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Research Article

Voice-related Biomarkers in Singing: Suggested Clinical Measurements Standards of Voice Complaints, Listeners' Evaluation, Acoustical Measurement and Airflow

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Abstract

The routine use of voice-related biomarkers of basic acoustic parameters, fundamental frequency (F0), Jitter, Shimmer and Harmonics to Noise Ratio (HNR), Voice Handicap Index (VHI), GRABAS test and Maximum Phonation Time (MPT) in singing pedagogy is suggested. These measures make it possible to evaluate voice pedagogy methods in a way that opens for a valid discussion of scientific evidence in future Randomized Controlled Studies (RCTs). In the modern era, voice educators face a new set of technical computer-related challenges and there is a need to safeguard vocal health in diverse performances. The abundant literature of singing pedagogy should be revised and seen from these approaches. The history of singing pedagogy was therefore studied. This article traces the development of singing pedagogy in practice in cooperation with medical doctors. The evaluation was that routinely measuring the voice with voice-related biomarkers, also with the help of artificial intelligence, especially during the training period and also in periods of voice hazards, will not only add substantially to the dialogue between laryngologists/phoniatricians and singing pedagogy, but also be a great help.

Keywords: Singing Pedagogy; History, Voice-Related Biomarkers; (Voice Handicap Index (VHI); GRBAS Test; Acoustic Measures (Fundamental frequency (F0); Jitter, Shimmer; Harmonics to Noise Ratio (HNR); Maximum Phonation Time (MPT)); Artificial Intelligence (AI)

Introduction

Singing is among the most ancient and universal forms of human expression [1]. Across all known civilizations, the human voice has served as a powerful medium for storytelling, spiritual practice, emotional release and social cohesion. Singing pedagogy, the structured teaching and learning of vocal technique, has developed alongside these traditions. It began as a process rooted in oral transmission and intuitive mimicry [2]. It has grown into a multidisciplinary domain trying to integrate aspects related to anatomy, acoustics, psychology, medicine and digital standardized technology [3]. In the modern era, voice educators face a new set of challenges: the democratization of singing across genres, Artificial Intelligence (AI) and the quantification of sound evaluation that demand evidence-based instruction and the need to safeguard vocal health in diverse performance contexts.

The traditional history of vocal pedagogy and training includes Ancient/Classical, Medieval, Renaissance, Baroque, Classical/Romantic (Bel Canto), 20th Century and Contemporary [2]. Pedagogical aspects from each era include both primary treatises and secondary scholarly interpretations. Institutional curricula from vocal pedagogy programs focus on course content, learning objectives and assessment methods. The historical development of voice pedagogy gives an explanation and background of today. But it is also a challenge for the changing aspects, where performance certainly is defined differently. The change is from rituals over solemnization to text expressiveness and ornamentation. Thereafter came an anatomic understanding

and a rather intensive dialogue with engineers on acoustics and physiology. The newest pedagogy has popular singing in focus and the pedagogic approach is based on visual and acoustic recordings, also from a laryngeal medical aspect that was hardly imaginable.

This study aims to present the integration into singing pedagogy, of measurement tools referring to a consensus of the European Union of Phoniatricians (UEP) and the Europeans Laryngological Society (ELS): acoustical analyses (Fundamental frequency (F0), Jitter, Shimmer and Harmonics to Noise Ratio (HNR)), Voice Handicap Index (VHI) GRBAS test and Maximum Phonation Time (MPT)) explored also in a book on voice-related biomarkers as indicators of pedagogical modernity [3-8].

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

Materials and Methods

The methods in this study draw from musicology, pedagogic theory and curriculum analysis. The intention was to highlight the continuity and also the innovation. Historical works include books on vocal methods by Marchesi, Lamperti and Tosi [9-11]. These foundational texts provide insight into the methods of singing, including the bel canto tradition, such as messa di voce with intensity variation of song tones, legato, phrasing and the art of portamento with smooth gliding from one tone to another. Physiological, acoustic and biological updated principles of voice production include contributions from Sundberg, Titze, Pedersen and Ragan [12-15]. The historical understanding of vocal mechanics, the development of voice, acoustic theory and interdisciplinary instructions are described by these authors.

Contemporary methods taking modern popular music into account include frameworks like Estill, Sadolin, LoVetri [16-18]. Traditional updated voice elements and ornamentation have developed enormously and have unexpected popularity. This development is made in tight cooperation with laryngologists and phoniatricians worldwide. Institutional sources include the Belmont University Vocal Pedagogy Program, the Voice Study Centre and the NATS Pedagogy Institute [19-21]. They collectively demonstrate how integrating science, artistry and technology is possible.

Results

Inconsistent Outcomes

Due to the lack of consensus on measures, the singing pedagogic results cannot be compared. As for historical aspects, the earliest form of singing instruction emerged in oral traditions. In ancient Greece, India and China, vocal practice was entwined with religious ritual and cultural preservation. Knowledge was passed directly from master to pupil through imitation. The lack of written records makes it difficult to reconstruct precise techniques, but archaeological and literary evidence suggests a focus on intonation, breath and narrative clarity.

During the Western Medieval period, vocal music became increasingly tied to ecclesiastical institutions. Gregorian chant was systematized in monastic settings and solmization systems such as those developed by Guido of Arezzo enabled the training of choirs [22]. By the Renaissance, the influence of humanism led to greater expressive flexibility. Singing schools were established in courts and cathedrals, with an emphasis on clarity of text and balance within polyphonic structures. The Baroque and Classical periods marked the institutionalization of Western singing pedagogy. Conservatories in Italy formalized instruction and the role of the castrato singer emerged as a symbol of vocal virtuosity. Bel canto pedagogy emphasized agility, phrasing, breath control and a seamless legato line. García's invention of the laryngoscope in the mid-19th century marked a scientific turn, allowing for observation of the vocal folds during phonation and paving the way for physiologically informed measures of the voice (Fig. 1, Table 1) [2,23-24].

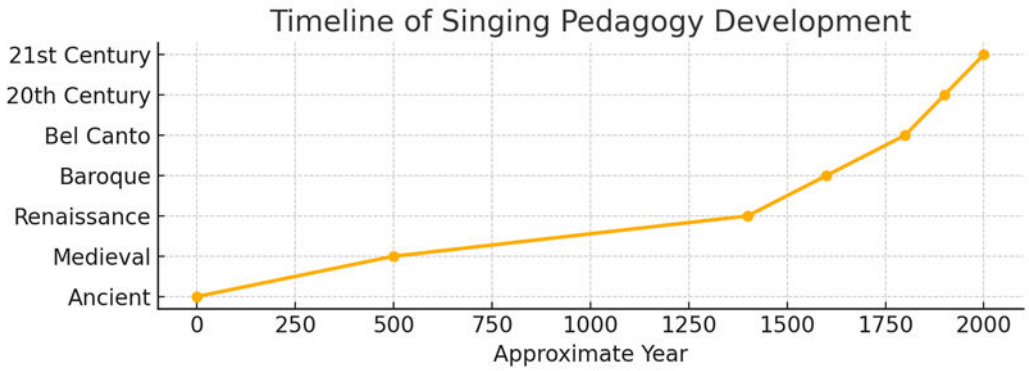

Figure 1: The timeline illustrates the evolution of pedagogical priorities and methodologies across some historical eras.

Era	Instruction Style	Key Features	Notable Figures
Ancient/Classical	Oral Transmission	Ritualistic, intuitive	Unknown
Medieval	Written Chant	Monastic training, solmization	Guido of Arezzo
Renaissance	Court/Cathedral	Text clarity, expressiveness	Vincenzo Galilei
Baroque	Conservatory	Ornamentation, messa di voce	Pier Francesco Tosi
Classical/Romantic	Formal Training	Legato, agility, technical drills	García II, Marchesi, Lamperti
20th Century	Scientific/Interdisciplinary	Laryngoscopy, voice labs	Titze, Sundberg, Pedersen
21st Century	Hybrid/Digital	Apps, online learning, modular systems	Estill, Sadolin, LoVetri
This table compares the pedagogical traits of major historical eras, highlighting instructional strategies and some examples of leading figures.			

Table 1: Comparative overview of pedagogical eras.

20th and 21st Century Innovation

The 20th and 21st centuries witnessed a pedagogical shift from aesthetic intuition to physiological precision. These innovations enabled teachers to explain concepts of singing strategies and phonation types using empirical data. This period saw the emergence of interdisciplinary collaboration, particularly between vocal pedagogues and medical doctors [12-15]. The period also includes the emergence of interdisciplinary collaborations advocating a continuous feedback loop between laboratory findings and studio practice [23]. Estill Voice Training provided a detailed taxonomy of vocal structures and their functions. Complete Vocal Technique (CVT) introduced a genre-inclusive system focusing on vocal effects and safety. LoVetri Somatic Voicework integrated physical alignment and vocal health principles, often used in therapeutic and rehabilitation settings, all in tight collaboration with laryngologists/phoniatricians [16-18].

The 21st century has brought further integration of digital tools into pedagogy. Acoustic analysis software, advanced laryngoscope visualization and mobile voice apps are now part of everyday instruction in many academic and private settings. These tools enable data-driven pedagogy. The suggested use of the basic voice-related biomarkers of acoustic measures (F0, Jitter, Shimmer and HNR), VHI, GRBAS scale and MPT as assessment instruments indicates a move toward standardized, practical, measurable outcomes in vocal education and treatment. These well-known measures described as voice-related biomarkers are discussed in the book given out by 5 members of the Biomarkers Committee of the Union of the European Union (UEP) as a basis for digital foundation models [3].

An example of an updated training program is the curriculum of Belmont University's Master of Music in Vocal Pedagogy program [19]. This program integrates laryngology studies, live and digital feedback mechanisms and a genre-inclusive approach to training. Students undergo instruction that includes hands-on labs, vocal health monitoring using objective tools and real-time feedback during lessons. Moreover, the curriculum covers classical, musical theatre and commercial music styles, allowing students to compare and contrast pedagogical strategies across genres. It includes research methodology, requiring students to engage with the latest voice science literature and produce original projects. Students receive mentorship in applying

both traditional bel canto techniques and modern frameworks such as Estill and Complete Voice Technique systems based on the individual needs of their students or clients [2,16,17]. It reflects a growing movement in voice education toward more science-oriented professionalism, health consciousness and pedagogical accountability across styles. Due to the lack of consensus on measures, the singing pedagogic results cannot be compared to other places of education.

Challenges of Standardization

Vocal teachers operate in an environment where artistic intuition, personal lineage and personal experiential knowledge still dominate. While this has fostered innovation and responsiveness to individual needs, it has also resulted in inconsistent outcomes across institutions and genres. The absence of common terminology, shared metrics and universal benchmarks makes it difficult to assess student progress or compare instructional efficacy. Unlike musical instruments, where tuning systems are standardized, vocal pedagogy lacks uniform scaffolding. The voice-related biomarkers of acoustic measures of F0, Jitter, Shimmer and HNR, as well as VHI, GRBAS test and MPT, are suggested based on a consensus of UEP and ELS 2023 in a modular framework [23] (Table 2).

Module	Key Topics
1. Vocal Anatomy and Health	Laryngeal function; vocal fold imaging; hygiene; voice-related biomarkers (F0, Jitter, Shimmer, HNR, VHI, GRBAS, MPT)
2. Breath and Body Awareness	Diaphragmatic breathing, postural alignment
3. Resonance and Registration	Chest, head, mix voice; voice tuning; practical acoustic exercises
4. Stylistic Technique and Expression	Classical vs. contemporary articulation; emotional intent; performance coaching
5. Technology in Voice Pedagogy	Digital biomarker analysis apps, remote learning strategies, voice monitoring and recording
This table shows the challenges of standardization	

Table 2: Emerging frameworks and modular pedagogy.

Technology and Digital Pedagogy

Technology has revolutionized not only the tools available in medicine but also in singing. Online platforms, video tutorials and mobile applications have transformed voice instruction. The aspect is a more accessible, scalable and dynamic enterprise. Students from all over the world can now study with renowned pedagogues and medical doctors through video conferencing platforms, while asynchronous feedback apps allow real-time analysis of voice-related biomarkers. The perspective is huge, with multiple possible measures.

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Evidence-based voice pedagogy in randomized controlled trials demands rigorous validation of learning outcomes, these studies have not been conducted [4]. Biomechanical modeling of the larynx, computerized acoustic correlates of emotional expressivity and neural imaging of performance anxiety inquiries stand to deepen our understanding of the connections between body, sound and emotion in the singing process.

Increased interest in cross-cultural and multilingual vocal instruction, with the globalization of music and education, supports a need for tools that address the specific and demands of non-Western musical traditions. Transgender singers are also gaining traction. Diverse musical traditions such as Indian raga, Arabic maqam, African call-and-response and indigenous chant all possess unique vocal aesthetics and training philosophies. Incorporating these is important. As music itself becomes increasingly global, laryngeal/phoniatric measurements and singing pedagogy follow, not just in content, but in standardized measuring [3].

Discussion

The history of singing training and pedagogy reflects the broader evolution of music education, from oral tradition and master-apprentice lineage to institutional training and, most recently, scientific, including medical and digital integration. Based on a book with suggested standards of voice-related biomarkers, it was interesting to evaluate the singing pedagogy development

[3]. To understand the necessity in modern times with up-to-date technology, a review was relevant. Technology and specified voice measurements have historically certainly not been used, but have a historical base.

There was a step forward with the development of laryngoscopy and further with acoustic and physiological measurements in well-equipped laboratories. The new change is to computerize the visual and acoustic aspects for everyone, including Artificial Intelligence (AI). The voice, as both a very basic biological reality and artistic tool, demands approaches to measures with incorporated standards. Evidence-based models and AI continue to shape the field; the emphasis is shifting toward more standardized, measurable outcomes, vocal health and genre inclusivity [23-25].

Collaboration among medical doctors/laryngologists/phoniatricians, singing pedagogy and technologists using standardized voice-related biomarkers and also inclusive institutions, will form the next generation of singers. The singers will benefit not only from more efficient training but from a more advanced understanding of their vocal instrument.

Conclusion

The history of singing voice pedagogy was studied in the abundant literature thereof, to understand and document the need for standardized voice measurements. History included descriptions of traditional and updated pedagogy. Since no standardized measurements have been made, the various training systems cannot be compared, nor the individual singing pedagogies, nor the institutions. Based on the development of computerized video and acoustic setups and AI, standardized basic measurements as presented in a book on voice-related biomarkers can be made [3]. This will make the dialogue between students, singing pedagogues and medical doctors much better, as a great benefit for singing pedagogy.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Institutional Review Board Statement

Not applicable.

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Data Availability

Data is available for the journal. Informed consents were not necessary for this paper.

Author's Contribution

None.

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