Echoes of a Legend: Luciano Pavarotti, the Unimitable Maestro of Do di Petto. Physiological and Phonetic Perspectives.

Valeria Caragli[1], Elisabetta Genovese[2], Antonella Coppi[3]

[1] *Audiology Program, Otorhinolaryngology Unit, Department of Medical and Surgical Sciences for Children and Adults, University of Modena and Reggio Emilia, 41124 Modena, Italy; valeria.caragli@unimore.it, https://orcid.org/0009-0005-7112-0282*
[2] *Audiology Program, Department of Maternal, Child and Adult Medical and Surgical Sciences, University of Modena and Reggio Emilia, 41124 Modena, Italy*
[3] *Faculty of Education of the Free University of Bolzano, Lecturer in Vocal Pedagogy and Conductor of the University Choir and Orchestra of the University of Modena and Reggio Emilia*

Abstract

Luciano Pavarotti, a celebrated tenor of the 20th century, is renowned for his powerful vocal abilities, particularly in executing high notes in the chest register, exemplified by his historic performance of nine "chest C" notes in the aria "Ah, mes amis, quel jour de fête!" from "La figlia del reggimento". This study aims to examine the physiological and phonetic aspects of Pavarotti's vocal technique. A comprehensive literature review was conducted utilizing Scopus and Google Scholar, focusing on publications regarding Pavarotti's vocal methods, with careful screening for original research and sound anatomical insights. Findings highlight that Pavarotti's impressive vocal capabilities stemmed from a combination of anatomical structure, extensive training, and effective use of resonance, which permitted the execution of high notes with clarity and richness. The interplay between Pavarotti's technical mastery, interpretive approach, and advancements in recording technology, alongside how lifelong training mitigated vocal aging. As a consequence, Pavarotti's achievements are not solely attributable to anatomical predisposition but also to disciplined artistry, establishing an enduring standard in operatic performance that highlights the complexities of the vocal art form.

Keywords*: Luciano Pavarotti, Larynx physiology, Vocal Technique, Chest Register*

Introduction

Luciano Pavarotti is widely regarded as one of the most celebrated tenors of the 20th century, renowned globally for his powerful voice and exceptional ability to reach high notes, particularly the famous "chest C," also referred to as "do di petto." His extraordinary talent has elicited admiration and curiosity, leading to extensive analyses by music experts and vocal technique specialists.

Pavarotti possessed a robust musical background, having studied under some of the most esteemed masters of his time. His vocal technique rested on several fundamental principles that enabled him to exert exceptional control over his voice (Pavarotti and Wierzbowski, 1996). Notably, his mastery of "mezzo-forte" and vocal projection is well documented in the scholarly literature on singing (Berg, 2020).

Different mechanisms of phonation contribute to the production of various vocal frequencies, which can be categorized into three primary mechanisms: active contraction, passive contraction, and the automatic opening of the vocal cords. Active contraction of the vocal cords yields lower sounds within the vocal range, typically associated with the chest register. This mechanism results in vibrations in the rib cage, generating a pronounced sensation of vibration in the chest. In contrast, passive distension—characterized by the control of respiratory flow—occurs as the arytenoid cartilages rotate, effectively stretching the vocal cords backward. This process facilitates the generation of notes with medium frequencies, known as the throat register, where the predominant vibratory sensations are perceived in the pharynx. The automatic opening of the vocal cords is employed for higher notes: the vocal cords are extended to their maximum limit, thereby allowing the production of lighter and higher sounds, which correspond to the head register, with the predominant sensations felt in the head region. These mechanisms can be combined in various ways depending on vocal needs and individual capabilities, allowing for the production of low, medium, and high sounds, respectively (Umberti, 1986).

In pure chest voice, the vocal cords, anchored at one end to the inner angle of the thyroid cartilage and at the other to one of the rotating arms of the arytenoid cartilages, transmit sound not only through bone vibrations to the resonators in the cranial cavity but also to the sternothyroid muscles, which are connected to the sternum, thus vibrating the entire thoracic cavity (Budden, 1993; Herbst, 2009). Emitting chest voice requires resonance not only in the chest but also in the cavities located above the nasal fossae, specifically those situated behind the frontal area of the skull, acting as a resonance chamber. This technique is technically akin to head voice; however, it utilizes a broader range of resonating organs. The pure chest voice permits the production of sounds with considerable intensity while exerting modest effort from the vocal cords (Stark, 2003). Musically, it is typically employed to create deep and intense sounds, contingent upon the technique utilized and the pitch at which the sounds are executed. Historically, it was commonly used by theatrical actors who needed to project their voices to large, often noisy audiences. However, it is now rarely employed—often with parodic intent—due to its ostentatious and artificial nature. Nonetheless, the chest voice retains significant importance, particularly in lyrical singing. It is predominantly used by male voices and is characteristic of the bass-baritone register, which is the most frequently utilized mode of emission (Stark, 2003). Notable examples of pure chest voices include those of Martti Talvela and Nicolaj Ghiaurov. In the upper middle register corresponding to the tenor voice, true chest voice is infrequently used, typically in heroic roles or Heldentenor parts (e.g., Plácido Domingo, Wolfgang Windgassen). Instead, various mixed emissions have supplanted it, yielding a voice that is predominantly head voice (through so-called register transitions), which is characteristic of lyric tenors (e.g., Alfredo Kraus, Juan Diego Flórez, and Luciano Pavarotti) (Titze, 2009).

The nonlinear source-filter theory for singing is predicated on the assumption that stored energy within the vocal tract can facilitate vocal fold vibration through feedback, with the stored energy quantified in terms of the acoustic reactance of the air column above or below the vocal folds (Fletcher, 1993). However, in singing, multiple resonances of the vocal tract are not generally “tuned” to the harmonics of the source due to two primary factors: the short length of the tube, typically 15–20 cm for a supraglottal vocal tract and 12–16 cm for a subglottal tract; and the necessity to convey verbal messages through vowels and consonants in conjunction with the musical content. Therefore, it is postulated that the singer learns to utilize supraglottal inertive reactance and, occasionally, subglottal compliant reactance to reinforce vocal fold vibration by selecting pitch-vowel combinations that maintain several harmonics within favourable reactance regions simultaneously (Titze, 2006), though not necessarily tuned to the formants. The degree of interaction between the source of vocal fold vibration and the accompanying glottal flow with the vocal tract filter is contingent upon the relationship between the source impedance and the vocal tract input impedance. As in electric circuit

theory (Skilling, 1966), when the source impedance is significantly larger than the vocal tract impedance, minimal interaction occurs. Conversely, if the impedances are comparable, substantial interaction takes place. The underlying hypothesis posits that reactive impedance, both above and below the glottis, can store energy and provide feedback to the source with a delayed or advanced phase, thereby either constructively or destructively influencing vocal fold vibration (Titze, 2009).

Pitch instabilities, such as pitch jumps, subharmonics, or occasionally aperiodic vibrations, may arise when a harmonic transition through a formant during pitch alterations (Titze, 2008). The data indicate that inertance changes rapidly near the formants. If vocal fold vibration is highly facilitated by supraglottal inertance, a sudden change may destabilize the modes of vibration. Consequently, a vocalist who relies on source-vocal tract interaction to enhance vocal power must learn to modify the vowel in order to seek optimal reinforcement for each harmonic.

In 1966, Luciano Pavarotti made history by flawlessly and naturally executing nine chest Cs in the aria of the character Tonio, "Ah, mes amis, quel jour de fête!" from "La figlia del reggimento", during a performance at Covent Garden in London. The final note was rendered with remarkable clarity and sustained for over six seconds, with a total duration of twelve seconds when considering the complete passage. This performance solidified Pavarotti's status as a Lyric Master and earned him the title of "King of the Chest C." His performances remain unmatched, and the arias he sang continue to resonate in the memories of audiences worldwide (Fantozzi, 2020).

The aim of this study is to investigate the physiological and phonetic aspects of Luciano Pavarotti's vocal technique, with a particular focus on his execution of high notes in the chest register.

Material and Methods

A comprehensive literature search was performed to gather studies and reviews pertinent to the singing techniques and abilities of Luciano Pavarotti. The databases Scopus and Google Scholar were utilized to perform the search on October 2024, employing the following search string: "(Luciano Pavarotti) AND ("larynx" AND "voice")". The search was confined to publications in the English language.

Articles eligible for inclusion were those that concentrated specifically on the subject matter of Pavarotti's vocal techniques. The retrieved full-text articles were subjected to a thorough screening process to identify original research data. Additionally, the bibliographies of these articles were examined manually to uncover additional studies of relevance.

Studies that did not provide sufficient data or lacked a clearly defined methodology were excluded from the review, as these criteria were established to ensure the reliability and verifiability of the findings.

Results

Luciano Pavarotti was a renowned tenor whose vocal capabilities were notable for their powerful tenor range and exceptional quality. These attributes were influenced by various factors, including his physical anatomy, vocal technique, and training (Pavarotti and Wierzbowski, 1996). Notably, Pavarotti's ability to produce exquisite performances, particularly his ability to reach a Chest C, was evident at specific junctures in his career and under particular physical conditions.

Pavarotti, with a height of approximately 180 cm, was not significantly taller than many of his tenor contemporaries. It is important to note that while a singer's physical size may influence certain aspects of vocal production, it is not the sole determinant of vocal depth or range (Taylor, 2023). Indeed, individuals of smaller stature may still possess deep voices if they have longer and thicker vocal cords, which tend to produce lower pitches. However, Pavarotti's unique sound was additionally shaped by his training, breath control, and the resonating spaces within his body, such as the chest and throat, contributing to the richness of his tenor voice. While Pavarotti's voice was not deep in pitch, it was characterized by a depth of texture and richness. Thus, the quality of Pavarotti's voice, as well as his capacity to produce a robust and powerful timbre, was contingent on his individual anatomy and vocal training rather than his phys-

ical size (Rössner, 2015). According to Mingo (2008), an essential aspect of Pavarotti's success was his proficiency in utilizing resonance and chest register, effectively combining the use of the diaphragm and abdominal support to produce high notes.

Pavarotti's vocal anatomy featured a well-developed larynx, which facilitated the attainment of higher registers without excessive strain. While he was recognized for his larger build and a wide neck, little is extensively documented regarding the remainder of Pavarotti's vocal tract. Titze (2009) endeavored to evaluate the anatomical structure of Pavarotti's larynx. In this analysis, it was assumed that his supraglottal vocal tract length was comparable to that of a baritone (albeit Pavarotti being a tenor of larger proportions). It was posited that Pavarotti had a wider pharynx (approximately 4 cm^2) and a narrowed epilarynx tube (0.3 cm^2) attributed to a distinctive resonance in his voice. The approximate 10 cm^2 area of his mouth could be extrapolated backward from the general MRI shape associated with lyric baritones (Titze, 2009).

Inertance is a quantity that can be scaled uniformly over a broad frequency range, facilitating the examination of the fundamental frequency-vowel interaction across large frequency ranges and the plotting of supraglottal vocal tract inertance. Examination of the inertograms for an inverted megaphone mouth shape extrapolated from Pavarotti's mouth indicated that 2F0 resides within both the subglottal compliance region and the supraglottal inertance region (below F2). Given that the trachea is slightly shorter than that associated with speech vowels, the first subglottal resonance (F11) appeared to overlap with the second supraglottal resonance (F2), providing combined reinforcement to 2F0. The third harmonic (3F0) was positioned favorably near the peak inertance point noted near F2. Additionally, the overall inertance within the 2500 Hz region was increased (relative to the original baritone inertograms) due to the narrowing of the epilarynx, which presumably contributed to a strong sixth harmonic (Titze, 2009).

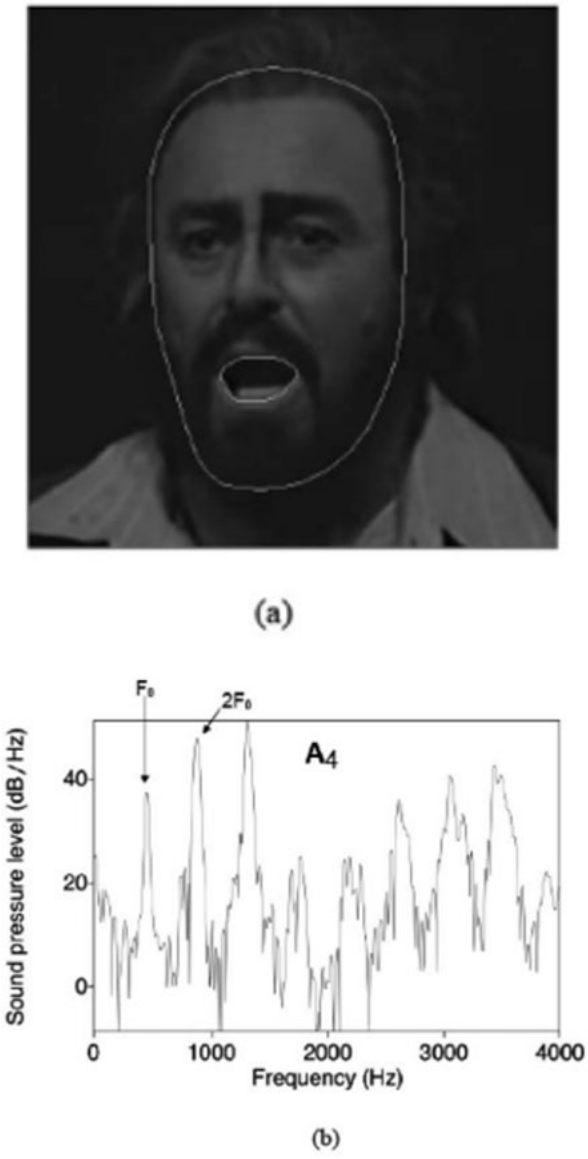

Figure 1: (a) Mouth area and head area for Luciano Pavarotti singing A4 on an /Å/ vowel. (b) Corresponding frequency spectrum. (Titze IR, Worley AS. Modeling source-filter interaction in belting and high-pitched operatic male singing. J Acoust Soc Am. 2009 Sep;126(3):1530. doi: 10.1121/1.3160296. PMID: 19739766; PMCID: PMC2757425).

For spectral analysis, PRAAT software and independently extracted spectra from non-compressed original recordings (Schutte et al., 2005) were employed. The magnitude spectrum (Figure 1) for Pavarotti indicated that F0, 2F0, and 3F0 were particularly pronounced, especially 2F0 and 3F0, as corroborated by the inertogram analysis. The lower three harmonics benefited from favorable

supraglottal inertance and subglottal compliance, specifically in the case of 2F0. Noteworthy, harmonics 6F0, 7F0, and 8F0 were also collectively prominent within the recording, with only 6F0 predicted to exhibit strength. Due to the uncertainty regarding the precise dimensions of Pavarotti's epilarynx, it remains plausible that 7F0 and 8F0 may have also been reinforced by the narrowed epilarynx tube and the clustering of F3 and F4, thereby producing the operatic ring, though further investigation would be warranted (Titze, 2009).

Regarding Pavarotti's career, during the initial phase of his 43-year tenure on the international stage, he primarily performed lyric roles; however, he increasingly took on more dramatic roles as his career progressed. His relatively swift vibrato appeared to be a characteristic trait, imparting a lyric quality to his singing. General vocal changes associated with the aging process may lead to a decline in vibrato rate (VR) and an increase in timbral vibrancy (VE). Nonetheless, lifelong laryngeal training can mitigate the manifestations of vocal aging. Interestingly, advanced age was correlated with a decrease in VR and a marked increase in VE. The heightened VE over time seemed to correspond with Pavarotti's rising engagement in dramatic roles in the latter stages of his career. These vocal changes appear to signify personal development, rather than being sole indicators of the aging process (Müller et al., 2021).

In explaining Pavarotti's vocal prowess, it is essential to consider the interpretive style of the lyric singer, which he himself emphasized. Pavarotti dedicated considerable attention to musicality and expression, and the manner in which he approached an aria significantly influenced his capacity to deliver high notes with ease. His charismatic personality and ardent passion for music contributed to the memorability and vibrancy of his performances.

Additionally, it is pertinent to acknowledge that Pavarotti benefited from advancements in recording techniques and sound dissemination. As discussed in the analysis by Wierzbowski (2021), audio technologies allowed for an exceptional capture of his voice, rendering every high note accessible and vibrant.

Discussion

The extraordinary vocal capabilities of Luciano Pavarotti have long captivated audiences and scholars alike. This study has explored the physiological and phonetic aspects underpinning the remarkable high notes execution of the tenor, particularly in the chest register. Pavarotti's historical achievement of executing nine "chest C" notes in a single aria exemplifies how exceptional anatomical and technical factors contribute to a tenor's artistry (Rössner, 2015).

The success of the singer can be attributed not only to his physical size and anatomical structure, but also to his training in various vocal techniques. The relationship between a singer's physical characteristics and their vocal capability has been discussed in previous studies, such as those by Titze (2009) and Mingo (2008). Though Pavarotti's stature was not outsized compared to other tenors, his well-developed larynx and control over resonant spaces were instrumental in achieving a rich, powerful tenor voice. The advantage of resonating cavities above the vocal folds is consistent with findings reported by Fletcher (1993), who noted the importance of vocal tract tuning in sound production. Pavarotti's ability to harness the resonating properties of his body led to enhanced tonal depth and clarity, which in part explains his renowned abilities.

The mechanics of phonation are essential for understanding how Pavarotti achieved his impressive vocal range. The mechanisms of active contraction for low notes, passive contraction for mid-range sounds, and automatic opening for high notes, as described by Umberti (1986), frame the complexity of vocal production. Echoing these mechanisms, Lienhard (2007) emphasized that advanced control of breath support allows singers to transition seamlessly between registers, enabling the execution of demanding passages like those in "La figlia del reggimento." The synergy between these factors highlights that vocal production extends beyond mere anatomical considerations to encompass the intricacies of trained muscle coordination and breath management.

While there is a consensus about the influence of anatomy and technique on vocal

ability, it is crucial to examine how Pavarotti's interpretative approach shaped his performances. According to Kauffman (2012), tension between vocal technique and emotional expression plays a pivotal role in a singer's resonance and dynamic range. Pavarotti often spoke of dedicating time to the musicality and expression embedded in each aria, and this commitment to artistry arguably enhanced his capacity to deliver high notes with clarity and ease. This aligns with research by Granqvist (2018), which posits that a singer's emotional dedication to a piece can facilitate vocal ease, particularly when navigating challenging passages.

Further complicating the discussion of high note execution is the role of contemporary recording techniques. Wierzbowski (2021) investigated how modern sound technology captures and enhances a vocal timbre, enabling singers like Pavarotti to project their artistry effectively. This technology not only showcases the technical brilliance of a vocalist but also contributes to the phenomenon of perceived vocal greatness, as audiences experience an idealized sound that may not fully represent live performance conditions. The ability to manipulate sound can create a perception of effortless high notes, raising questions about the interplay between technology and traditional vocal training.

Researching Pavarotti's vocal aging process reveals another vital perspective. As outlined in other literature, including studies by Ronzitti (2020), vocal changes through aging can influence vibrato rate and vocal efficiency. Pavarotti's transition from lighter lyric roles to dramatic parts is theorized to be a result of lifelong training, suggesting that singers can mitigate age-related changes through consistent practice. This new understanding offered insights into his evolving vocal technique and artistic interpretations as he matured, demonstrating the impact of technical adaptation over time.

Finally, the nonlinear source-filter theory articulates how vocal fold vibration and resonating chambers interact dynamically during singing. Titze (2008a) noted that an understanding of these interactions sheds light on a singer's ability to modulate pitch and harmonic strength. Our study examined how Pavarotti's acknowledgement of these principles might have underpinned his exceptional capacity to perform technically demanding repertoire while maintaining tonal clarity.

Conclusions

Luciano Pavarotti's phenomenal achievements in vocal performance were the result of a unique interplay between anatomical predisposition, detailed vocal training, interpretive commitment, and technological advancements. Pavarotti's disciplined training and dedication to the intricacies of vocal control and resonance further distinguished him in the world of opera, enhancing both the clarity and emotional expression of his performances. His ability to merge technical prowess with artistic interpretation fostered a unique voice that resonated deeply with listeners, embodying the spirit and passion of each aria he performed.

Reflecting on his contributions to the world of singing, it becomes increasingly clear that Pavarotti's feat of achieving multiple chest Cs in a single performance will remain unparalleled. While other contemporary singers may emulate aspects of his technique, the singular combination of his anatomical gifts and honed skills positions him firmly in a class of his own. Thus, Pavarotti not only etched his name in the annals of operatic history but also set an abiding standard that will be nearly impossible to replicate. His legacy serves as an enduring reminder of the heights of human vocal potential, showcasing the profound beauty and complexity embodied in the art of singing.

As vocal pedagogy continues to evolve, insights gained from Pavarotti's method can serve to educate emerging singers while honoring the complexities of the art form.

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