e-ISSN: 2987-131X

Sriwijaya Journal of Otorhinolaryngology (SJORL)

Journal website: https://phlox.or.id/index.php/sjorl

Evaluating Voice Quality and Pharyngeal Function in Professional Singers: A Cross-Sectional Study in Indonesia

Indri Yani Septiana[1], Nur Diana[2], Eva Naritawati[3*], Maximillian Wilson[4], Made Swastika[5]

[1]Department of Anatomy, CMHC Research Center, Palembang, Indonesia

[2]Department of Physiology, CMHC Research Center, Palembang, Indonesia

[3]Department of Radiology, Phlox Institute, Palembang, Indonesia

[4]Department of Radiology, Mananjary State Hospital, Mananjary, Madagascar

[5]Department of Otorhinolaringology, Phlox Institute, Palembang, Indonesia

ARTICLE INFO

Keywords:
Acoustic analysis
GRBAS
Pharyngeal function
Singers
Voice quality

***Corresponding author:**
Eva Naritawati

E-mail address:
eva.naritawati@phlox.or.id

All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.59345/sjorl.v1i2.93

A B S T R A C T

Introduction: Professional singers heavily rely on their vocal capabilities, necessitating a thorough understanding of the interplay between voice quality and pharyngeal function to maintain vocal health and prevent disorders. This study aimed to evaluate these aspects in professional singers in Indonesia. **Methods:** This cross-sectional study involved 30 professional singers (15 males, 15 females) aged 20-40 years from Jakarta, Indonesia. Voice quality was assessed using the GRBAS scale (Grade, Roughness, Breathiness, Asthenia, Strain) and acoustic analysis (fundamental frequency, jitter, shimmer, harmonics-to-noise ratio). Pharyngeal function was evaluated via videofluoroscopy, measuring pharyngeal constriction ratio (PCR) during swallowing and vowel phonation. **Results:** Most singers exhibited normal voice quality per the GRBAS scale. Acoustic analysis revealed significantly higher fundamental frequency in females ($p<0.05$). Jitter, shimmer, and harmonics-to-noise ratio were within the normal range for both genders. PCR values were significantly higher during vowel phonation than swallowing in both genders ($p<0.05$), indicating increased pharyngeal constriction during singing. **Conclusion:** Professional singers in this study demonstrated good voice quality and adapted pharyngeal function to meet singing demands. Higher PCR during phonation suggests specific pharyngeal muscle activation patterns for vocal production. Further research is needed to explore the long-term effects of singing on pharyngeal function and identify potential risk factors for voice disorders in Indonesian singers.

1. Introduction

The human voice, an intricate and versatile instrument, serves as a cornerstone of human communication, artistic expression, and emotional conveyance. It arises from a complex interplay of physiological processes involving the respiratory, phonatory, and resonatory systems, each contributing to the unique acoustic characteristics that define an individual's voice. For professional singers, the voice transcends its communicative role, becoming a finely-tuned instrument demanding exceptional control, extensive range, and unwavering quality to meet the rigorous demands of their craft. Professional singers, unlike casual voice users, routinely push their vocal capabilities to the limits, navigating demanding performance schedules, diverse musical genres, and intricate vocal techniques. They require exceptional vocal stamina, agility, and precision to execute

intricate melodies, sustain prolonged notes, and project their voices effectively across varying performance spaces. This sustained vocal exertion necessitates a profound understanding of the physiological mechanisms underlying voice production and a keen awareness of factors that contribute to vocal health and the prevention of voice disorders. Voice disorders, characterized by alterations in voice quality, pitch, loudness, or vocal endurance, pose a significant threat to a singer's career and overall well-being. These disorders can manifest as hoarseness, breathiness, vocal fatigue, loss of vocal range, or even complete voice loss, severely impacting a singer's ability to perform and maintain their livelihood. Understanding the etiology, risk factors, and preventative measures associated with voice disorders is crucial for singers, vocal coaches, and healthcare professionals involved in the care of the professional voice.[1-3]

The pharynx, a musculomembranous tube extending from the base of the skull to the esophagus, plays a multifaceted role in both voice production and swallowing. During phonation, the pharynx acts as a dynamic resonating chamber, shaping and amplifying the sound produced by the vocal folds. Its intricate architecture, comprising the superior, middle, and inferior constrictor muscles, along with the palatopharyngeus and stylopharyngeus muscles, allows for precise adjustments in its shape and size, influencing the resonance characteristics of the vocal tract and contributing to the unique vocal qualities of individual singers. The pharyngeal muscles, through their coordinated contractions and relaxations, modulate the cross-sectional area of the pharynx, altering its acoustic properties and influencing vocal timbre, projection, and resonance. The superior constrictor muscle, originating from the pterygoid hamulus and pterygomandibular raphe, contributes to velopharyngeal closure, preventing nasal air escape during phonation and influencing the production of nasal consonants. The middle constrictor muscle, arising from the hyoid bone and stylohyoid ligament, narrows the oropharynx and contributes to the shaping of vowel sounds. The inferior constrictor muscle, originating from the thyroid and cricoid cartilages, plays a crucial role in pharyngeal constriction during swallowing and may also contribute to the production of low-pitched sounds. The coordinated action of these pharyngeal muscles, along with the palatopharyngeus and stylopharyngeus muscles, allows singers to fine-tune their vocal resonance, achieving desired vocal qualities and navigating the dynamic demands of their musical repertoire. However, excessive or improper use of these muscles can lead to muscle tension, fatigue, and potentially contribute to the development of voice disorders.[4-6]

Previous research has underscored the importance of pharyngeal function in voice production, particularly in singers. Studies employing various imaging techniques, such as videofluoroscopy, magnetic resonance imaging (MRI), and nasopharyngoscopy, have revealed distinct patterns of pharyngeal muscle activation in singers compared to non-singers. These adaptations, often acquired through years of vocal training and practice, enable singers to achieve greater control over vocal resonance, projection, and timbre, allowing them to meet the specific demands of their singing style and repertoire. Studies have shown that singers exhibit increased pharyngeal constriction during singing, particularly during high-pitched notes and sustained phonation. This constriction, achieved through the coordinated action of the pharyngeal constrictor muscles, effectively narrows the pharyngeal cavity, altering its resonance characteristics and influencing the perceived quality of the voice. Furthermore, singers demonstrate greater variability in pharyngeal shape and size compared to non-singers, reflecting their ability to dynamically adjust their vocal tract to produce a wide range of vocal sounds and effects. Despite the growing body of research on voice quality and pharyngeal function in singers, limited attention has been devoted to Indonesian singers. Indonesia, a vast archipelago nation with a rich and diverse cultural heritage, boasts a multitude of traditional and contemporary singing styles, each with its unique vocal characteristics and performance practices. Understanding the vocal demands and pharyngeal adaptations associated with these diverse singing

styles can provide valuable insights into the interplay between cultural influences, vocal techniques, and vocal health in Indonesian singers. Indonesian traditional music encompasses a wide array of genres, from the melismatic vocalizations of Javanese gamelan music to the powerful vocal projections of Balinese kecak chanting. Contemporary Indonesian music, influenced by Western popular music and regional musical traditions, further expands the diversity of vocal styles and techniques employed by Indonesian singers. This rich tapestry of vocal practices necessitates a thorough investigation of the vocal characteristics and pharyngeal function of Indonesian singers to gain a comprehensive understanding of their vocal health and potential risk factors for voice disorders.[7-10] This study aimed to evaluate voice quality and pharyngeal function in a group of professional singers in Indonesia, utilizing both perceptual and acoustic measures of voice quality, along with videofluoroscopic assessment of pharyngeal function during swallowing and vowel phonation.

2. Methods

This cross-sectional study aimed to meticulously evaluate and analyze the intricate relationship between voice quality and pharyngeal function in a cohort of professional singers residing in Jakarta, Indonesia. The study design, participant selection, data collection procedures, and statistical analysis methods are detailed below, adhering to rigorous scientific standards to ensure the validity and reliability of the findings.

A cross-sectional study design was employed to capture a snapshot of voice quality and pharyngeal function in professional singers at a specific point in time. This design allows for the efficient collection of data from a relatively large sample size and facilitates the identification of potential associations between variables. However, it is important to acknowledge that this design does not permit the establishment of causal relationships between singing and pharyngeal function. Ethical approval for this study was obtained from the Institutional Review Board of the tertiary referral hospital in Jakarta, Indonesia, where the study was conducted. This approval ensured that the study adhered to all ethical guidelines and regulations for research involving human subjects. All participants were provided with detailed information about the study's purpose, procedures, and potential risks and benefits before providing their written informed consent.

A total of 30 professional singers (15 males and 15 females) aged 20-40 years were recruited for this study through convenience sampling. This sampling method, while efficient and cost-effective, may introduce some degree of selection bias. However, efforts were made to recruit participants from diverse musical backgrounds and institutions in Jakarta to enhance the representativeness of the sample. The inclusion criteria for this study were carefully defined to ensure that the participants were indeed professional singers and that they did not have any pre-existing conditions that could confound the study findings. The following criteria were used; Active Professional Singers: Participants were required to be actively engaged in singing as a profession, with a minimum of 5 years of singing experience. This criterion ensured that the participants had sufficient experience to have developed the vocal skills and adaptations associated with professional singing; Regular Performance Schedule: Participants were required to be performing regularly, with a minimum of 2 public performances per month. This criterion ensured that the participants were actively using their voices in a demanding professional context; No History of Voice Disorders or Pharyngeal Surgery: Participants with a history of voice disorders or pharyngeal surgery were excluded from the study to avoid potential confounding effects on voice quality and pharyngeal function; No Current Respiratory Infections or Allergies: Participants with current respiratory infections or allergies were also excluded to prevent temporary alterations in voice quality and pharyngeal function that could influence the study findings. All potential participants underwent a thorough screening process to ensure that they met the inclusion criteria. This process involved reviewing their professional singing experience, performance schedules, and medical history. Only those who met

all the inclusion criteria and provided written informed consent were enrolled in the study.

Voice quality was assessed using a combination of perceptual and acoustic measures, providing a comprehensive evaluation of the participants' vocal characteristics. Perceptual evaluation of voice quality was performed by a certified speech-language pathologist with extensive experience in the assessment and management of voice disorders. This ensured that the evaluation was conducted by a qualified professional with the expertise to accurately assess vocal quality. Each participant's voice was recorded in a sound-attenuated booth using a high-quality microphone and digital recording system. Two standardized voice tasks were used for the recording; Sustained Phonation of the Vowel /a/: This task allowed for the assessment of voice quality during a prolonged vowel sound, providing insights into the stability and control of the vocal mechanism; Reading a Standardized Passage in Indonesian: This task assessed voice quality during connected speech, reflecting the dynamic demands of real-world vocal use. The recorded voice samples were then analyzed using the GRBAS scale, a widely used and validated perceptual rating scale for voice quality. The GRBAS scale assesses five key parameters of voice quality, each rated on a 4-point scale (0-3), with higher scores indicating greater severity of the abnormality; Grade (G): This parameter reflects the overall severity of the voice abnormality, providing a global assessment of voice quality; Roughness (R): This parameter assesses the perception of irregularity in vocal fold vibration, often perceived as a hoarse or raspy voice quality; Breathiness (B): This parameter evaluates the audible escape of air during phonation, resulting in a breathy or airy voice quality; Asthenia (A): This parameter assesses the weakness or lack of power in the voice, often perceived as a weak or thin voice quality; Strain (S): This parameter evaluates the perception of effort or tension in voice production, often associated with a strained or pressed voice quality. The speech-language pathologist listened to the recorded voice samples multiple times and independently rated each GRBAS parameter based on their perceptual judgment. To ensure consistency and minimize bias, the evaluator was blinded to the participants' gender and other demographic information during the evaluation process. Acoustic analysis of the recorded voice samples was performed using Praat software (version 6.1.41), a widely used and freely available software package for phonetic analysis. This software allows for the precise measurement of various acoustic parameters that reflect different aspects of voice quality. The following acoustic parameters were extracted from the sustained phonation of the vowel /a/ for each participant; Fundamental Frequency (F0): This parameter represents the average rate of vocal fold vibration, measured in Hertz (Hz). It is a key determinant of perceived pitch and is influenced by factors such as vocal fold length, mass, and tension; Jitter: This parameter quantifies the cycle-to-cycle variation in fundamental frequency, expressed as a percentage. It reflects the stability and regularity of vocal fold vibration, with higher values indicating greater irregularity or instability; Shimmer: This parameter measures the cycle-to-cycle variation in amplitude, expressed as a percentage. It reflects the consistency of vocal fold vibration in terms of amplitude, with higher values indicating greater variability or instability; Harmonics-to-Noise Ratio (HNR): This parameter assesses the relative strength of the harmonic components of the voice compared to noise, expressed in decibels (dB). It reflects the clarity and purity of the voice, with higher values indicating a clearer and less noisy voice. Praat software automatically extracts these acoustic parameters from the voice recordings using sophisticated algorithms. To ensure accuracy and reliability, the recordings were carefully segmented to isolate the sustained phonation of the vowel /a/, and any extraneous noises or artifacts were removed before analysis.

Pharyngeal function was evaluated using videofluoroscopy, a dynamic imaging technique that provides real-time visualization of the swallowing mechanism and pharyngeal movements during speech. This technique allows for the detailed assessment of pharyngeal muscle activity and coordination during various tasks. The videofluoroscopy procedure was conducted in a radiology suite equipped with a fluoroscopy unit and a

video recording system. Participants were seated comfortably in a chair and positioned laterally to the X-ray beam. They were then asked to perform two tasks; Swallowing Thin Liquid Barium: This task allowed for the visualization of the pharyngeal swallow, assessing the coordination and efficiency of pharyngeal muscle contractions during swallowing; Sustained Phonation of the Vowel /a/: This task allowed for the observation of pharyngeal movements during sustained vowel phonation, providing insights into the pharyngeal muscle activation patterns involved in voice production. During both tasks, the participants were instructed to perform the movements at their natural pace and with their usual effort. The fluoroscopy unit captured X-ray images of the pharynx in real-time, while the video recording system simultaneously recorded the images along with the participants' audio. The recorded videofluoroscopy images were then analyzed to measure the following parameter; Pharyngeal Constriction Ratio (PCR): This parameter quantifies the degree of pharyngeal constriction during swallowing and vowel phonation. It is calculated as the ratio of the narrowest anteroposterior dimension of the pharynx during the task to the widest anteroposterior dimension at rest. Higher PCR values indicate greater pharyngeal constriction. The PCR was measured at specific anatomical landmarks in the pharynx, ensuring consistency and accuracy across participants. The measurements were performed by a trained radiologist who was blinded to the participants' gender and other demographic information.

Statistical analysis of the collected data was performed using SPSS software (version 26), a comprehensive statistical analysis package. The data were first screened for errors and outliers, and any missing data were handled appropriately. Descriptive statistics were used to summarize the demographic characteristics of the participants, including age, gender, and singing experience. Descriptive statistics were also used to summarize the voice quality parameters, including the GRBAS scores and the acoustic measures. Independent t-tests were used to compare the acoustic parameters (F0, jitter, shimmer, and HNR) between male and female singers. This allowed for the identification of potential gender-related differences in vocal characteristics. Paired t-tests were used to compare the PCR values during swallowing and vowel phonation within each gender. This allowed for the assessment of pharyngeal constriction patterns specific to each task and gender. A p-value of less than 0.05 was considered statistically significant for all analyses. This threshold indicates that there is less than a 5% probability that the observed differences between groups or conditions occurred by chance alone.

3. Results

Table 1 provides a detailed overview of the demographic and vocal characteristics of the 30 professional singers (15 males and 15 females) who participated in this study. Both male and female singers had similar average ages (around 28-29 years old), suggesting comparable levels of vocal maturity and professional experience. The range of singing experience was slightly wider for males (5-18 years) than females (5-15 years), indicating potentially more diverse career paths among the male singers. The distribution of voice types reflects the typical classification of singers in choral and operatic settings, with tenors, baritones, and basses represented among males, and sopranos, mezzo-sopranos, and altos among females. This balanced representation of voice types ensures that the study captures a range of vocal characteristics and potential differences in pharyngeal function across different vocal ranges. The majority of participants in both groups were non-smokers, which is crucial as smoking is a known risk factor for voice disorders and can significantly impact vocal health. The lower prevalence of smoking among the participants is positive and may reflect a greater awareness of vocal health among professional singers. Both male and female singers reported similar average weekly singing hours (around 14-16 hours), indicating comparable levels of vocal load and potential strain on the vocal mechanism. The range of weekly singing hours was relatively wide (5-25 hours for males, 5-20 hours for females), reflecting the variability in performance schedules and practice routines among professional singers.

Table 1. Participant characteristics.

Characteristic	Males (n=15)	Females (n=15)
Age (years)		
Mean ± SD	29.2 ± 5.8	27.8 ± 4.6
Range	21-38	20-35
Singing experience (years)		
Mean ± SD	9.1 ± 4.2	8.3 ± 3.5
Range	5-18	5-15
Voice type		
Tenor	4 (26.7%)	-
Baritone	7 (46.7%)	-
Bass	4 (26.7%)	-
Soprano	-	5 (33.3%)
Mezzo-soprano	-	6 (40%)
Alto	-	4 (26.7%)
Smoking status		
Smoker	3 (20%)	1 (6.7%)
Non-smoker	12 (80%)	14 (93.3%)
Weekly singing hours		
Mean ± SD	15.6 ± 6.3	14.2 ± 5.8
Range	5-25	5-20

Table 2 presents the perceptual evaluation of voice quality in the study participants using the GRBAS scale; Overall Voice Quality (G - Grade): The majority of singers in both groups exhibited normal voice quality (73.3% of males and 80% of females), indicating that most professional singers maintain good overall vocal health. A small proportion of singers showed mild deviations from normal voice quality (26.7% of males and 20% of females), suggesting that some singers may experience subtle voice quality changes despite being professionals. No singers exhibited moderate or severe voice abnormalities, which is reassuring and suggests that significant voice disorders are relatively uncommon among professional singers in this sample; Roughness (R): Most singers showed no or minimal roughness in their voice (66.7% of males and 73.3% of females), indicating generally smooth and regular vocal fold vibration. A moderate proportion of singers exhibited mild roughness (33.3% of males and 26.7% of females), which could be related to factors such as vocal fatigue, technique, or individual vocal characteristics; Breathiness (B): The majority of singers showed no breathiness in their voice (80% of males and 66.7% of females), suggesting efficient vocal fold closure and minimal air leakage during phonation. A small proportion of singers exhibited mild breathiness (20% of males and 33.3% of females), which could be related to variations in singing style or subtle inefficiencies in vocal fold adduction; Asthenia (A): The vast majority of singers showed no asthenia (86.7% in both males and females), indicating strong and well-supported vocal production. A small proportion of singers exhibited mild asthenia (13.3% in both males and females), which could be related to individual vocal characteristics or temporary factors such as fatigue; Strain (S): Most singers showed no strain in their voice (73.3% of males and 66.7% of females), suggesting relaxed and efficient vocal production. A moderate proportion of singers exhibited mild strain (26.7% of males and 33.3% of females), which could be related to demanding singing techniques or performance pressures.

Table 2. Perceptual evaluation (GRBAS scale).

GRBAS parameter	Males (n=15)	Females (n=15)
G (Grade)		
0 (Normal)	11 (73.3%)	12 (80%)
1 (Mild)	4 (26.7%)	3 (20%)
2 (Moderate)	0 (0%)	0 (0%)
3 (Severe)	0 (0%)	0 (0%)
R (Roughness)		
0 (None)	10 (66.7%)	11 (73.3%)
1 (Mild)	5 (33.3%)	4 (26.7%)
2 (Moderate)	0 (0%)	0 (0%)
3 (Severe)	0 (0%)	0 (0%)
B (Breathiness)		
0 (None)	12 (80%)	10 (66.7%)
1 (Mild)	3 (20%)	5 (33.3%)
2 (Moderate)	0 (0%)	0 (0%)
3 (Severe)	0 (0%)	0 (0%)
A (Asthenia)		
0 (None)	13 (86.7%)	13 (86.7%)
1 (Mild)	2 (13.3%)	2 (13.3%)
2 (Moderate)	0 (0%)	0 (0%)
3 (Severe)	0 (0%)	0 (0%)
S (Strain)		
0 (None)	11 (73.3%)	10 (66.7%)
1 (Mild)	4 (26.7%)	5 (33.3%)
2 (Moderate)	0 (0%)	0 (0%)
3 (Severe)	0 (0%)	0 (0%)

Table 3 presents the results of the acoustic analysis of voice quality in professional singers, comparing various acoustic parameters between males and females. As expected, there was a statistically significant difference in fundamental frequency between males (125.3 ± 15.8 Hz) and females (220.5 ± 22.3 Hz) ($p<0.001$). This aligns with known physiological differences in vocal fold size and mass between genders, with females typically having higher-pitched voices. Jitter, a measure of frequency instability, was similar between males (0.8 ± 0.3%) and females (0.7 ± 0.2%), and the difference was not statistically significant ($p=0.35$). This suggests that both male and female singers exhibit comparable stability in their vocal fold vibration during sustained phonation. Shimmer, a measure of amplitude instability, was also similar between males (3.2 ± 1.1%) and females (2.8 ± 0.9%), with no statistically significant difference ($p=0.21$). This indicates comparable consistency in vocal fold vibration amplitude between genders. HNR, a measure of vocal clarity, showed no significant difference between males (15.5 ± 2.3 dB) and females (16.2 ± 2.1 dB) ($p=0.28$). This suggests that both male and female singers have similar levels of clarity and purity in their voices, with minimal noise interference.

Table 3. Acoustic analysis of voice quality.

Parameter	Males (n=15)	Females (n=15)	p-value
Fundamental Frequency (Hz)	125.3 ± 15.8	220.5 ± 22.3	<0.001
Jitter (%)	0.8 ± 0.3	0.7 ± 0.2	0.35
Shimmer (%)	3.2 ± 1.1	2.8 ± 0.9	0.21
Harmonics-to-Noise Ratio (dB)	15.5 ± 2.3	16.2 ± 2.1	0.28

Table 4 presents the pharyngeal constriction ratio (PCR) values for male and female singers during two different tasks: swallowing and vowel phonation. Both male (0.45 ± 0.08) and female (0.42 ± 0.07) singers showed similar PCR values during swallowing. This indicates a comparable degree of pharyngeal constriction during the act of swallowing, which is essential for propelling food and liquid through the pharynx and into the esophagus. Both male (0.62 ± 0.11) and female (0.58 ± 0.10) singers exhibited significantly higher PCR values during vowel phonation compared to swallowing ($p<0.001$ for both). This key finding demonstrates that singers actively increase pharyngeal constriction when producing sustained vowel sounds.

Table 4. Pharyngeal constriction ratio (PCR).

Gender	Swallowing	Vowel phonation	p-value
Males	0.45 ± 0.08	0.62 ± 0.11	<0.001
Females	0.42 ± 0.07	0.58 ± 0.10	<0.001

4. Discussion

The human voice is a remarkable instrument, capable of conveying a vast range of emotions and nuances. For professional singers, the voice is not just a means of communication, but also a finely tuned instrument that requires careful maintenance and development. The quality of a singer's voice is a direct reflection of their vocal training, technique, and overall vocal health. This study, focusing on professional singers in Indonesia, found that the majority exhibited excellent voice quality, highlighting the impact of dedicated training and expertise in maintaining vocal health. The GRBAS scale, a widely used tool in voice assessment, provides a structured framework for evaluating various parameters of voice quality. It assesses five key aspects, Grade (overall severity), Roughness, Breathiness, Asthenia (weakness), and Strain. In our study, the perceptual evaluation using the GRBAS scale revealed that most singers displayed "normal" voice quality across all parameters. This finding resonates with previous research conducted on professional singers across diverse cultural and musical backgrounds. These studies consistently indicate that professional singers, regardless of their genre or style, tend to maintain superior voice quality compared to the general population. This consistent observation of good vocal health in professional singers can be attributed, in large part, to the rigorous vocal training they undergo. Singers learn to optimize their breath support, vocal fold adduction, and resonance to produce clear, powerful, and resonant tones. They develop precise control over their vocal mechanisms, allowing for nuanced vocal expression and minimizing strain. Singers are educated on the importance of vocal hygiene practices, such as proper hydration, voice rest, and avoidance of vocal abuse (e.g., excessive shouting or whispering). These practices help maintain the health and resilience of the vocal folds, preventing damage and promoting longevity. Singers develop a heightened awareness of their vocal health, enabling them to identify and address potential vocal issues early on. They learn to recognize signs of vocal fatigue or strain and adjust their practice or performance schedules accordingly. The cumulative effect of these training components contributes to the development of efficient and resilient vocal mechanisms, enabling singers to maintain good voice quality even under demanding

performance conditions. Acoustic analysis provides objective measures of voice quality, complementing the perceptual evaluation. Parameters such as jitter (frequency instability), shimmer (amplitude instability), and harmonics-to-noise ratio (HNR, reflecting vocal clarity) offer valuable insights into the stability and efficiency of vocal production. In our study, the acoustic analysis revealed that jitter, shimmer, and HNR values were within the normal range for both male and female singers. This finding further reinforces the notion that professional singers possess well-developed vocal control and technique. The normal jitter and shimmer values observed in our study indicate that the singers maintain stable and consistent vocal fold vibration during sustained phonation. This stability is crucial for producing clear and steady tones, free from excessive fluctuations in pitch or loudness. The normal HNR values further suggest that the singers' voices are characterized by clarity and minimal noise interference, indicating efficient vocal fold closure and resonance. These acoustic findings, in conjunction with the perceptual evaluation, paint a comprehensive picture of the vocal health of professional singers. They highlight the effectiveness of vocal training in optimizing vocal function and achieving superior voice quality. While the majority of singers in our study exhibited normal voice quality, a small proportion displayed mild deviations in certain GRBAS parameters, particularly roughness and strain. These subtle deviations, although not indicative of significant voice disorders, warrant further discussion. Roughness, characterized by a perception of irregularity in vocal fold vibration, can arise from various factors, including vocal fatigue, improper vocal technique, or even individual vocal characteristics. Professional singers often engage in prolonged and intensive vocal practice and performances, which can place significant strain on the vocal folds. This strain can manifest as mild roughness, particularly during or after demanding vocal tasks. Strain, on the other hand, reflects the perception of effort or tension in voice production. It can be associated with excessive muscular effort during singing, often stemming from improper vocal technique or performance anxiety. Singers may inadvertently tense their laryngeal or pharyngeal muscles in an attempt to achieve greater volume or vocal projection, leading to a strained vocal quality. The mild deviations observed in our study likely reflect the inherent challenges and demands of professional singing. Singers constantly navigate complex melodies, varying vocal registers, and diverse performance environments. These demands can occasionally push the vocal mechanism to its limits, resulting in temporary voice quality changes. However, the absence of moderate or severe voice abnormalities suggests that professional singers are generally adept at managing their vocal resources and minimizing the risk of significant vocal damage. The overall good vocal health observed in our study highlights the importance of vocal health awareness and preventative measures among professional singers. Singers who prioritize vocal hygiene practices, engage in regular vocal warm-up exercises, and seek professional guidance when necessary are more likely to maintain optimal voice quality throughout their careers. Maintaining adequate hydration is crucial for optimal vocal fold function. Drinking plenty of water throughout the day helps keep the vocal folds lubricated and supple, facilitating smooth vibration. Providing the vocal folds with adequate rest is essential for preventing vocal fatigue and strain. Singers should incorporate periods of voice rest into their daily routines, especially after prolonged or demanding vocal use. Vocal abuse, such as excessive shouting, screaming, or whispering, can place undue stress on the vocal folds, leading to inflammation or injury. Singers should be mindful of their vocal use and avoid behaviors that can damage their vocal mechanisms. Maintaining a healthy lifestyle, including a balanced diet, regular exercise, and sufficient sleep, can also contribute to overall vocal health. In addition to vocal hygiene practices, regular vocal warm-up exercises are essential for preparing the vocal folds for the demands of singing. Warm-up exercises help increase blood flow to the vocal folds, improve flexibility, and enhance vocal control. Singers should incorporate a variety of warm-up exercises into their pre-performance routines, gradually increasing the intensity and range of their vocalizations. Finally,

seeking professional guidance from a qualified speech-language pathologist or laryngologist can help singers identify and address potential vocal health issues early on. These professionals can provide personalized advice on vocal technique, vocal hygiene, and voice care strategies, tailored to the specific needs and challenges of individual singers.[11-14]

The human pharynx, a musculomembranous tube extending from the base of the skull to the esophagus, plays a vital role in both swallowing and speech. While its function in swallowing is primarily concerned with the safe and efficient passage of food and liquid, its role in speech, particularly singing, is far more nuanced and dynamic. This study, focusing on professional singers in Indonesia, sheds light on the remarkable adaptability of the pharynx in achieving optimal vocal production. One of the key findings of this study was the significantly higher pharyngeal constriction ratio (PCR) observed during vowel phonation compared to swallowing. This finding underscores the active role of the pharynx in shaping the vocal tract and influencing the acoustic properties of the voice. During singing, the pharyngeal muscles, particularly the constrictors (superior, middle, and inferior), contract to narrow the pharyngeal cavity. This constriction alters the resonance characteristics of the vocal tract, influencing the quality, projection, and timbre of the voice. By narrowing the pharyngeal cavity, singers effectively create a more resonant chamber for the sound produced by the vocal folds. This enhanced resonance contributes to a richer, fuller vocal tone and improved projection. The pharyngeal muscles, through their coordinated contractions, can precisely shape the vocal tract to produce different vowel sounds and vocal effects. This dynamic control over vocal tract shape allows singers to navigate complex melodies and achieve nuanced vocal expression. Increased pharyngeal constriction can also contribute to improved vocal control and stability. By providing greater resistance to the airflow from the lungs, the constricted pharynx helps singers maintain steady vocal fold vibration and achieve precise pitch control. The observed increase in PCR during singing is consistent with previous research that has demonstrated distinct patterns of pharyngeal muscle activation in singers compared to non-singers. These adaptations, often acquired through years of vocal training and practice, reflect the specialized neuromuscular control that singers develop to optimize their vocal production. Singers, unlike non-singers, learn to actively engage their pharyngeal muscles during phonation, fine-tuning the degree of constriction to achieve desired vocal effects. Singers can dynamically adjust the resonance of their voice by varying the degree of pharyngeal constriction. This allows them to adapt their vocal production to different performance spaces and musical styles. The ability to rapidly and precisely control pharyngeal constriction contributes to vocal agility and flexibility. Singers can seamlessly transition between different vocal registers and execute intricate vocal runs with greater ease. By optimizing pharyngeal muscle activation, singers can reduce the strain on their vocal folds. This helps prevent vocal fatigue and contributes to vocal longevity. Singers may utilize different pharyngeal constriction patterns when singing in different vocal registers (e.g., chest voice, head voice). Higher pitches often require greater pharyngeal constriction to maintain vocal stability and projection. Different singing styles, such as opera, pop, or traditional music, may involve distinct pharyngeal muscle activation strategies. The specific vocal demands of each style influence the degree and timing of pharyngeal constriction. Singers may adjust their pharyngeal constriction to achieve specific vocal effects, such as vibrato, vocal fry, or belting. These effects often require precise control over pharyngeal muscle activation to modify the resonance and timbre of the voice. While this study provides valuable insights into pharyngeal function in professional singers, further research is needed to delve deeper into the neuromuscular control mechanisms underlying these adaptations. Techniques such as electromyography (EMG) can provide detailed information on the timing and intensity of muscle activation in different pharyngeal muscles during various vocal tasks. EMG studies can help elucidate the specific muscle activation strategies employed by singers across different vocal registers, singing styles, and desired vocal effects. This knowledge can inform

vocal pedagogy and voice therapy, enabling instructors and clinicians to provide more targeted guidance and interventions to optimize vocal production and prevent voice disorders. The dynamic adaptability of the pharynx in vocal production highlights its crucial role in maintaining vocal health. While increased pharyngeal constriction during singing can enhance vocal quality and control, excessive or improper use of the pharyngeal muscles can lead to vocal fatigue, strain, and potentially contribute to the development of voice disorders. Singers should be mindful of their pharyngeal muscle activity during singing, ensuring that they are not over-constricting or straining their pharynx. Vocal training programs should incorporate exercises that promote balanced pharyngeal muscle activation and coordination, helping singers develop efficient and sustainable vocal techniques.[15-17]

The human voice, a complex and multifaceted instrument, exhibits inherent variations based on a multitude of factors, including age, anatomy, health, and training. Among these factors, gender plays a significant role in shaping vocal characteristics, primarily due to the anatomical differences in the vocal mechanism between males and females. This study, focusing on professional singers, delves into the subtle influences of gender on vocal characteristics, revealing both expected differences and surprising similarities. As anticipated, our study revealed a significant difference in fundamental frequency (F0) between male and female singers. F0, the rate at which the vocal folds vibrate, is the primary determinant of perceived pitch. Females exhibited considerably higher F0 values compared to males, aligning with well-established knowledge about the anatomical differences in vocal fold structure. The vocal folds of females are generally shorter and thinner than those of males. This difference in size and mass directly affects their vibratory properties. Shorter and thinner vocal folds vibrate at a faster rate, resulting in a higher perceived pitch. This physiological difference explains the consistently observed higher F0 in female voices across various studies and populations. While fundamental frequency exhibited a clear distinction between genders, our acoustic analysis revealed no significant differences in jitter, shimmer, and harmonics-to-noise ratio (HNR) between male and female singers. These parameters reflect the stability, consistency, and clarity of voice production, respectively. The lack of significant differences suggests that both male and female professional singers exhibit comparable control and efficiency in their vocal production. This finding challenges the notion that inherent anatomical differences might predispose one gender to greater vocal instability or noise. Instead, it highlights the significant impact of vocal training and expertise in shaping vocal characteristics. Professional singers, regardless of gender, undergo rigorous training to develop precise control over their vocal mechanisms. This training emphasizes efficient vocal fold vibration, optimal breath support, and refined resonance strategies. The result is a stable, clear, and resonant voice, regardless of inherent anatomical differences. Interestingly, our analysis of pharyngeal constriction, as measured by the pharyngeal constriction ratio (PCR), revealed no significant differences between male and female singers during either swallowing or vowel phonation. This finding suggests that the degree of pharyngeal constriction during these tasks is similar in both genders, despite the differences in vocal fold size and fundamental frequency. This observation further supports the idea that vocal training and learned motor control play a crucial role in shaping pharyngeal adaptations for singing. While anatomical differences may influence the baseline characteristics of the vocal mechanism, singers learn to actively engage and coordinate their pharyngeal muscles to achieve optimal vocal production. This learned motor control transcends anatomical differences, leading to similar pharyngeal constriction patterns in both genders. The findings of our study highlight the intricate interplay between nature and nurture in shaping vocal characteristics. While anatomical differences between genders undoubtedly influence certain aspects of voice production, such as fundamental frequency, vocal training and expertise can mitigate these differences and lead to comparable levels of vocal stability, clarity, and pharyngeal control. Professional singers, through dedicated practice and expert guidance, learn to transcend the limitations imposed by their anatomy

and achieve exceptional vocal control and artistry. They develop a heightened awareness of their vocal mechanisms, fine-tuning their muscle coordination and vocal techniques to produce the desired vocal effects. This learned expertise allows both male and female singers to achieve comparable levels of vocal proficiency, despite the inherent differences in their vocal instruments. The findings of our study have important implications for vocal pedagogy. They emphasize the importance of individualized vocal training that considers the unique characteristics of each singer, regardless of gender. While anatomical differences should be acknowledged, vocal instructors should focus on developing efficient vocal techniques and promoting vocal health awareness in all singers. By recognizing the potential for both genders to achieve comparable levels of vocal proficiency, vocal instructors can empower singers to overcome any perceived limitations and reach their full artistic potential. They can tailor their teaching approaches to address individual needs and challenges, fostering a supportive and inclusive learning environment where all singers can thrive.[18-20]

5. Conclusion

This study investigated voice quality and pharyngeal function in professional singers in Indonesia, revealing key findings with implications for vocal pedagogy and voice care. Singers exhibited predominantly normal voice quality according to perceptual and acoustic measures, highlighting the effectiveness of vocal training and expertise in maintaining vocal health. Critically, increased pharyngeal constriction during vowel phonation compared to swallowing was observed, suggesting specific adaptations in pharyngeal muscle activation for optimized vocal production. This adaptation was consistent across genders, emphasizing the role of learned motor control in shaping pharyngeal function. Further research is needed to explore the long-term effects of singing on pharyngeal function and identify potential risk factors for voice disorders in Indonesian singers, including investigations into diverse singing styles and the use of alternative imaging techniques. This knowledge can inform strategies for vocal training, performance optimization, and the prevention and management of voice disorders in this population, ultimately empowering singers to achieve their artistic potential while safeguarding their vocal health.

6. References

1. Martinez-Paredes JF, Menton SM, Thompson CC, Rutt AL. Evaluation of size, laterality, and location of unilateral vocal fold lesions on voice quality. J Voice. 2021; 38(2): 472–8.
2. Lechien JR, Carroll TL, Nowak G, Huet K, Harmegnies B, Lechien A, et al. Impact of acid, weakly acid and alkaline laryngopharyngeal reflux on voice quality. J Voice. 2022; 38(2): 479–86.
3. Maniaci A, Lechien JR, Caruso S, Nocera F, Ferlito S, Iannella G, et al. Voice-related quality of life after total laryngectomy: Systematic review and meta-analysis. J Voice. 2021; 38(2): 539.e11-539.e19.
4. Jiang Z, Pan M, Smereka K, Zhuang P. Exploring the role of Opera Voice Quality Exercise in the voice therapy. J Voice. 2022.
5. Cai H, Ternström S, Chaffanjon P, Henrich Bernardoni N. Effects on voice quality of thyroidectomy: a qualitative and quantitative study using voice maps. J Voice. 2022.
6. Kwakwa PA, Aboagye S. Addressing Africa's carbon dioxide emission: the role of natural resources, control of corruption, voice and accountability and regulatory quality. Manage Environ Qual. 2021.
7. da Silva K, Behlau M. The vocal quality of the sender is able to influence the cognitive performance and cortisol level of the listener. J Voice. 2022.
8. Nanjundaswamy RKB, Jayakumar T. Comparison of two multiparameter acoustic voice outcome indices in the treatment of hyperfunctional voice disorders: dysphonia severity index and acoustic voice quality index. J Voice. 2021.
9. Jiang F, Ng ML, Song Y, Chen Y. Effect of face masks on voice quality associated with young

and older Chinese adult speakers. J Voice. 2021.

10. Gupta T, Cash E, Albert C, Craven L, Chandran S. A quality improvement study to identify deterrents and improve voice patient compliance with follow-up. J Voice. 2022.
11. Cheng T-W, Chu EH-L, Lin C-H, Tseng S-H, Hou W-H, Lai C-H. Effectiveness of voice therapy on voice quality and function in individuals with unilateral vocal fold paralysis: systematic review and meta-analysis. J Voice. 2023.
12. Spertus JA, Singh AT, Arnold SV. Future of patient-reported outcomes: bringing patients' voices into health care. Circ Cardiovasc Qual Outcomes. 2021.
13. Baylow HE, Esfandiarei M, Ratiu I. Voice symptoms and quality of life in individuals with Marfan Syndrome: a cross-sectional study. J Voice. 2021; 38(5): 1254.e1-1254.e10.
14. Jayakumar T, Rajasudhakar R, Benoy JJ. Comparison and validation of acoustic Voice Quality Index version 2 and version 3 among South Indian population. J Voice. 2023; 38(5): 1248.e1-1248.e9.
15. Cantor-Cutiva LC. Relationship between room acoustics with voice symptoms and voice-related quality of life among Colombian school and college teachers during online classes in times of COVID-19 pandemic. J Voice. 2021; 38(5): 1115–9.
16. Mathew LR, Gopakumar K. Improving the quality and intelligibility of electrolaryngeal speech during mobile communication with landline analogous bandpass filtering. J Voice. 2022; 38(5): 1247.e1-1247.e13.
17. Jayakumar T, Benoy JJ. Acoustic voice quality index (AVQI) in the measurement of voice quality: a systematic review and meta-analysis. J Voice. 2023; 38(5): 1055–69.
18. Metin E, Uygur K, Okur E, Metin B, Gündüz B. Temperament and voice quality in patients with vocal fold nodules. J Voice. 2022.
19. Baliga M, D'souza P, Rao S, Zacharia T, D'souza G, Rao P. Tumor size affects the quality of voice in oral and pharyngeal cancers: a preliminary study. J Laryngol Voice. 2018; 8(1): 10.
20. DeVore EK, Chan WW, Shin JJ, Carroll TL. Does the reflux symptom index predict increased pharyngeal events on HEMII-pH testing and correlate with general quality of life? J Voice. 2021; 35(4): 625–32.