Effect of Core Stabilization Exercises on Acoustic Properties and Performance of Voice

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Summary: Voice production is a complex process requiring coordination of multiple bodily systems, including core muscles, which play a crucial role in breath control and vocal stability. This study aimed to investigate the impact of core stabilization exercises on vocal performance and acoustic properties in individuals undergoing voice training. A total of 27 music students were divided into an experimental group (n = 17) and a control group (n = 10). The experimental group participated in a 10-week core stabilization program under physiotherapist supervision, while the control group did not receive any intervention. Assessments included acoustic voice analysis, vocal performance evaluation, and muscle strength tests conducted before and after the program. Results showed significant improvements in the experimental group compared to the control group in key acoustic parameters (mean pitch, jitter, shimmer, and harmonics), vocal performance (musicality, technique, and breath control), and core muscle strength. Participants reported better vocal control, improved breathing, and greater singing comfort. These findings suggest that core stabilization exercises can enhance vocal performance by improving respiratory control and core muscle strength. Integrating such exercises into vocal training programs may benefit singers and voice professionals. Further studies with larger samples and long-term follow-ups are recommended.

Key Words: Core stabilization—Vocal performance—Acoustic properties.

Voice is the most effective means of communication between individuals, and all people use their voices to a greater or lesser extent during the day. Although sound production may seem easy from the outside, it is achieved by the coordinated use of many systems in our body. A song constitutes a continuation of speech, whereas an instrumental piece represents the transposition of a song onto a musical instrument. Linguistic elements are incidental within the composition of a song. The fundamental nature of a song lies in its melody, which functions as an extended auditory expression akin to a single elongated Word.[1] Training the voice is a very difficult process, both because we cannot see it and because it is directly affected by many changes in the body. In addition to overcoming technical difficulties, a relaxed mind and body are required for the correct and effective use of voice, especially for those who use their voice professionally.[2]

The respiratory process in humans is not limited to diaphragmatic movement and lung function. The participation of abdominal and lumbar muscles is also necessary to facilitate and support respiration.[3] Human respiration depends on the rhythmic contraction and relaxation of abdominal and lumbar musculature also called core muscles to support diaphragmatic motion and pulmonary function.[4] It is important to note that both core muscle strength and core stability directly affect vocal performance, but they are two different concepts. Core muscle strength generally refers to the ability of the core muscles to produce force, while core stability focuses more on trunk stability and control, and this stability mostly depends on the deep muscles.[5] A correct understanding of the functional effect of the core muscles and the development of a scientifically based exercise plan in this direction are very important for vocal training.[6] In addition to their vital functions, respiratory muscles play a fundamental role in controlling posture and act simultaneously with the core muscles. Conversely, the core muscles simultaneously assist in respiration.[7,8] Hodges et al showed a relationship between the activity of the pelvic floor muscles and expiration muscles. They emphasized the need of a good pelvic floor muscle activity for a normal function of the deep abdominal muscles, such as the transversus abdominis.[9] The transversus abdominis provides, together with other stabilizing musculature, a profound lumbopelvic stability, which is necessary for breath support during singing.[10–13] It is reported in the literature that core and exercises increase dynamic performance by improving breath support and control and also improve posture and voice resonance and pitch accuracy.[2,6,14] Despite this, there are few large-sample and long-term studies in the existing literature examining the effects of core exercises on voice performance and acoustic properties. Therefore, in this study, 27 participants were included in a 10-week core muscle strengthening program, and the effects of this program on the voice were investigated.

METHODS

Participants

This study was approved by the local ethics committee (Approval No: 2024-10-82). The research group consists of volunteer students studying at the Music Department of the Faculty of Fine Arts who have completed 4 half-term

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voice training. A total of 27 individuals receiving voice training were included in the study, 17 of whom were in the experimental group and 10 in the control group.

Participants were assigned to the experimental and control groups by simple random method (drawing lots) in the presence of a third observer. The numerical imbalance between the groups (17 vs. 10) was due to the number of individuals who volunteered to participate in the active exercise program.

Inclusion criteria: (1) Having received voice training for at least two years, (2) No known vocal cord pathology, (3) No neurological or musculoskeletal disease, (4) Voluntary participation. Exclusion criteria: (1) Chronic respiratory disease, (2) Abdominal or back surgery in the last six months, and (3) Not being able to participate in the exercise program regularly.

Before determining the groups, the voice performance and core muscle strength of all participants were evaluated, and no significant difference was found in the initial values. This shows that the groups were equivalent at the beginning.

The participants' socio-demographic information, such as age, gender, height, and body weight were recorded. Then, pre exercise assessments were made to the participants.These assessments:

1. Evaluation of the acoustic properties of the voice.
2. Evaluation of voice performance.
3. Evaluation of muscle strength.

The exercise protocol was applied for 30 sessions, 3 days a week for 10 weeks. This duration and frequency were determined based on studies in the literature showing neuromuscular adaptations in the respiratory/core muscles.[15,16] After the initial assessments, the participants performed a total of 30 sessions of core stabilization exercises with the help of a physiotherapist 3 days a week for 10 weeks. At the end of the 10th week, the assessments were repeated and the changes were compared. Each exercise session consisted of a training program that started with a 10-minute warm-up program and ended with a 5-minute cool-down program, lasting a total of 60 minutes. In addition, individual interviews were conducted with the core stabilization group at the end of the 10th week.

OUTCOME MEASURES

1. **Acoustic properties:** The acoustic properties of the voice were evaluated by voice recording. Before the recordings were taken, the participants were made to do voice warm-up exercises. Voice warm-up exercises were performed with single, double, triple, quadruple, quintet, and sextet consecutive sounds and skips (combinations of 1-3-5th degrees of the exercised tone or 1-3-5-8th degrees etc, for example; do-mi-sol or do-mi-sol-do) with legato and staccato exercises, lip trill exercises. Voice exercises were performed before performance and acoustic analyses. Voice Recording The participants' voices were recorded with a PG57 Shure brand microphone and the Audacity program. During the measurement, the distance between the mouth and the microphone was set as 15 cm and the microphone was placed under the mouth at a 45° angle. The participants were asked to give the /a/ sound in four voices: in the chest register, middle register, head register, and speech tone. Each measurement was repeated three times, and the best measurement they could make was analyzed. The voice types of the participants were determined as follows (Figure 1). The sounds given in the chest, middle, and head registers were voiced with the piano, and the participants were asked to produce a sound with the vowel "a" at the same frequency as the sound they heard from the piano. The sounds given from the piano were determined according to the participants' voice type as follows and are shown in red on the piano touch in Figure 1.

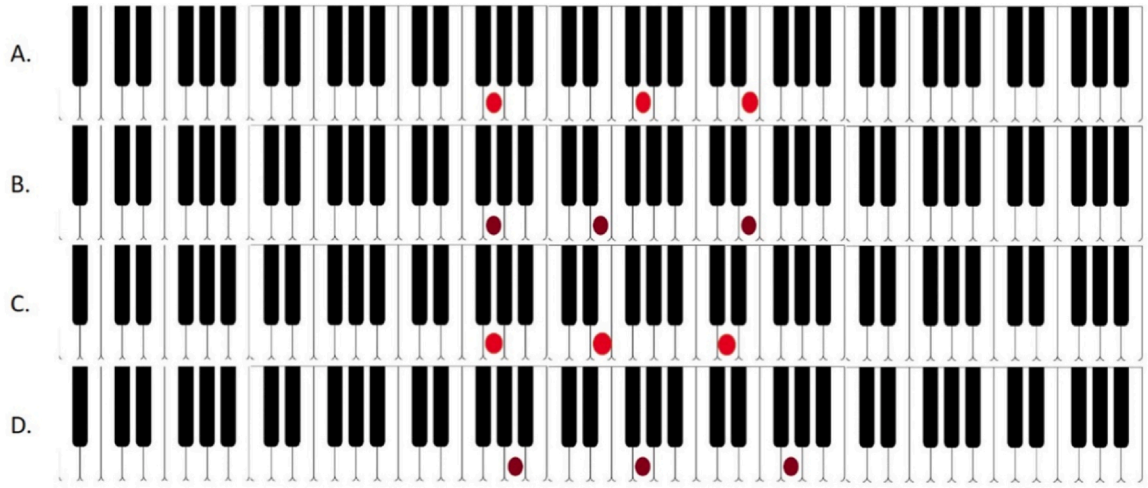

FIGURE 1. **A.** Tenor, **B.** Alto, **C.** Baritone, and **D.** Soprano.

A) Tenor: The left voice in the 3rd octave of the chest register piano, the left voice in the 4th octave of the middle register piano, and the mi voice in the 5th octave of the head register piano.

B) Alto: The left voice in the 3rd octave of the chest register piano, the mi voice in the 4th octave of the middle register piano, and the mi voice in the 5th octave of the head register piano.

C) Baritone: The left voice in the 3rd octave of the chest register piano, the mi voice in the 4th octave of the middle register piano, and the D voice in the 5th octave of the head register piano.

D) Soprano: The a voice in the 3rd octave of the chest register piano, the left voice in the 4th octave of the middle register piano, and the left voice in the 5th octave of the head register piano.

The recordings were made with the supervision of a faculty member who is an expert in the field of music. The obtained voice recordings were analyzed with the Praat program.

2. **Vocal performance:** A video recording was made in the same environment to evaluate vocal performance. Before recording, participants were made to do vocal warm-up exercises. These recordings were made with works appropriate to the participants' own vocal characteristics and levels. The video recordings were evaluated by three faculty members (not from the research team) who are experts in the field of vocal training. In the video, the participant's musicality, technique, correct use of breath, correct use of body, and legato singing characteristics were scored between 0 and 100 points. The average of the vocal performance evaluated by the three experts was taken.
3. **Muscle strength:** Muscle strength was evaluated by timed functional tests. Sorensen, Curl-up, Side Plank (right), Side Plank (left), and Prone Plank tests were used for functional evaluations.
4. **Student opinions:** At the end of the 10th week, individual interviews were conducted with the core stabilization group and student opinions were evaluated. Participants in the experimental group were interviewed individually using open-ended questions as:

- Please evaluate the differences between your performance before doing core stabilization exercises and your performance after the 10-week exercise program?
- What effects of the exercise did you observe on yourself?

Intervention

The abdominal drawing-in maneuver was practiced as a starting exercise for all patients. With this maneuver, the transversus abdominus muscle was taught to contract in isolation. Diaphragmatic breathing was practiced on the participants. The participants were asked to inflate their abdomen while breathing. The effectiveness of the application was determined by the researcher physiotherapist who performed the exercise, checking whether the muscle contracted or not. The exercises were performed in three stages: beginner, intermediate, and advanced. All participants were taught to activate the deep abdominal muscles. When these activation techniques were learned and the transversus abdominis muscle was activated, upper extremity exercises were added. The starting exercises were performed in the supine, crotch position, and crawling position. When the participants could successfully perform the exercises (three sets, 15 repetitions, and 10 seconds of contraction), they gradually moved on to intermediate level exercises. Plank exercises were added at this level and exercises performed on unstable surfaces were included in the program at the advanced level. Visuals of the exercise program are presented in Figure 2. A control group was also used in the study and the control group participants were not included in any exercise program. Only acoustic properties, voice performance, and muscle strength were evaluated in the control group at the beginning and at the end of the 10th week.

Statistical analysis

In our study, statistical analyses were performed to evaluate the effect of the exercise program applied to the experimental and control groups. The Shapiro-Wilk test was used to examine the conformity of the data to normal distribution, and it was determined that the data did not show a normal distribution. Therefore, nonparametric tests were preferred. Wilcoxon Signed Rank Test was used to evaluate the change between the pretest and post test measurements of the experimental and control groups. This test allowed the comparison of the effect of the exercise program within the groups in both groups. Mann-Whitney *U* Test was applied to evaluate the difference between the post test measurements of the experimental and control groups. This test was used to determine whether the exercise program created a significant difference between the groups.

In addition to the quantitative data in the study, qualitative data analysis was also performed to understand the experiences and opinions of the students. In this direction, individual interviews were conducted with the students, and the data obtained from the interviews were evaluated with the descriptive analysis method. Frequency analysis was applied to determine the most frequently used words and phrases in the students' statements. Within the scope of this analysis, the interview records were transcribed, the texts were coded, and the frequency distribution of the most frequently repeated expressions was obtained. The findings were used to interpret the students' general perceptions and experiences of the exercise program by supporting them with quantitative data.

FIGURE 2. Example of exercise levels **A-B-C**: beginner, **D-E-F**: intermediate, and **G-H-I**: advanced.

RESULTS

The demographic characteristics of the participants included in the study are given in Table 1. Accordingly, no significant difference was found between the core stabilization group and the control group in terms of demographic characteristics. The comparison of the acoustic characteristics of the voice, voice performance and muscle strength before and after the core stabilization exercises is given in Table 2. Accordingly, no significant difference was found between the core stabilization and control groups in terms of the acoustic characteristics of the voice, voice performance, and muscle strength before the exercise program was implemented. In the experimental group that applied the core stabilization exercise program, significant improvements were observed in both voice parameters and muscle strength and vocal performance components. According to the voice analysis results, in the core group, mean fundamental frequency (mean pitch) values increased significantly in all vocal registers (chest, head, middle, speaking); significant decreases in jitter and shimmer percentages and significant increases in harmonics-to-noise ratio (HNR) values were detected ($P < 0.05$). In contrast, no significant change occurred in these parameters in the control group ($P > 0.05$). In the comparisons between the groups, statistically significant differences were found in favor of the core group in terms of all voice parameters ($P < 0.05$).

In the evaluations regarding muscle strength, significant increases were observed in the Sorensen test, plank variations (front, right, and left) and curl-up tests in the core

TABLE 1.
Demographic Characteristics

		Core Stabilization Group Mean ± SD	Control Group Mean ± SD	*P*
Gender	female (*n*) %	15 (88.2)	7 (70)	0.059
	male (*n*) %	2 (11.8)	3 (30)	
Age (years)		25.17 ± 7.36	30.40 ± 7.38	0.054
Height (cm)		163.94 ± 7.26	167.40 ± 5.50	0.062
Weight (kg)		60.00 ± 8.75	65.10 ± 12.11	0.227

TABLE 2.
Comparison of Acoustic Properties of Voice, Vocal Performance, and Muscle Strength Before and After Core Stabilization Exercises

	Core Stabilization Group			Control Group			*P* (Between group comparison)	
	Before Mean ± SD	After Mean ± SD	*P* Mean ± SD	Before Mean ± SD	After Mean ± SD	*P* Mean ± SD	Before	After
Chest Register								
Mean pitch (Hz)	173.79 ± 27.2	179.02 ± 26.15	**< 0.05***	174.96 ± 23.19	177.23 ± 26.23	> 0.05	> 0.05	**< 0.05***
Jitter (%)	0.72 ± 0.30	0.44 ± 0.28	**< 0.05***	0.49 ± 0.3	0.55 ± 0.29	> 0.05	> 0.05	**< 0.05***
Shimmer (%)	3.58 ± 0.50	2.40 ± 0.48	**< 0.05***	2.16 ± 0.48	2.86 ± 0.44	> 0.05	> 0.05	**< 0.05***
HNR (dB)	11.55 ± 2.65	18.68 ± 2.60	**< 0.05***	12.84 ± 2.61	13.88 ± 2.66	> 0.05	> 0.05	**< 0.05***
Head Register								
Mean pitch (Hz)	178.66 ± 23.25	185.15 ± 27.05	**< 0.05***	175.55 ± 24.2	171.13 ± 26.15	> 0.05	> 0.05	**< 0.05***
Jitter (%)	0.72 ± 0.30	0.37 ± 0.29	**< 0.05***	0.41 ± 0.3	0.37 ± 0.3	> 0.05	> 0.05	**< 0.05***
Shimmer (%)	3.85 ± 0.49	2.06 ± 0.45	**< 0.005***	2.28 ± 0.46	2.76 ± 0.46	> 0.05	> 0.05	**< 0.005***
HNR (dB)	13.11 ± 2.69	19.45 ± 2.62	**< 0.005***	13.74 ± 2.68	13.7 ± 2.64	> 0.05	> 0.05	**< 0.005***
Middle Register								
Mean pitch (Hz)	176.89 ± 24.22	182.92 ± 28.18	**< 0.05***	175.94 ± 25.24	180.12 ± 27.24	> 0.05	> 0.05	**< 0.05***
Jitter (%)	0.81 ± 0.33	0.16 ± 0.33	**< 0.05***	0.16 ± 0.31	0.29 ± 0.33	> 0.05	> 0.05	**< 0.05***
Shimmer (%)	3.67 ± 0.47	2.73 ± 0.45	**< 0.05***	2.37 ± 0.48	2.17 ± 0.49	> 0.05	> 0.05	**< 0.05***
HNR (dB)	12.23 ± 2.62	19.20 ± 2.61	**< 0.05***	14.06 ± 2.69	13.91 ± 2.63	> 0.05	> 0.05	**< 0.05***
Speaking								
Mean pitch (Hz)	184.59 ± 25.2	190.36 ± 29.12	**< 0.05***	183.87 ± 24.23	186.85 ± 29.10	> 0.05	> 0.05	**< 0.05***
Jitter (%)	0.75 ± 0.31	0.57 ± 0.26	**< 0.05***	0.67 ± 0.26	0.71 ± 0.32	> 0.05	> 0.05	**< 0.05***
Shimmer (%)	3.92 ± 0.46	2.51 ± 0.44	**< 0.05***	2.83 ± 0.47	2.82 ± 0.48	> 0.05	> 0.05	**< 0.05***
HNR (dB)	11.34 ± 2.64	18.12 ± 2.63	**< 0.05***	15.31 ± 2.66	13.27 ± 2.64	> 0.05	> 0.05	**< 0.05***
Muscle Strenght								
Sorensen (Extension)	46.23 ± 24.62	92.17 ± 40.89	**< 0.001***	53.30 ± 32.52	65.70 ± 4905	0.673	0.920	0.083
Prone Plank	20.11 ± 12.07	44.35 ± 13.48	**< 0.001***	22.40 ± 15.41	25.70 ± 17.01	0.053	0.900	**0.007***
Side Plank (right)	12.17 ± 7.09	31.11 ± 9.63	**0.001***	12.80 ± 7.19	17.60 ± 12.96	0.07	0.899	**0.006***
Side Plank (left)	11.12 ± 3.44	30.87 ± 10.73	**< 0.001***	12.80 ± 3.70	16.50 ± 10.15	0.09	0.194	**0.001***
Curl-up (Fleksion)	28.64 ± 16.51	69.58 ± 36.40	**< 0.001***	25.70 ± 7.39	27.70 ± 13.14	0.877	0.960	**0.001***
Performance								
Musicality (%)	58.92 ± 8.47	83.52 ± 9.08	**< 0.001***	55.66 ± 11.17	54.66 ± 12.16	0.279	0.400	**< 0.001***
Technique (%)	60.68 ± 8.10	85.58 ± 8.39	**0.001***	56.00 ± 11.03	58.50 ± 12.17	0.445	0.260	**< 0.001***
Correct use of breath (%)	57.15 ± 8.63	86.95 ± 8.60	**0.002***	55.16 ± 10.34	55.33 ± 11.21	0.414	0.596	**< 0.001***
Correct use of breath (%)	59.60 ± 6.85	85.68 ± 8.10	**0.002***	56.00 ± 10.48	55.00 ± 11.65	0.379	0.289	**< 0.001***
Legato singing (%)	58.92 ± 7.94	85.49 ± 8.39	**0.001***	56.00 ± 7.94	54.50 ± 11.73	0.260	0.414	**< 0.001***
Total Performance (%)	59.07 ± 7.85	85.47 ± 8.29	**0.001***	55.86 ± 10.54	54.96 ± 11.70	0.340	0.375	**< 0.001***

Abbreviations: SD, standard deviation; HNR, mean harmonics-to-noise ratio.

* Results in bold type are statistically significant

TABLE 3.
Student Perspectives

Code	Frequency (*n*)
Better vocal control	33
Breathing properly	26
Singing comfortably	15
The benefits of exercise	6
Increased muscle strength	6

group ($P < 0.001$). In the control group, no significant improvement was recorded in muscle strength measurements. In the comparisons between the groups, significant differences were obtained in favor of the core stabilization group in all tests ($P < 0.05$).

When evaluated in terms of vocal performance, the core group showed significant increases in musicality, technique, correct breathing, legato singing, and total performance scores ($P < 0.001$). In the control group, no statistically significant change was observed in performance parameters. The differences between the groups were found to be significant in favor of the core stabilization group in all performance components ($P < 0.001$). The codes and frequencies according to the descriptive analysis in which the student opinions were taken are given in Table 3.

DISCUSSION

This study investigated the effects of core stabilization exercises on the acoustic properties and performance of the voice in individuals receiving voice training. According to the study results, a statistically significant difference was found in the group that performed regular core stabilization exercises for 10 weeks compared to the control group in terms of both acoustic parameters and voice performance.

During singing, motor control, and muscular endurance levels are the determining factors in terms of muscle-voice coordination. Optimum oxygenation of the whole body depends on the endurance of the respiratory muscles. This endurance is related to increasing lung capacity through appropriate respiratory exercises.[14] At this point, it is important to emphasize that our study focuses on "core stability" rather than "core muscle strength." Core muscle strength refers to the force-producing capacity of the muscles; while core stability requires the body to remain in a controlled balance during movement and especially the coordination of deep muscle groups (transversus abdominis, multifidus, etc). The core muscles form a cylindrical block surrounding the thoracic cavity, pelvic floor, abdominal and lumbar region.[17] The majority of these muscles assist in breathing. The exercises applied in this study primarily targeted deep stabilizer muscles such as the transversus abdominis, multifidus, diaphragm, and pelvic floor. In addition, superficial muscles, such as the obliques and spinal extensors were secondarily activated through plank and unstable floor exercises. Therefore, strengthening the core muscles improves the endurance of the respiratory muscles in singers and increases respiratory capacity. Thus, the singer can develop his artistic skills by using his voice more economically with the activation of the core muscles.[18] Therefore, in this study, considering the literature data mentioned above, core stabilization exercises targeting basic aspects of singing, such as respiratory capacity, vocalization, and artistic skill were tested on individuals receiving voice training. As a result of our study, the acoustic properties of the voice and vocal performance were found to be better in the group performing core stabilization exercises.

Without proper breath control, a singer's tone can become shaky, weak, or breathy, which negatively affects performance. Inconsistent subglottic breath pressure can cause pitch and tone distortion and make it difficult to sustain long musical phrases due to excessive air loss. While the power of the voice is provided by exhaling air from the lungs. Phonation—the vibration of the vocal cords in the larynx—is the basis of the voice. It is important for singers to skillfully use breath control in order to achieve a strong and consistent tone and effectively fulfill the requirements of their art.[19] It can be thought that the core stabilization exercises applied in our study increased the core muscle strength in the abdominal region and therefore improved respiratory control through the diaphragm.

Improving the flexibility and coordination of core and respiratory musculature significantly influences the function of the vocal folds, enabling singers to achieve more precise pitch modulation, particularly in higher registers. Existing literature suggests that singers can exert greater control over their vocal folds, resulting in enhanced pitch stability at elevated frequencies.[20] This minimization of extraneous sound variations contributes to increased stability in jitter, shimmer, and harmonic balance, ultimately enhancing vocal esthetics and achieving a more polished and consistent singing performance. Similarly, findings from our study indicate that mean pitch values are higher in the intervention group compared to the control group across all register points. As a result of a study measuring abdominal muscle thickness during phonation in 25 healthy singers. It was reported that peri-abdominal muscles play an important role in supporting performance or professional voice control in healthy singers.[21] In our study, the core group muscles, including the peri-abdominal muscles, were trained and as a result, a significant difference was observed in favor of the experimental group in all acoustic properties of the voice and vocal performance parameters compared to the control group. Based on these results, it can be said that not only peri-abdominal muscles but also other core muscles are effective in the process.

Working only one muscle group in music education can lead to muscle imbalances, and in some cases, it has been shown to increase the risk of injury.[22] There is some debate about abdominal and shoulder exercises for singers. Some

literature argues that doing sit-ups and abdominal muscle exercises will cause tension in the rectus abdominis muscle, neck tension, spinal injuries/hyperflexion, and limitation of respiratory function while singing due to the inability to fully release the abdominal muscles during inhalation. Instead, sit-ups or abdominal muscle exercises should be done together with spinal extension exercises such as arm leg extensions in crawling. It is also important to consider isometric exercises such as front/side planks. Front/side planks can be useful in increasing the strength and stability of the abdominal muscles.[23] In our study, the exercises were performed under supervision to prevent possible injury or incorrect application risks.

In a study conducted on patients with central nervous system disorders, it was reported that strengthening the abdominal muscles may have positive results on vocalization.[24] In a study investigating the effects of musculoskeletal exercises and muscle stretching on the duration of vocalization time. Participants were asked for their personal opinions after 8 weeks of exercise and most of them said that the body looked more balanced and that breathing had a positive effect on good vocalization.[25] In this study, the participants' opinions were also taken at the end of the process, and they stated that they had better voice control, correct breathing, comfortable singing, and increased muscle strength.

In addition, the Alexander technique (AT) has been described in the literature. The AT is a psychophysical reeducation method that helps individuals identify and change negative movement habits by increasing their kinesthetic awareness. This approach supports the person in releasing unnecessary tension in the muscles and achieving better coordination in body use. Thus, the person's movement and behavior in various activities becomes more efficient. This improved use can facilitate more comfortable movement and breathing, especially in areas related to performance, such as sound production and technical skills in musicians. This technique was shaped by Alexander's observation that vocal strains that occur during poetry reading were associated with head-neck posture disorder. Thereupon, he developed the principles of "inhibition" and "direction," which aim to replace habitual and automatic reactions with conscious and controlled movements. These principles aim to restore the dynamic and balanced relationship between the head, neck, and spine and form the basis of the method. In the literature, the relationship between body awareness, vocal performance, and posture has been known for many years within the scope of A.[26] It is also reported in the literature, that the core muscles must be strong for correct posture.[27,28] In our study, as a result of the core muscle strengthening exercise applied, vocal performance in individuals increased. This situation is consistent with the AT hypothesis that core stabilization ensures correct posture formation and thus increases body awareness and self-confidence.

STUDY LIMITATIONS

This study has some limitations. First, the sample size is limited, and the generalizability of the findings may be limited. Second, EMG or imaging methods were not used to confirm the activation of the targeted muscles during exercise. In these respects, more comprehensive and long-term studies are recommended.

CLINICAL IMPLICATIONS

The findings of this study suggest that core stabilization exercises can improve voice production quality and performance by increasing respiratory support in vocal artists. Integrating such exercises into conservatory education programs or voice therapy processes may provide benefits in terms of both performance and vocal health.

According to the results of this study, although strengthening the core muscles improves acoustic performance. There are many factors that affect acoustic performance, such as gender,[29] mood, blood pressure, ambient temperature, vital capacity, and hormonal status.[30] In order to have more definitive judgments on this issue, it is necessary to standardize most of the factors affecting the voice. As a result, it has been observed that core stabilization exercises play an important role in improving vocal performance. Therefore, it can be recommended that exercise programs for singers include core muscle strengthening training and breathing exercises.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Ceylan İ, Doğanyiğit S, Özüdoğru A. Immediate effects of cervical mobilization on acoustic properties and performance invoice training students. *Int J Tradit Complement Med Res.* 2025;4:145–152.
2. Nusseck M, Immerz A, Spahn C, Echternach M, Richter B. Long-term effects of a voice training program for teachers on vocal and mental health. *J Voice.* 2021;35:438–446.
3. Karagiannakis DN, Mandalidis DG. Acute effects of voluntary breathing patterns on postural control during walking. *Human Mov Sci.* 2025;99:103326.
4. Saxon KG. Care of the professional voice: vocal exercise physiology: same principles, new training paradigms. *J Sing Off J National Assoc Teach Sing.* 2009;66:51–57.
5. Willardson JM. *Developing the Core*. Champaign, IL: Human Kinetics; 2024.
6. Hou Z, Zhang T, Zou Y, et al. Classic vocal performance training through C-VaC method: study of core muscle stability warm-up techniques via computer-aided analysis. *J Voice.* 2024. https://doi.org/10.1016/j.jvoice.2024.10.014. Article in press.
7. Finta R, Boda K, Nagy E, Bender T. Does inspiration efficiency influence the stability limits of the trunk in patients with chronic low back pain? *J Rehabil Med.* 2020;52:jrm00038.
8. Finta R, Nagy E, Bender T. The effect of diaphragm training on lumbar stabilizer muscles: a new concept for improving segmental stability in the case of low back pain. *J Pain Res.* 2018;11:3031–3045.

9. Hodges PW, Sapsford R, Pengel LH. Postural and respiratory functions of the pelvic floor muscles. *Neurourol Urodyn.* 2007;26:362–371.
10. O'Sullivan PB, Grahamslaw KM, Kendell M, Lapenskie SC, Möller NE, Richards KV. The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. *Spine.* 2002;27:1238–1244.
11. Saunders SW, Rath D, Hodges PW. Postural and respiratory activation of the trunk muscles changes with mode and speed of locomotion. *Gait Posture.* 2004;20:280–290.
12. Thorpe CW, Cala SJ, Chapman J, Davis PJ. Patterns of breath support in projection of the singing voice. *J Voice.* 2001;15:86–104.
13. Urquhart DM, Hodges PW, Story IH. Postural activity of the abdominal muscles varies between regions of these muscles and between body positions. *Gait Posture.* 2005;22:295–301.
14. Kang J, Scholp A, Jiang JJ. A review of the physiological effects and mechanisms of singing. *J Voice.* 2018;32:390–395.
15. Hlaing SS, Puntumetakul R, Khine EE, Boucaut R. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial. *BMC Musculoskelet Disord.* 2021;22:1–13.
16. Kuzu Ş, Özüdoğru A, Tuncay F. Effects of external and internal focus of attention exercises in chronic low back pain: a randomized controlled trial. *Pain Manag Nurs.* 2025. https://doi.org/10.1016/j.pmn.2025.02.011. Article in press.
17. Yumuşak Ş, Büyükturan B, Karartı C, Büyükturan Ö. Genç bireylerde kor kasları kuvvetinin ve enduransının fonksiyonel parametrelerle ilişkisinin İncelenmesi. *Hacettepe Univ Fac Health Sci J.* 2020;7:296–309.
18. Tyshchenko V, Bosenko A, Kozak Y, Denysovets A, Atamanyuk S, Veritov O. Enhancing respiratory function through Yoga and Pilates in women aged 45-50. *Pedag Phys Cult Sports.* 2024;28:440–446.
19. Yilmaz C, Bostanci Ö, Eken Ö, Alkahtani R, Aldhahi MI. Maximizing phonation: impact of inspiratory muscle strengthening on vocal durations and pitch range. *BMC Pulm Med.* 2025;25:15.
20. Titze IR, Martin DW. Principles of voice production. *J Acoust Soc Am.* 1998;104:1148.
21. Macdonald I, Rubin JS, Blake E, Hirani S, Epstein R. An investigation of abdominal muscle recruitment for sustained phonation in 25 healthy singers. *J Voice.* 2012;26:815.e9–815.e16.
22. Anıl Özüdoğru İ. Rehabilitation results of mobilization with movement technique in a pianist with painful thumb: case report. *Lokman Hekim Health Sci.* 2021;2:62–65.
23. Ellenbecker TS, Pluim B, Vivier S, Sniteman C. Common injuries in tennis players: exercises to address muscular imbalances and reduce injury risk. *Strength Cond J.* 2009;31:50–58.
24. Reyes A, Castillo A, Castillo J, Cornejo I, Cruickshank T. The effects of respiratory muscle training on phonatory measures in individuals with Parkinson's disease. *J Voice.* 2020;34:894–902.
25. Lee M, Lee J, Kwon MG. The effects of Musculoskeletal training and stretching on the duration of vocalization time. *Ann Appl Sport Sci.* 2023;11:1–4.
26. Woodman J, Moore N. Evidence for the effectiveness of Alexander Technique lessons in medical and health-related conditions: a systematic review. *Int J Clin Pract.* 2012;66:98–112.
27. Kavcic N, Grenier S, McGill SM. Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine.* 2004;29:2319–2329.
28. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. *Sports Med.* 2006;36:189–198.
29. Gurel S. Comparison of piano practicing habits and attitude levels of vocal students. *Int Online J Educ Sci.* 2022;14:359–373.
30. Banks RE, Cantor-Cutiva LC, Hunter E. Factors influencing teachers' experience of vocal fatigue and classroom voice amplification. *J Voice.* 2022;39:113–122.