4.0	9.5	6.7	1.7		2.0	9.5	7.4	1.7		-0.00 ^c	
Loudness	H	5.0	8.0	6.6	1.0	0.00 ^a	1.0	8.0	5.5	1.9	0.01 ^a	0.01 ^c	
	UH	5.0	9.0	7.3	1.2		3.0	9.5	7.3	1.8		-0.00 ^c	
Metal quality	H	0.5	7.0	4.1	2.3	0.00 ^a	1.0	9.0	5.7	2.1	0.00 ^a	0.01 ^c	
	UH	0.5	9.0	5.0	2.8		2.0	10.0	7.4	2.1		-0.03 ^c	
Vibrato	H	2.5	8.5	5.8	1.7	0.00 ^a	3.0	9.5	6.9	2.1	0.00 ^a	0.00 ^c	
	UH	3.0	9.5	7.0	1.7		6.0	10.0	8.2	1.3		0.00 ^c	
Breathiness	H	0.0	1.5	0.3	0.5	0.28 ^a	0.5	5.0	3.0	1.4	0.00 ^a	-0.07 ^c	
	UH	0.0	1.5	0.2	0.4		0.0	5.5	1.5	1.6		0.07 ^c	
Resonance	H	0.0	6.5	3.5	2.2	0.11 ^b	2.5	9.5	5.2	2.3	0.83 ^b	0.01 ^c	
	UH	0.0	8.0	4.1	2.7		0.0	9.5	4.1	2.7		0.01 ^c	

^aWilcoxon test for related samples; ^bMarginal Homogeneity Test for related samples; ^cKappa coefficient (alpha = 0.05 and 95% confidence interval for all tests)

Caption: H = high notes; SD = standard deviation; SpTh = speech therapists; Max = maximum value; Min = minimum value; SiTe = singing teacher; UH = upper high notes

Chart 1. Self-reported quotes from sopranos in relation to the emission of upper high notes

	During the emission of upper high notes, what are the sensations in your body?	During the emission of upper high notes, is there any laryngeal movement? How?	Is there a need to perform any “adjustments” in order to make the emission of upper high notes possible?
S1	“I feel this upper high note is a combination of support and sustaining the air.”	“I can't tell you precisely if it stays down, but I don't think so. [...] The upper high note requires a different type of adjustment that, for me, is not a totally lowered (larynx).”	“Yes, sustaining.”
S2	“I have the sensation in the whole body. I try to get prepared for the high note by supporting and breathing deeper.”	“I think, in fact, that during the upper high notes the larynx tends to rise.”	“I try to support more intensely during the upper high note.”
S3	“I have a sensation in the zygomatic muscle that, when I move, for example, from A pro D, there is an elevation of the muscle and [...] a lowering of the lower part of the mouth.”	“From high to upper high notes, I think there is an elevation [of the larynx].”	“There is abdominal support.”
S4	“When you have the upper high note, I feel it's different [...], the upper high note feels like it fits elsewhere, it's not the same feeling you get with a high note, for example.”	“Feels like it's a small difference.”	“You need more support and the feeling you have is that it has a downward support, so that the upper high note comes out more easily.”
S5	“I feel the whole body is ... like it's growing, like it's getting bigger.”	“Maybe what I feel is a little upwards.”	“What I feel is that when it works, it is because it didn't make the diaphragm close.”

Caption: S1 = subject 1; S2 = subject 2; S3 = subject 3; S4 = subject 4; S5 = subject 5

DISCUSSION

Based on the current panorama of scientific knowledge on upper high notes, this study sought auditory-perceptual information from two professional classes routinely working with singers: speech therapists and singing teachers. The gathering of such information was made possible with the use of an inexpensive tool⁽¹²⁾ and that is an essential component of their daily professional life, namely their auditory perception. In the description of upper high notes, speech therapists and singing teachers considered that this type of emission is characterized by the presence of brightness, high loudness, voice metallization, vibrato, little or no breathiness, and anterior resonance. The perception of both classes of professionals demonstrated sound characteristics that make it possible to differentiate the emission of high notes from that of upper high notes. These parameters were not explored in studies addressing this topic^(1,2,7). Based on such observations, both groups seem to indicate that upper high notes present with characteristics that should be observed in a singing class or a speech therapy consultation.

As for breathiness, the results draw one's attention to the difference between the scores assigned by the two groups of evaluators. Speech therapists assigned a lower breathiness score than that by singing teachers. Possibly, this difference is due to the nature of the work done by each class of professionals. On the one hand, a singing teacher has undergone auditory training so as to be able to notice small changes that might interfere with the performance of his or her students. The speech therapist, on the other hand, is trained to deal with voice disorders, which might would make him or her more permissive in perceiving breathiness⁽¹³⁾. Accordingly, a singing teacher would be able to perceive less pronounced breathiness levels than would a speech therapist. In comparing the evaluation conducted for the two groups, the discrepancy between them for metal quality, breathiness, resonance in the emission of high notes, and brightness, metal, vibrato, and breathiness in the emission of upper high notes becomes evident. Such differences may also be accounted for by the nature of the work conducted by each class of professionals, artistic performance, and the treatment of dysphonia, the approach of which is based on definitions that may differ. In Speech Therapy, for example, voice metallization is understood mainly as a raise in the second voice formant (F2)⁽¹⁴⁾. For singers, the same term refers to a vocal emission whose fundamental frequency is high⁽¹⁵⁾.

In order to enrich the data of this study and raise hypotheses for future works, the singers' physical perception during the emission of upper high notes was investigated. In their self-report, sopranos were asked to report relevant physical sensations during vocal emission. In the analysis of interview contents, whose corresponding extracted quotes are shown in Chart 1, it is possible to notice two key features in the emission of upper high notes: elevation of the larynx and a need for respiratory support⁽¹⁶⁾. Individual previous experience in voice physiology can be considered as an information bias in the collected information. Still, all singers reported aspects that were unanimously repeated, even though they exchanged no

communication amongst themselves. In the first question, each of the singers reported different aspects of bodily sensations, which emphasizes that there is no standard bodily sensation to recur amongst them. Each singer could refer to sensations to which she was most attentive while singing as being influenced by her non-musical background experiences/training (voice physiology, theater, dance) or by her physical state at the time of recording (indisposition, tiredness, anxiety)⁽¹⁷⁾. In the second question, on the perception of laryngeal movement, the singers reported feeling elevation of the larynx when emitting upper high notes. The first singer (S1), although uncertain about laryngeal elevation, questions the "totally lowered" position advocated by many lyric singing teachers. In the third question, aimed at permitting a less biased response, all singers reported that respiratory support is the adjustment needed for emitting upper high notes. Given that this question did not direct the soprano's perception towards any particular part of her body, it allowed her to reflect freely and respond as she considered relevant. This convergence of sensations among the singers indicates a common axis of respiratory support in the emission of upper high notes and, indeed, in all vocal emission⁽¹⁸⁾. Although some authors do consider the classical singer not capable of describing his or her physical sensations during singing⁽¹⁹⁾, the sopranos in their self-report referred to concrete elements during the emission of upper high notes. These comparisons do not converge to a pattern of sensations during the emission of upper high notes, which demonstrates that vocal production is greatly influenced by the singer's individuality.

We considered as limitations to this study sample size and participants' characteristics such as age and time of professional experience, as well as a memory bias in the interview when it was conducted right after recording the singing voice. Each participant's individual vocal characteristics should also be taken into account, given that they all belong to a naturally a higher vocal subclassification. In addition, the absence of definitions for the aspects evaluated in the auditory-perceptual analysis may have contributed to the differences observed between the two groups of evaluators. The data presented in this article are expected to contribute to the training of new singers and to improving the performance of sopranos, either beginners or professionals. It also provides the basis for more assertive approach and performance in speech therapy and vocal pedagogy while at the same time both aiming at achieving vocal quality that is appropriate to the musical style and providing information on physical sensations that may occur during the emission of upper high notes.

CONCLUSION

When compared to high notes, upper high notes were characterized by bright vocal emission, with high loudness, metallic quality, with vibrato, having little or no breathiness and anterior resonance. With regard to proprioception, the singers reported that in order for them to sing the upper high notes, they elevated their larynx and felt a need for more effective respiratory support.

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Author contributions

DEF: designed the study, subjects enrollment, data collection, data analysis, final manuscript writing; MAAS: data analysis, discussion and project supervision.