Postural Control in Lyric Singers

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Summary: Background. Singers are unique musicians because they use their whole body as a musical instrument. Posture and proprioception are key components for a robust and healthy voice.
Objective. This study aimed to analyze the postural control of lyric singers in different sensorimotor conditions.
Methods. Seventeen lyric singers were compared to a control group of 12 participants in static postural control test in eyes open (C1) and eyes closed (C2) conditions. Postural control of singers was also assessed in four specific singing conditions: singing posture eyes open (C3) and eyes closed (C4), vocalization (C5) and free aria (C6), low values being representative of good postural control. Singers also completed the Singing Voice Handicap Index (SVHI) French version, low scores reflecting a good SVHI result.
Results. No significant difference was observed between the two groups in C1 and C2. Postural control of singers was more accurate in C3 than in C1. Increased values in all postural parameters were seen in the singing conditions. Scores obtained at the SVHI were correlated to the area covered by the center of foot pressure in C5, low scores at the SVHI being correlated with low area values in this postural condition.
Conclusions. Singing is a multitask situation which involves several movements including breathing, and management of factors such as stress. This can affect balance and so rigorous work on posture and proprioception is required as soon as a singer begins to perform in order to take care of the voice.
Key Words: Lyric singers−Postural control.

INTRODUCTION

Production of a sound mobilizes the whole body, which is composed of segments connected to each other and influencing each other, and requires a coordination of breath, vibration, and resonance.[1]

Singing necessitates an optimization of the body in the production of sound. This discipline, as a sport, requires regular and rigorous vocal work. The singer learns how to breathe, how to position himself/herself and also develop proprioceptive capacities; he/she is striving for a harmony between the different forces in action.

In order to maintain or move in such a constrained physical environment, the human body, a multiarticulated organism subject to the inevitable laws of gravity, must implement a considerable flow of information (vestibular, visual, proprioceptive) that will be processed by the nervous centers in order to control the muscular activity necessary to ensure mechanical cohesion between the different body segments. The motor response must be adapted to the task to be performed and the environmental conditions, as well as intended to allow orientation in three-dimensional space.[2]

The proprioceptive system provides continuous positional information about the limbs and body to the central nervous system.[3] The proprioceptors are sensors providing conscious or nonconscious information about joint angle, muscle length and muscle tension, and tendon organs.

Among sensory systems which are involved in balance control, proprioception is the one most likely to be acquired or educated through the practice of physical activities.

The posture of lyric singers is a reference posture for vocal physiology**.** The typical posture, from the soles of the feet to the top of the skull, is described as follows: feet in contact with the ground, slightly apart, well anchored, knees relaxed, unrestrained, chest open, in high position, relaxed shoulders, and vertical cervical spine. Specific attention is required with respect to head, back, and pelvis position to account for kyphosis and physiological lordosis of the body, without exaggerating or erasing them.[4,5] The singer modulates and adapts his/her body to the vocal pieces he/she needs to interpret: the sound parameters of the intensity requirements, the duration and the pitch of the interpreted vocal pieces and the environment (ie, the specificities of the scene). The muscular activity that prevents the singer from losing balance is controlled by postural activity that receives information from the movement itself and from visual, somatosensory, and vestibular information received by the sensory receptors. These receptors detect any fluctuation, and a motor response permits stabilization of posture.[2,6-8] An effective posture allows a singer in a static or dynamic posture to shift the tension between muscles more fluidly, allowing for a free movement of the larynx without blockage and with benefits to voice production.[9,10] The singer researches coordination between the different parts of the body, which makes it easier to modulate and control it, in particular when high notes are produced.[5]

Whether the voice is sung or spoken, posture is a key element. If posture is distorted, it can become the cause or the consequence of a vocal dysfunction.

Accepted for publication April 28, 2020.
Conflict of Interest: None declared.
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Journal of Voice, Vol. ■■, No. ■■, pp. ■■−■■
0892-1997

https://doi.org/10.1016/j.jvoice.2020.04.019

Correct posture requires a permanent adaptation of the body, with a minimum of tension. Disorders can be organic and emotional,[11] with emotions that may precede singing, or may be concomitant. The learning of a vocal practice with an adapted posture, the correction of inappropriate attitudes, and attention to psychological factors are complementary to prevent dysphonia and musculoskeletal disorders.

Knowledge of the sensorimotor strategy adopted will help to exploit strengths and improve weaknesses. The study of the relationships between postural control and voice in lyric singers, recognized for their specific posture, seems relevant to get a better understanding of the links between posture and voice.[12] This work aimed to assess whether and to what extent voice performance during singing in lyric singers impacts body posture according to different sensorimotor conditions.

PARTICIPANTS AND METHODS

Setting and participants

Seventeen singers of the singing class of the Epinal Conservatory of Music, France (mean age: 27.69 ± 8.77 years) participated in this study. Five women were sopranos and two were mezzo-sopranos; four men were tenors, four baritones, one was bass-baritone, and one man was deep bass.

The singers were compared to a control group of 12 participants (mean age: 24.97 ± 3.15 years). The singer group participants had to attend vocal training at the Conservatory concurrently at the time of the experiment. Exclusion criteria were history of postural diseases (neuro-otological diseases, scoliosis, recent lumbago, sprains in the lower limbs within the past 3 months), pregnancy beyond 3 months, dysphonia, and amateur singers without vocal instruction.

The different conditions of the test were randomized and controlled. All participants gave written informed consent prior to participation.

Postural control statement

Postural control tests, the main endpoint, were carried out in a specially designed sound proof room devoted to posturography recordings. A vertical force platform, fitted with three strain gauge force transducers (Medicapteurs, Balma, France) was used to perform posturography and to provide a measurement of the body sway in terms of displacement of the center of foot pressure (CoP) in a two-dimensional horizontal plane (recording time: 25.6 seconds, acquisition frequency: 40 Hz, sampling: 1024 points). The signals from the transducers were amplified, converted from analog into digital form, and then recorded on a computer. The sway path traveled and area covered by the CoP trajectory were used to quantify postural sway, low values being representative of good postural control. The length function of surface (LFS) was calculated with the following equation: LFS = sway path/396× exp (0.0008× area).[13,14] It provides information about the precision (area) of postural control and the effort made (efficiency, sway path) by the participant.

Each subject was asked to stand upright on the platform, without shoes, arms along the body, remaining as stable as possible and breathing normally.[15-17]

Postural control of singers was evaluated under six conditions. Measurements were recorded on firm support eyes opened (C1) and eyes closed (C2) in the singers and the control group. Postural control of singers was also assessed in four specific singing conditions. Conditions 3 and 4 were the singing posture learned at the conservatory feet parallel, knees and shoulders relaxed, and respecting physiological lordosis and kyphosis of the body. The measurements were performed eyes opened (C3) and eyes closed (C4). For conditions 5 and 6, the posture was free and the movements accompanying singers were allowed. In condition 5 (C5), the singers had to sing a vocalization divided into two parts. Notes were the same for all singers, across all vocal ranges. The first part aimed to work on the mobility of the abdominal strap. The musical sentence was made up of four notes on the syllables /blo blo o o/. The vocalization started on the note A. For each sentence, the first, the second and the last notes were the same, the first /o/ was sung on the third (eg, B B D B / A A Csharp A). Each sentence was sung by following A major scale on one descending octave. Breaths in were located before and after each first /blo/. The second part consisted in a rise and then a descent on the syllable /blo/ on A major scale. Only one breath in was required. In condition 6 (C6), the singers were instructed to sing an aria of their choice. Conditions 5 and 6 were performed with eyes open. In C6, the singer's vocal gesture was qualitatively analyzed: presence of tension in the body, type of breathing (thoracoabdominal, abdominal, or upper thoracic), presence or absence of inspiratory restart at the thoracic level, anchoring on the ground, flexibility of the knees and presence of accompanying movements while singing.

Questionnaire

Singers completed a questionnaire about parameters that can influence postural control and voice. The questions concerned (1) traumatic history of the ankle and of the knee and of low back pain, (2) vocal habitude, including the number of years of singing and the length of the vocal training.

Singers also evaluated their voice from the Singing Voice Handicap Index (SVHI) French version. This scale, which is calibrated, reliable, and validated, is sensitive to the vocal complaint.[18] It has 30 items divided in 3 subgroups: emotional feeling, physical symptoms at the voice and the functional aspects of the voice of the daily life of the singer, for a highest value of 120. Low score means a good SVHI.

Statistical analysis

Qualitative data were expressed in terms of number (n) and percentage (%). Quantitative data were expressed as mean and SD. Due to the small sample size nonparametric tests were used. A Mann-Whitney test was used to compare the singers to the control group. The test of Wilcoxon was used to compare the different conditions of the postural control test in the singers. ANOVA was used to study the relationships between the movements accompanying the singers and the postural control in condition 6. The univariate linear model was used to analyze the effect of the number of years of practice or/and age on the postural control. The test of Pearson was used to research a correlation between the score of SVHI and the postural control parameters.

A probability level $P \leq 0.05$ was considered significant. The SPSS statistical software (IBM, Armonk, NY), version 23.0 was used in this study for data analysis.

RESULTS

Participants

No statistically significant difference was observed for anthropometric variables, age ($P = 0.744$) and sex ($P = 0.263$), between the two groups (Table 1).

In the singer group, the average time of weekly vocal practice was 4:40 ± 2:35 (3-9 hours per week) and the average number of singing years practice was 5 years 11 months ± 4 years 10 months.

Postural control

No difference was observed between the two groups in C1 and C2 for sway path, area, LFS.

In the singers group:

- values of sway path were higher in C6 than in C1 ($P < 0.001$), C3 ($P < 0.001$), C5 ($P < 0.001$), and in C5 than in C1 ($P < 0.001$) and C3 ($P = 0.002$; Figure 1);
- values of area were higher in C6 than in C1 ($P < 0.001$), C3 ($P < 0.001$), C5 ($P < 0.001$), and in C1 than in C3 ($P = 0.015$; Figure 1). In C4, the area was lower with the higher of numbers years of experience in singing ($P = 0.010$), a tendency to lower was observed in C3 ($P = 0.056$) and a tendency to increase was observed in C6 ($P = 0.055$; Figure 2);
- values of LFS were higher in C5 than in C1 ($P = 0.009$) and C3 ($P = 0.014$; Figure 1).

Subject age had no effect on the postural control for the area, sway path, and LFS parameters in all the conditions of the test.

TABLE 1.
Comparison of Anthropometric Variables Between Singers and Control Group

	Singers	Control Group	*P* Value
	Mean ± SD	Mean ± SD	Mann-Whitney
Age (years)	27.69 ± 8.77	24.97 ± 3.15	0.744
	n (%)	n (%)	
Sex, males	10 (58.82)	4 (33.33)	0.263

SD, standard deviation.

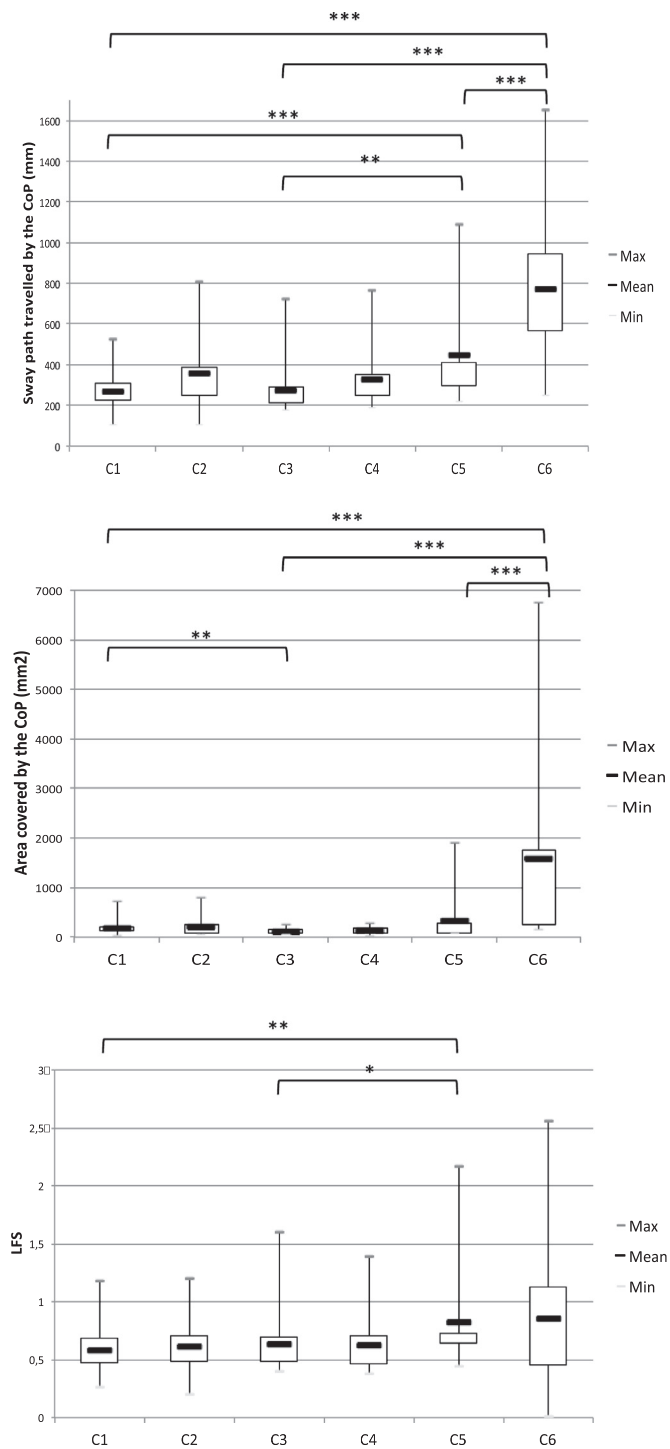

FIGURE 1. Comparison between each evaluation of sway path, area and LFS. * $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$. C1, eyes open; C2, eyes closed; C3, singing posture with eyes open; C4, singing posture with eyes closed; C5, free posture with vocalize; C6, free posture with singing.

When singing an aria of their choice, no corporeal tension was observed in 70.6% of the singers. For others, tensions were observed in the hands (clenching, clenched fists), arm, neck muscles, and jaw. Diaphragmatic breathing was

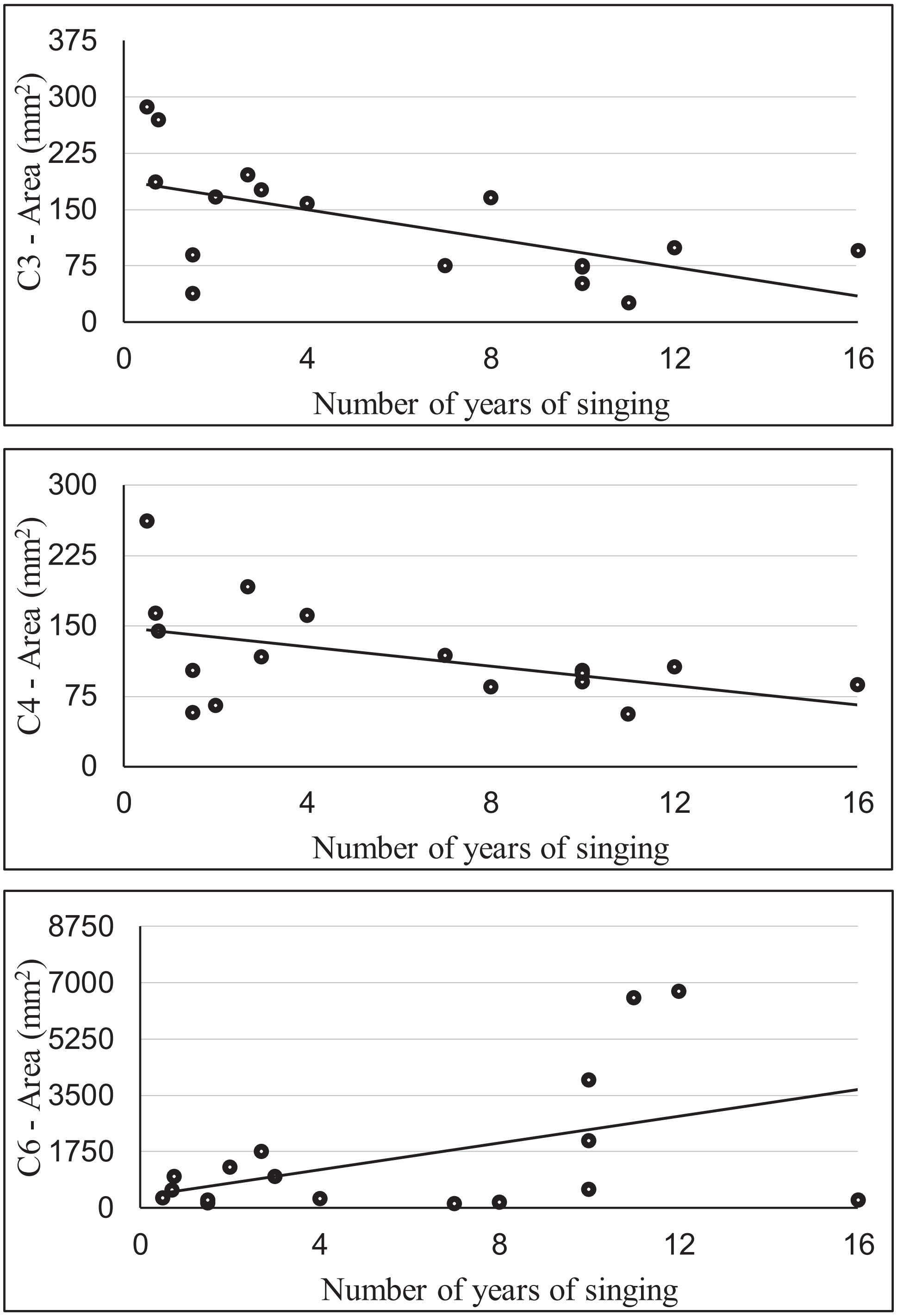

FIGURE 2. Linear regression line—area according to the number of years of singing in C3 ($P = 0.056$; I = –5.1): singing posture with eyes open; C4 ($P = 0.010$; I = –9.6): singing posture with eyes closed; C6 ($P = 0.055$; I = 207.8): free posture with singing. I, inclination of the line.

observed in 70.6% and thoracic breathing in 23.5% of the singers. One singer showed clavicular breathing.

The singers were free to position the feet as they wished. Ground anchoring was solid for almost all singers. In three singers (17.65%), there were several weak swings from right to left or back and forth.

The shoulders of all the singers were in a low position. Flexible knees were observed in 58.82% of them and others lock the knees.

Arm or hand movements accompanied the singing of 47.05% of the singers. The movements had no effect on sway path ($P = 0.830$), area ($P = 0.110$), and LFS ($P = 0.093$) in the condition 6 of the postural control test.

Questionnaire

VHI questionnaire Global and subscores are presented in Table 2.

TABLE 2.
Scores Obtained to the Singing Voice Handicap Index (n = 17)

	Mean ± SD	Q1	Q3	Min	Max
Global score (/120)	20.82 ± 11.35	11	28	3	42
Functional subscore (/40)	6.59 ± 3.52	4	9	1	14
Physical sub-core (/40)	7.65 ± 4.87	4	11	1	20
Emotional subscore (/40)	6.59 ± 5.79	2	9	0	20

SD, standard deviation; Q1, 1st quartile; Q3, 3rd quartile; Min, minimum; Max, maximum.

TABLE 3.
Bivariate Correlation Between the Scores of Singing Voice Handicap Index and the Postural Control Parameters in C3 to C6 in the Singers

		C3 *P* Value	C4 *P* Value	C5 *P* Value	C6 *P* Value
Area	Global score	0.832	0.118	**0.019**	0.254
	Functional subscore	0.855	0.156	**0.019**	0.280
	Physical subscore	0.477	0.605	**0.021**	0.169
	Emotional subscore	0.252	0.078	0.258	0.673
Sway path	Global score	0.371	0.911	0.099	0.095
	Functional subscore	0.505	0.939	0.052	0.078
	Physical subscore	0.400	0.716	0.130	0.056
	Emotional subscore	0.528	0.968	0.445	0.548
LFS	Global score	0.343	0.609	0.993	0.604
	Functional subscore	0.496	0.870	0.702	0.923
	Physical subscore	0.419	0.597	0.883	0.737
	Emotional subscore	0.451	0.646	0.734	0.497

C1, condition 1; C2, condition 2; C3, condition 3; C4, condition 4; C5, condition 5; C6, condition 6. In bold: significant values.

In C5, the area increased when the global score ($P = 0.019$), the functional ($P = 0.019$), and physical subscore ($P = 0.021$) increased (Table 3).

DISCUSSION

This study aimed to compare the lyric singer postural control in different conditions with or without singing. When not singing, no difference was observed between the singers and the control group, eyes open and eyes closed. The postural control of singers was better in posture learning to sing than in conventional posture (for sway path travelled by the COP in eyes open condition). This study showed that the more experienced the singer was, the better the postural control was, eyes open and eyes closed, in the posture learned at the Conservatory. Important variations of postural control were observed in the singing conditions.

Postural control was better when the global score, physical and functional subscores of SVHI decreased.

The singers had better postural control when they were in singing posture compared to conventional posture in eyes open condition. In other words, their singing posture seems to offer them more stability through a solid ground anchoring and free movements for the rest of the body. This stable anchorage becomes that of reference through a learning on which the "postural experience" is built with better postural efficiency.

In experienced singers, this precision was more important with or without gaze stabilization. Years of experience seems to permit a singer to internalize singing posture and to develop strong proprioceptive landmarks. In this sense, Kleber et al[19] explained that singers are special musicians because they have no visual control over what they produce. They have to rely on what they feel, as proprioception or auditory feedbacks. These authors highlighted specific neural networks in opera singers. These neural networks are different from those activated in beginner singers or singers specialized in other repertoires.

Singing is a multitasking activity requiring a sharing of attentional resources.[20-23] The singer must master several technical elements as position of the body, pneumo-phono-resonantial coordination, articulatory coordination, management of sound parameters, melody or interpretive elements. The more an activity is developed, the more energy is necessary to obtain precision in postural control. In vocalization conditions of the postural control test, the ratio between sway path and area was higher than in conventional postural condition and singing posture. The singers were forced to spend more energy for a precise postural control.

On the one hand, singing requires articulatory movements, the intelligibility of words being a primary element in the interpretation of a song and movements of breathing; on the other hand, the inspirations are shortened and the expirations lengthened in comparison with normal breathing (not used during singing). The lyric singers also use the technique of "appoggio," a breathing technique which consists of slowing down the diaphragmatic rise during exhalation.[24] However, the respiratory and articulatory movements influence the postural control.[25,26] The respiratory and articulatory movements could explain the increase of the body oscillations highlighted in the sung conditions.

Postural control of singers was more effective in the vocalizing condition than in the singing condition. The singers were used to this vocalized phrase that they sang regularly during vocal warm-ups that required little articulatory movements since it was sung on repetitions of /blo/; breaths in were similarly located for all and the melody was simplified. It seems that singing a vocalized phrase required less attentional resources than singing a song, which would explain the less significant body oscillations in vocalization condition in comparison to the song interpretation.

For the majority of singers, the vocal gesture was respectful of vocal physiology. For almost 30% of them, some clavicular breathing or costo-abdominal breathing was observed in spite of a diaphragmatic breathing technique, but muscular tensions at the neck, jaw, arms, and hands or knees were also seen. Ground anchoring could also be altered by slight body swings, particularly in the anterior-posterior plane. Vigilance and careful observation of the vocal gesture, especially the posture, are needed from the voice professionals to prevent the appearance of vocal disturbances in singers.[9]

The voice is linked to the role, and both intervene on the posture. The performance takes into account the operatic role, the skill of the singer and the interaction with other singers, the orchestra and the audience.

CONCLUSION

A singer uses his/her body as a musical instrument. Posture is a key element with respect to vocal physiology and the prevention of vocal disruption. Singing posture influences postural control. During a performance the singer must manage many external environmental factors; some of them predictable (eg, conductor's orders, musicians, chorus, singing partner, lighting, clothing, scene size, and configuration), and some of them unpredictable (eg, noises such as coughing in the audience, effect of opacifying mist). He/she must also deal with individual factors (eg, mental task, working posture, stress, emotional condition, fatigue). In order to take into account these requirements and the attention resources needed for interpretation and singing, it is important that vocal gesture and posture are anchored in the singer, which necessitates preferential use of proprioception.

AUTHOR CONTRIBUTION

All authors listed have made substantial, direct, and intellectual contributions to the work, and approved it for publication.

Acknowledgments

The authors thank Mr Robert Boschiero, singing teacher, for this fruitful collaboration permitting to realize the postural control statement with his singing class. The authors acknowledge Dr. Art Mallinson (Vancouver, British Columbia, CA) for his helpful advice in the final read-through of the manuscript.

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