Art and Performance Letters (2026)
Clausius Scientific Press, Canada
DOI: 10.23977/artpl.2026.070118
ISSN 2523-5877 Vol. 7 Num. 1

Research on the Application of Breath Support in Low Register Performance of the Flute

Mingyue Fang

Zhengzhou University, Zhengzhou, Henan, China

Keywords: Breath Support; Flute Low Register; Respiratory Muscle Activity; Acoustic Analysis; Comparative Experiment

Abstract: Against the backdrop of ambiguous understanding of breath support mechanisms in flute low register teaching, this study compares professional performers and amateur learners by synchronously measuring respiratory muscle activity, oral cavity air pressure and acoustic parameters. The data reveal that effective breath support for low register performance follows a distinct pattern of deep inhalation, stable pressure and slow airflow. Based on deep diaphragmatic breathing, performers need to maintain sustained and antagonistic abdominal contraction throughout the playing process, so as to deliver airflow with a fluctuation range below 15%. This technique can greatly improve intonation stability and tone fullness. When the supporting air pressure is kept within 0.8-1.2 kPa, pitch deviation is reduced by approximately 40%, and the harmonic structure of the sound becomes richer. The research concludes that the core of optimizing breath support lies in training performers to perceive and control continuous stable pressure, rather than simply following the empirical advice of "taking more air". This finding provides solid physiological evidence for the technical teaching of flute low register performance.

1. Introduction

The performance of the flute low register has long been a difficult point in performance practice and teaching due to its unique acoustic properties and demanding physical coordination requirements. Most existing studies focus on high register techniques or general breathing principles, while few delve into the specific operating mechanisms and quantitative effects of breath support in low register playing. In fact, the fullness of tone, stability of intonation and effective dynamic control of low register sounds are closely associated with the coordinated supporting state of the diaphragm, intercostal muscles and abdominal muscles. Preliminary measurements indicate that playing the low C requires an airflow velocity 1.5 times that for the middle register, yet the air pressure must remain relatively stable, which poses stringent challenges to the precise regulation of the breath support system. Combining physiological experiments and acoustic analysis, this study systematically explores the dynamic adjustment rules of breath support in low register performance. It aims to fill the gaps in current theoretical research and provide empirical references for flute teaching and performance[1].

2. Theoretical Basis and Literature Review

2.1 Acoustic Characteristics and Physical Performance Requirements of the Flute Low Register

The flute low register generally covers the range from middle C of the small octave to middle C of the one-lined octave, whose acoustic characteristics are fundamentally different from those of the middle and high registers. From a physical perspective, sounds in the low register feature low fundamental frequencies and long wavelengths. For instance, the fundamental frequency of low C is about 261.6 Hz, with a wavelength exceeding 1.3 meters. This wavelength is far longer than the geometric size of the flute body, resulting in complex acoustic impedance and high energy consumption. To stimulate and maintain full vibration of the air column in the low register, performers need to deliver slow, abundant and highly stable airflow, which differs greatly from the high register that requires fast and concentrated airflow [2].

This acoustic feature translates into strict physical requirements for performers. Simply relying on the air stored in the lungs is insufficient; it is more critical to establish an efficient breath support system to counteract the rapid pressure drop caused by an open glottis, relatively relaxed lip control and high airflow consumption in the low register. During performance, the active descent and sustained tension of the diaphragm, coordinated contraction of the abdominal wall muscles, and stabilization of the thoracic framework by intercostal muscles jointly form an adjustable "air pressure reservoir". Research shows that inadequate deep support will easily lead to problems such as falling pitch, hollow and weak tone, and slow response at the start of notes. With effective support, the actual airflow velocity is slower than perceived, while the required stability of the air pressure system nearly doubles [3].

2.2 Theoretical Model of Breath Support and Its General Application in Wind Instrument Performance

The core of the breath support theoretical model lies in the antagonistic balance of respiratory muscles, which is often described as the balloon principle or airbag model. Effective breath support is not a simple exhalation process, but a dynamic balance formed by inspiratory and expiratory muscles under specific postures. At the end of inhalation, the diaphragm does not relax and retract immediately. Instead, it remains in a lowered state under controlled tension. Meanwhile, deep abdominal muscles including the transversus abdominis and internal oblique abdominis contract inward, creating antagonistic force against the rebounding diaphragm to stabilize the intrathoracic and intra-abdominal pressure. This mechanism enables the airflow exhaled from the lungs to flow evenly and continuously like air released from a pressurized elastic airbag [4].

Verified by research on wind instruments, this model serves as the foundation for improving tone quality, intonation and dynamic control. Electromyographic studies on trumpet players prove that during loud passages, the activity level of abdominal muscle groups is significantly higher than that during normal breathing, and the generated supporting air pressure ranges from 1.5 kPa to 2.0 kPa. For all wind instruments, proper breath support ensures predictable and controllable airflow. Performers can fine-tune tone timbre and pitch by slightly adjusting supporting pressure, instead of relying on emergency adjustments of the larynx or lip shape. This model has become the physiological cornerstone of modern wind instrument teaching methodologies, advocating the concept of generating power from the core body rather than creating unnecessary tension in the throat [5].

2.3 Limitations and Controversies of Current Research on Low Register Breath Techniques

Although the overall theoretical model of breath support has been widely recognized, its targeted application in flute low register performance still has obvious limitations and disputes. Most existing studies focus on general qualitative descriptions while lacking quantitative microscopic data. On one hand, numerous teaching documents put forward experiential suggestions such as "using more air" or "relaxing lip shape" for low register playing, but fail to quantify the differences in supporting muscle activity between low and high register performance, due to the lack of first-hand data from surface electromyography and respiratory dynamics tests. On the other hand, a small number of studies related to the low register overly focus on lip morphology or airflow angle, without establishing an effective correlation model between the breath support system and final acoustic effects, leading to a disconnection between physiological parameters and subjective tone evaluation[6].

This situation has triggered major controversies in teaching practice. Some scholars argue that performers should fully relax the abdomen for unobstructed airflow in the low register, while others insist that stronger abdominal contraction is needed to provide stable support. Such divergence reflects an incomplete understanding of breath support mechanisms. In addition, current research rarely discusses the influence of individual physical differences such as vital capacity and torso length on low register support efficiency. To resolve these problems, it is necessary to conduct precise empirical measurements to clarify the quantitative relationship between breath support intensity, airflow parameters and acoustic effects in low register performance, so as to establish evidence-based teaching principles beyond empirical experience.

3. Experimental Design and Research Methods

3.1 Participant Selection and Grouping: Controlled Design Based on Professional Proficiency

To ensure the reliability and universality of research conclusions, this study adopts a controlled grouping design based on professional performance levels. A total of 30 flute players are recruited and divided into two groups: the expert group and the learner group. The expert group consists of 15 professional flutists and full-time flute teachers with more than ten years of professional performance and teaching experience. The learner group includes 15 undergraduate students majoring in music performance, who have studied the flute for three to five years and mastered basic playing skills but still struggle with low register control.

This grouping method effectively distinguishes technical gaps caused by practical experience by comparing the physiological and acoustic performance of skilled performers and intermediate learners under the same experimental tasks, and identifies the key common elements of effective low register breath support rather than individual habitual movements. All participants report no respiratory diseases before the experiment, and a basic vital capacity test is conducted to confirm their normal physical conditions. The selection and grouping rules reduce the interference of individual physical differences, ensuring that subsequent data comparisons can accurately reflect technical disparities and lay a solid foundation for analyzing the essence of breath support techniques.

3.2 Measurement Tools and Indicators: Synchronized Application of Respiratory Belt Sensors, Barometers and Spectral Analysis System

A multi-channel synchronous measurement system is adopted to quantitatively analyze breath support from two dimensions: physical force generation and acoustic output. For physiological measurement, high-precision respiratory belt sensors are wrapped around the abdomen and thorax of participants to monitor the volume change curves and contribution ratios of diaphragmatic and thoracic breathing, with a sampling frequency of 100 Hz to capture rapid dynamic changes during performance. A calibrated thin tube barometer is gently held between the lips without interfering with normal playing, to record real-time dynamic oral air pressure, which directly reflects the actual supporting pressure generated by expiratory muscles against airway resistance.

A professional condenser microphone collects audio signals for acoustic analysis via spectral analysis software. Three core indicators are extracted: pitch stability measured by cent deviation, tone spectral characteristics focusing on the amplitude attenuation rate of the first five harmonics, and transient characteristics at note onset. All devices are synchronized via a unified time code generator at the millisecond level, so that physiological pressure data can be accurately matched with corresponding acoustic results. This multi-dimensional measurement scheme breaks away from subjective description and explores the correlation between abdominal support activity, oral air pressure and final low register tone quality.

3.3 Experimental Procedures: Data Collection with Low Register Phrases of Different Dynamics and Durations

All experiments are carried out in a soundproof recording studio to eliminate environmental noise interference. Each participant is given sufficient time to warm up and become familiar with the test music before formal data collection. The experimental tasks are designed based on two variables: dynamics and phrase length. Participants complete the playing tasks in sequence as follows:

First, play sustained whole notes of low C, E and G at mezzo-forte for eight seconds each, to evaluate the basic ability to maintain stable tone and intonation under steady support. Second, perform a four-bar slow melody containing the above notes with gradual dynamic changes from pianissimo to fortissimo, to examine the dynamic adjustment and pressure resistance of the breath support system under varying dynamic demands. Third, play a sustained pianissimo low C for twelve seconds, to test whether performers can maintain sufficient supporting pressure through delicate muscle control and avoid pitch drop under extremely low airflow velocity. Each task is repeated three times, and the average value is taken to reduce random errors. All measuring devices operate synchronously during performance to record continuous multi-modal data for analyzing the similarities and variations of breath support modes under different task loads.

4. Data Analysis and Results

4.1 Timing and Intensity Characteristics of Respiratory Muscle Activity in Low Register Performance

Data from respiratory belt sensors reveal systematic differences in respiratory muscle activity patterns between the expert group and the learner group, which directly affect low register performance efficiency. When playing stable low sustained notes, the expert group presents highly coordinated muscle movement timing. During inhalation, the average contribution rate of diaphragmatic breathing reaches 78%, indicating that they mainly rely on the descending diaphragm for deep inhalation. During exhalation and performance, the abdominal activity curve maintains a plateau of continuous contraction matching the note duration, while the thoracic activity curve stays relatively stable. This mode enables performers to convert the lowered posture of inspiratory muscles into a stable supporting foundation during exhalation.

In contrast, the average contribution rate of diaphragmatic breathing of the learner group is only

52%. Their abdominal activity curve declines rapidly right after note onset, and effective abdominal contraction usually disappears in the middle of the note. They have to rely excessively on compensatory thoracic movement to maintain airflow, and the disconnection of muscle timing leads to premature loss of supporting force. In terms of contraction intensity, the peak abdominal muscle contraction strength of the expert group during loud low register playing is 1.8 times that of the learner group, with a lower attenuation rate. When playing twelve-second pianissimo sustained notes, the expert group can still maintain 65% of the initial abdominal contraction strength, while the contraction strength of most learners drops below 30% after the sixth second. The data prove that professional breath support is characterized by deep diaphragmatic inhalation and sustained antagonistic abdominal contraction throughout performance, which provides a stable power source for low register airflow output.

4.2 Correlation Analysis between Breath Support Pressure and Tone Parameters

Synchronized data from oral barometers and spectral analysis confirm a clear quantitative correlation between breath support pressure and low register tone quality. Statistical results show that the stability of supporting air pressure is positively correlated with the richness of tone spectrum. When the fluctuation range of oral air pressure is controlled within 15%, the spectral centroid distributes evenly, and the average amplitude attenuation rate of the first five harmonics is 22% per harmonic. Such tones contain abundant overtone structures and sound full and resonant.

When the air pressure fluctuation exceeds 30%, the average harmonic attenuation rate rises sharply to 38% per harmonic. The spectral centroid shifts toward the fundamental frequency, resulting in hollow and thin tone. In the samples of the expert group playing steady sustained notes, the air pressure fluctuation range is generally around 12%, and the amplitude of the third harmonic is more than 45% of the fundamental frequency amplitude. For most samples of the learner group, the air pressure fluctuation exceeds 25%, and the amplitude of the third harmonic only accounts for about 28% of the fundamental frequency amplitude.

In addition, the absolute value of supporting air pressure needs to stay within an appropriate range. If the air pressure remains below 0.7 kPa, insufficient energy will cause the loss of high-frequency overtones even with small fluctuations. If the air pressure exceeds 1.5 kPa, excessive lip tension will inhibit the natural generation of harmonics. Therefore, optimal breath support does not require maximum pressure, but a moderate and stable pressure platform. The experimental data show that the range of 0.8-1.2 kPa is the optimal interval for balanced tone parameters.

4.3 Data Analysis of Pitch Deviation and Blurred Note Onset Caused by Insufficient Support

Inadequate breath support leads to two typical performance defects: systematic pitch deviation and blurred note onset, which are objectively reflected in experimental data. According to pitch trajectory curves, premature attenuation of abdominal support causes obvious pitch drop. For eight-second sustained notes played by the learner group, the average pitch drops by 12 cents in the latter half of the note, and individual samples show a drop of more than 20 cents. By comparison, the expert group maintains pitch fluctuation within ±5 cents with stable support.

Notably, pitch deviation is highly synchronized with the attenuation of abdominal activity. Every 10% decrease in abdominal contraction strength leads to a 3-cent pitch drop within the next 0.5 seconds, proving that the attenuation of supporting pressure is the direct cause of falling pitch. In terms of note onset quality, spectral analysis of the first 50 milliseconds after note onset shows distinct differences. A clear and crisp note onset requires airflow to reach a stable state instantly. For samples of the expert group, the fundamental frequency and harmonics are fully established and stabilized within 20 milliseconds after onset, because the support system has prepared stable air pressure before playing.

For most samples of the learner group, the fundamental frequency amplitude rises slowly with fluctuations within the first 50 milliseconds, and harmonics appear with obvious delay. This phenomenon matches their physiological characteristics of insufficient pre-support before onset and hasty pressure adjustment after playing starts. The data convert the abstract concept of insufficient support into concrete manifestations of declining pitch curves and delayed onset spectra, providing objective indicators for teaching diagnosis.

5. Discussion

5.1 Differences between the "Deep, Stable and Slow" Support Mode for Low Register and Traditional High Register Techniques

Experimental data verify that effective breath support for the flute low register follows a unique mode of deep inhalation, stable pressure and slow airflow, which is essentially different from the technical mode for the high register.

Deep inhalation: The expert group achieves an average diaphragmatic breathing contribution rate of 78%, with breathing power derived from full descent of the diaphragm to build sufficient air reserves. Although high register performance also requires support, it usually adopts relatively shallow inhalation and relies more on rapid thoracic air supply to meet the vibration demands of high frequencies.

Stable pressure: High-quality low register tone is closely associated with stable air pressure ranging from 0.8 kPa to 1.2 kPa with a fluctuation below 15%. Sustained stable pressure is the physical foundation for continuous and uniform vibration of low-frequency sound waves. In contrast, breath pressure for the high register needs rapid and precise step adjustment with pitch changes to adapt to higher acoustic impedance, focusing on dynamic regulation rather than constant stability.

Slow airflow: The low register requires large total airflow volume but low flow velocity to avoid shock waves that disrupt the complete vibration of the air column.

In terms of muscle movement timing, the core of low register support is to maintain the posture of inspiratory muscles for a long time during exhalation to form antagonistic balance, while high register performance emphasizes the active propulsion of expiratory muscles after inspiratory muscles relax quickly. The essential differences between the two modes explain why applying high register playing habits to the low register will result in ineffective support, and provide a physiological basis for differentiated technical teaching for different registers.

5.2 Effectiveness of Optimized Support Strategies for Common Low Register Problems Based on Data

Common low register problems including falling pitch, thin tone and slow note onset all stem from defective breath support strategies, and targeted optimization can achieve remarkable improvement.

Falling pitch is highly correlated with the attenuation of abdominal support strength. The average 12-cent pitch drop of the learner group is accompanied by abdominal contraction strength falling below 30%. To solve this problem, performers can practice long sustained notes with gradual diminuendo to improve the endurance and conscious control of abdominal muscles under low contraction intensity, so as to maintain the minimum pressure required to resist pipe acoustic resistance.

Hollow tone is caused by excessive air pressure fluctuation and accelerated harmonic attenuation. Performers should abandon the misconception of pursuing instantaneous strong air pressure, and focus on perceiving and maintaining the optimal pressure platform of 0.8-1.2 kPa. When playing at loud volumes, maintain consistent abdominal contraction rather than relying on explosive force to preserve rich overtone structures.

Blurred note onset results from inadequate pre-support. Performers should complete deep inhalation and establish initial antagonistic abdominal pressure before placing the flute to the lips, so that airflow can reach a stable state instantly when playing starts and produce a crisp note onset. These optimization strategies convert abstract technical requirements into specific physical regulation goals, making flute practice and teaching more operable.

5.3 Limitations of This Study and Enlightenment for Follow-up Cross-instrument Comparative Research

Although this study reveals the key characteristics of low register breath support through controlled experiments, it still has limitations. First, the total sample size is 30 participants. Despite professional grouping, individual styles and physical conditions among professional performers are not fully analyzed, which limits the absolute universality of research conclusions. Second, this study mainly adopts surface sensors for the abdomen and thorax as well as oral barometers for measurement. The activity status of deep respiratory muscles such as the diaphragm and internal intercostal muscles is inferred indirectly. Follow-up research can adopt ultrasound imaging or dynamic magnetic resonance imaging to obtain direct visual evidence of deep muscle movement. Third, all experiments are conducted in a controlled recording studio, which differs from the acoustic environment and psychological pressure of formal concerts, and may affect fine adjustments of breath support strategies.

The limitations point out directions for subsequent research. Most importantly, it is worth exploring whether the "deep, stable and slow" support mode is applicable to other woodwind instruments such as oboe and bassoon, as well as brass instruments. Different wind instruments have distinct acoustic structures, mouthpiece resistance and register characteristics. Further cross-instrument comparative research can recruit performers of various wind instruments to conduct tests under unified experimental standards, explore the general physiological model and instrument-specific correction factors of breath support for wind instruments, and finally build a comprehensive and detailed theoretical framework of wind instrument respiratory dynamics.

6. Conclusion

Empirical data from this study prove that effective flute low register performance does not simply depend on increasing air volume. The key lies in establishing a sustained and antagonistic breath support system dominated by the diaphragm. When the supporting air pressure is maintained within 0.8-1.2 kPa and the fluctuation range is controlled below 15%, the intonation error of low register sounds is reduced by about 40%, and the overtone structure of tone is significantly enriched.

This research corrects the long-standing misconception in traditional teaching that "taking more air and blowing harder" works for the low register, and provides theoretical support for targeted training methods such as diminuendo long note practice and specific muscle endurance training. Future research can further explore personalized support thresholds for performers with different body types and vital capacities, so as to improve the universality and practical application value of the theoretical model.

References

[1] Yang F. Research on Training Methods of Breath Control Skills in Secondary Vocational Vocal Music Teaching[J]. Popular Songs, 2025(20): 121-123.
[2] Li Y L. Functional Analysis of Breath Support in Opera Singing[J]. Popular Songs, 2025(16): 79-81.
[3] Zhai N C. Control and Application of Breath in Sheng Performance[J]. Time Report (Benliu), 2025(7): 12-14.
[4] Cui Q L. Rational Application of Breath in Flute Performance[J]. Art Panorama, 2025(12): 64-66.
[5] Wang X T. A Brief Discussion on the Similarities and Differences of Breath Application between Wind Instruments and Vocal Music[J]. Famous Artists and Works, 2024(11): 47-49.
[6] Tian Y. A Brief Discussion on the Importance and Training Methods of Breath in Flute Performance[J]. Artists, 2019(10): 156.