Journal of Voice
Vol. 13, No. 2, pp. 219–226

Preliminary Study on the Ability of Trained Singers to Control the Intrinsic and Extrinsic Laryngeal Musculature

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Summary: Little literature is available on professional musical theater female singers, a population that regularly uses a wide variety of vocal qualities. This study tested the hypothesis that different vocal qualities cause observable specific configurations of muscular movements and structural changes of the larynx, hypopharynx, oral pharynx, and oral cavity for individual singers. Fiberoptic rigid and flexible endoscopic observation were used to determine visual analysis of such configurations. This study documents observable physiologic changes that were made by professional musical theater female singers in specific vocal qualities. **Key Words:** Belt—Head—Legit—Mix—Register changes—Endoscopic observations—Musical theater female singers.

Musical theater frequently requires women to sing in several different vocal qualities in one role. Descriptions of these qualities vary from show to show but the terms most often used are *belt*, *mix*, and *legit*. Musical theater women are expected to know what these words mean and are supposed to be able to easily negotiate these quality differences, not only from one show to another but often within one role and sometimes within one song. There is no absolute definition of these qualities, but women come to know through exposure to the repertoire which specific sounds are expected in each quality. For the purposes of this paper, *belt* refers to a powerful chest or modal register,[1] *mix* refers to a lighter sound, as might be imagined by combining modal register with loft register,[2-5] or *belt* with *head* register. *Legit* refers to a strong head voice such as might be produced by an opera singer. It is very rare for the words *belt* and *mix* to be used in reference to males. *Legit* is used for both males and females who have been classically trained. For the purposes of this paper *head* will be used for *legit*.

Because singing in these styles is learned mostly through listening and trial and error, many singing teachers are not aware of how these qualities happen and cannot teach their singers how to sing in these qualities. Nevertheless, the Broadway market continues to demand great skill from women in these areas. There is little literature or research about these qualities, especially as pertains to this specific population of musical theater women.

Accomplished women singers are able to change qualities and often do so easily. The following is a listing of casting call requirements seen in recent issues of *Backstage*, the trade publication for Broadway and the New York City theater community. This

Accepted for publication August 3 , 1998.

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This paper was presented at the 26th Annual Symposium: Care of the Professional Voice, Philadelphia, Pennsylvania, U.S.A., June 5, 1997.

paper publishes casting notices for all auditions of Broadway, off-Broadway, and regional theater companies for New York.

"20's – early 30's, soprano-belt"

"female lead: late 20's to mid-30's, strong show voice, belt-legit"

"leading lady, strong mix and strong belt to D"

"major jazz dancer who sings excellently, soprano up to B flat and belt"

"cruise ship seeking sopranos, must have C with strong belt"

"Ms. Saigon; Ellen: must have strong chest belt from G up to an E"

"High lyric or coloratura soprano, light belt and soprano."

In 1992, Karen Ziemba, a well-known Broadway performer, was interviewed by the *New York Times*. She was appearing at the time as Lizzie in a production of *110 in the Shade* at the New York City Opera. The following is an excerpt from that article by Glenn Collins:

"Of her own vocal range, Ms. Ziemba said, 'I sing mezzo-soprano, soprano and belt.' 'Belt?' 'You know, Ethel Merman. You find the note somewhere. Then you just belt it out.'" (*New York Times*, July 30, 1992)

Almost all of the respected books on vocal pedagogy have been written by teachers who have spent many years working with classically trained singers, that is, those being prepared to sing opera, oratorio, and art songs. The application of the middle register, which we call here *mix*, as used in musical theater by women at the present, has not been extensively studied. Estill[6] has observed differences in belting and classical qualities but does not note the mix quality as used by the musical theater community in her work.

There is some disagreement among both singing teachers and scientists about the stability of the larynx and about other vocal tract behaviors in trained singers. Both voice teachers and scientific researchers have observed adjustments in vocal production, but there is no consensus regarding the relationship of those adjustments to any particular musical styles.

Appleman[7] has noted that the larynx in the phonatory tube changes much more in the trained voice than it does in an untrained voice. Richard Miller,[8] citing Sonninen, observed that at the identical pitch varying ratios of thyroarytenoid or cricothyroid function may occur. Further, he suggested that the cricothyroid joint is not at a fixed position, that the thyroid and cricoid cartilages have several possibilities of movement in relation to the spine and to each other. Contrastingly, Sataloff[2] remarked that the extrinsic muscles are critical in maintaining a stable laryngeal skeleton so that the delicate intrinsic musculature can work effectively. In the Western classically trained singer the extrinsic muscles maintain the larynx in a relatively constant position. According to Vennard[3] high larynx singing is poor, and shows an inability of the singers to control pitch by the intrinsic muscles. Further, Vennard believes that there is at least an octave that can be sung in either chest or head, and that if the singer cannot easily move from one register to the other there will be a crack.

Husler[9] discussed the complexity of the vocalis, suggesting that not only single muscle bundles operate but that separate muscle fibers are capable of isolated work, contributing to almost limitless variations of tension within the larynx itself.

Because some issues are not clear we looked at how these singers' vocal quality changes affected anatomic configurations in individual singers and between singers.

MATERIALS AND METHODS

This study looked at 7 trained professional female musical theater singers who stated they could sing in belt, mix, and head qualities with equal ease. Their age range was 23 to 48 years, length of training was 11 to 32 years, and the amount of professional experience using these qualities was 7 to 32 years. Six

singers were in good health on the days of the testing but 1 singer had small bilateral nodules, previously diagnosed by a well-known otolaryngologist as being caused by a trauma. This woman is a highly successful jazz artist who performs extensively and teaches. The nodules did not interfere with her performance of the research tasks and were disregarded in this study.

Examination of the oral cavity and oral pharynx

Examination of the oral cavity and oral pharynx was done without topical anesthesia. The subject was seated in an upright position. A condenser microphone with a fixed microphone-to-lip distance was used to record the sound onto the videotape and produce the signal for on-line decibel statistics. A zero-degree photodocumentation Hopkins rod rigid laryngoscope (Storz 8701 AG) was placed into the vestibule of the oral cavity and stabilized on the maxillary incisors of the subject. The rigid telescope was attached to a 3-chip endoscope camera with standard Super-VHS recording using the videostroboscope equipment (Kay Elemetrics 9100 with on-line display of statistics and computer integration). Without changing the endoscope camera position or angle, the oral cavity and oral pharynx were recorded during sustained sung vowels, as described below. Attempts were made to keep the decibel level constant throughout the tasks. After a brief period, all subjects were able to tolerate the equipment and the test environment and could produce consistent vowel productions of the various tasks.

Examination of the larynx, hypopharynx and base of the tongue

Examination of the larynx, hypopharynx, and the base of the tongue required endoscopic evaluation with a flexible fiberoptic endoscope. The Olympus 3.7-mm flexible fiberoptic endoscope (ENF-P3) was passed by the physician (PW) after topical nasal anesthesia. Care was taken to anesthetize only the nasal cavity by using 2% Pontocaine on cotton carriers. Six of 7 subjects received anesthesia nasally. The flexible endoscope was placed to the tip of the uvula, allowing a full view of the pharynx and larynx. This placement was fixed by securing the fiberscope against the alar cartilage of the nasal cavity, thus also fixing the endoscope position relative to the tip of the nose. This allowed observation of laryngeal height adjustments and other laryngeal configurations from a stable and unchanged position. The flexible endoscopic observation used the same setup and video equipment as that used for examination of the oral cavity and oral pharynx, as above.

For the purposes of this study we considered the intrinsic vocal musculature to be that within the larynx, and looked for things such as anterior/posterior constriction and degree of medial compression. Extrinsic vocal musculature was considered to be seen as operating in laryngeal height change and other vocal tract configuration adjustments.

During the observation with the rigid endoscope, each singer was asked to sing the vowel /a/ on A4 (415 Hz). The initial task was to sing in head quality at approximately 80 dB for approximately 2 seconds on a "dark" vowel. A "dark" vowel was assumed to be one where the resonance of the sound was felt in the back of the mouth near the soft palate rather than in the front of the mouth near the teeth and to have a connotation of sadness or somberness. The meaning of *dark* was not given to the singers at the time of the test. Each singer was assumed to have her own understanding of the term. The second task was to remain in the same quality (head), at the same pitch, at the same loudness and to sing a "bright" vowel sound on /a/. A "bright" vowel was assumed to be one where the resonance of the sound was felt in the front of the mouth with a happy or cheerful quality. Again, no definition was given. The singer was then asked to perform the above tasks in mix quality and then in belt quality. The rigid endoscope was held in the mouth to view differences in the tongue, soft palate, and oral pharynx throughout all tasks.

Mix dark was chosen for the baseline because it was assumed to be the most likely register quality and vowel sound quality to be used by women in musical theater material not specifying belt or head, that is, their "home base."

During the observation with the flexible endoscope, each singer was asked to produce /i/ on A4 (415 Hz). The singers were asked to sing in head quality, then mix quality, then belt quality. They were asked to sing each quality for approximately 2 seconds, pausing for 1 second between changing quali-

ties. They were asked to maintain the same loudness (approximately 80 dB) for all tasks.

All subjects could see the monitor, although not all subjects chose to view the monitor while performing the tasks. The monitor showed the decibel level, and the endoscopic picture.

The singers each believed they had changed both the vowel sound and the register quality as asked. The vowel and register quality changes were verified by at least 2 other singers who were in the room.

The results were evaluated by the 3 coauthors, who independently rated the visual changes in the endoscopic and fiberoptic observations on each of the subjects. The data were acceptable if 2 out of the 3 evaluators agreed. In all the following tables, "no agreement" between evaluators' observations was indicated by the letters *NA*. Where the anatomic structures were obscured from view, data were designated not "visible," indicated by the letters *NV*. "No change" was indicated by the letters *NC*.

RESULTS AND OBSERVATIONS

Comparison of vowel quality using the rigid endoscope (Table 1)

This test was done with the rigid endoscope. The subjects were asked to begin with a dark /a/ vowel and change to a bright /a/ vowel in each of the 3 register qualities: head, mix, and belt. The brighter vowels were made predominantly by some manner of reducing the space in the back of the mouth through combinations of adjustment of the posterior two thirds of the tongue, the palate, and the oral pharynx. All subjects brought the tongue up; some brought the palate down, or brought the oral pharynx in, or did a combination of gestures while combining two or three. This reduction of space occurred in all bright vowels in all register qualities for 90% of the tasks.

Observations of comparison of register quality using the rigid endoscope (Table 2)

These data were extracted from the same test samples above. In head register as compared to mix, for most subjects (4 of 7) the tongue was raised, the palate was higher (3 of 7), and the oral pharynx seemed inconsistent. In belt, there was no consistent change in the tongue, the palate was up in 5 of 7, and the oral pharynx was more vaulted (narrower) in 4 of 7 subjects.

Observations of comparison of register quality using the flexible endoscope (Table 3)

In this test subjects were asked to sing /i/ in each of 3 register qualities: head, mix, and belt. In head register, in most of the observations, it was found that there was less constriction in the larynx and pharynx, and consequently more room in both structures. Belt register performed according to expectations, which generally have found that belting is associated with high levels of tension or constriction. However, in 2 areas, larynx height and pharyngeal wall position, there were unusual data, contrary to some previous studies, which may indicate less tension or constriction.

In head production, the larynx height was lower than in mix in all subjects, as would be expected. When laryngeal anterior-posterior constriction was observed, 6 of 7 subjects had vocal folds that were shorter in belt production as compared to mix, and 1 subject's data were inconclusive. All subjects had vocal folds that were longer in head production as compared to mix. When laryngeal lateral constriction was observed, 4 of 7 subjects had more constriction in belt production as compared to mix, 1 subject did not change, and 2 subjects' data were inconclusive.

In head production as compared to mix, 5 of 7 subjects had less lateral constriction, 1 subject did not change, and 1 subject's data was inconclusive. When movement of the lateral pharyngeal wall in belt production as compared to mix was observed, 4 of 7 subjects did not change, two subjects widened, and 1 subject's data were inconclusive. We determined that not only were 4 subjects able to maintain the same amount of pharyngeal space for belt, but 2 subjects actually made more pharyngeal space for belt than for mix. Because belting has been found to cause a narrowing of the pharyngeal walls, these data were unexpected.[10] Further investigation would seem warranted.

In head production as compared to mix, 3 of 7 subjects did not change their lateral pharyngeal wall, 2 subjects had a more medial movement, and 2 subjects' data were inconclusive. In movements of the tongue base in belt production as compared to mix, 4 of 7 subjects had posterior movement, 1 sub-

TABLE 1. *Comparison of vowel quality changes using the rigid endoscope*

Tasks	Subjects						
	1	2	3	4	5	6	7
Mix dark	baseline	baseline	baseline	baseline	baseline	baseline	baseline
Mix bright							
Tongue—posterior ⅔	up	up	up	up	up	up	down
Palate	NA	down	NV	down	up	NC	up
Oral pharynx	more vaulted	NA	NV	more vaulted	more vaulted	NA	more vaulted
Belt dark	baseline	baseline	baseline	baseline	baseline	baseline	baseline
Belt bright							
Tongue—posterior ⅔	up	up	NA	up	up	up	up
Palate	NC	down	down	down	up	up	down
Oral pharynx	more rounded	more rounded	more vaulted	more vaulted	more vaulted	NA	NA
Head dark	baseline	baseline	baseline	baseline	baseline	baseline	baseline
Head bright							
Tongue—posterior ⅔	up	up	up	up	up	up	up
Palate	NA	up	down	down	NC	NA	NA
Oral pharynx	more rounded	NA	NA	NC	more rounded	NC	more rounded

Note: NA = no agreement; NV = not visible; NC = no change.

TABLE 2. *Comparison of register quality changes using the rigid endoscope*

Tasks	Subjects						
	1	2	3	4	5	6	7
Mix dark	baseline	baseline	baseline	baseline	baseline	baseline	baseline
Chest dark							
Tongue—posterior ⅔	up	NC	up	down	NA	down	down
Palate	down	up	up	up	up	up	down
Oral pharynx	more rounded	more vaulted	more vaulted	more vaulted	NC	NA	more vaulted
Head dark							
Tongue—posterior ⅔	down	NC	up	up	up	up	down
Palate	NA	NA	up	down	NA	up	up
Oral pharynx	more vaulted	NA	more vaulted	more rounded	more rounded	NA	more vaulted

Note: NA = no agreement; NV = not visible; NC = no change.

TABLE 3. *Comparison of register quality using the flexible endoscope*

Tasks	Subjects						
	1	2	3	4	5	6	7
Mix	baseline	baseline	baseline	baseline	baseline	baseline	baseline
Chest							
Larynx height	lower	higher	lower	NC	NC	lower	lower
Laryngeal anterior-posterior constriction	shortest	shortest	shortest	shortest	NA	shortest	shortest
Laryngeal lateral constriction	more	NA	more	NC	NA	more	more
Lateral pharyngeal wall	NC	NC	NC	NC	wider	wider	NA
Tongue base	posterior	posterior	posterior	NV	posterior	NA	NC
Epiglottis position	curled back	NC	curled back	NC	curled back	curled back	NC
Head							
Larynx height	lowest	lower	lower	lower	lower	lower	lower
Laryngeal anterior-posterior constriction	longest	longest	longest	longest	longest	longest	longest
Laryngeal lateral constriction	NC	NA	less	less	less	less	less
Lateral pharyngeal wall	NC	NC	more medial	NA	more medial	NC	NA
Tongue base	anterior	NA	anterior	NA	NV	anterior	NC
Epiglottis position	NC	NC	NA	NC	forward	forward	NC

Note: NA = no agreement; NV = not visible; NC = no change.

ject did not change, 1 subject's tongue base was not visible, and 1 subject's data were inconclusive.

In head production as compared to mix, 3 of 7 subjects had anterior movement, 1 subject did not change, 1 subject's tongue base was not visible, and 2 subjects' data were inconclusive. In epiglottis position in belt production as compared to mix, 4 of 7 subjects had a curled back position and 3 subjects did not change. In head production, 4 of 7 subjects did not change epiglottis position, 2 subjects had a forward position, and 1 subject's data were inconclusive.

DISCUSSION

In Table 1 it was observed that bright vowels are the product of smaller space. The variation of how that space was made smaller was very individual to each singer. Sometimes the changes made in the oral pharynx, palate, and posterior tongue were very small and difficult to detect, yet the observers' ears could perceive a distinct difference in the sound. At other times, the changes in the position of the 3 components of the oral cavity moved considerably from the dark home base /a/ vowel to the brighter quality, yet the aural change was less distinct. Remembering that the decibel level remained reasonably constant, what else may be affecting these changes? Were they affected by the shape of the mouth, the position of the head or jaw? Were they influenced by the abdominal muscles or other factors? All of these points would be interesting for further exploration.

It was expected that register quality would not affect the oral cavity in any significant way; however, data from Table 2 indicate that register changes do affect this area more than was anticipated. Singing teachers would ask, what is the difference between the tone quality and the vowel color or resonance? Classical singers blend tone quality and resonance very smoothly but music theater singers, especially women, are often called on to do the exact opposite. It appears that changes in the mouth, palate, and posterior tongue are related to changes in both the pharynx and larynx and do affect register quality and vowel sound quality.

The data in Table 3 were surprising in that the larynx height of belt production was lower than mix in 4 of 7 subjects. This is counter to much of the literature, where a high larynx position is expected in belt. In addition, 2 more subjects had no change in the larynx height in belt compared to mix. This would also be unexpected, as this indicates that vertical larynx position can remain the same and still produce a different register quality.

In other studies head register was found to be produced with a low larynx position, a generally more relaxed laryngeal configuration, and a higher tongue placement in the mouth. The data in this study also agreed with these findings. We concluded that our singers produced head register similarly to those who had been observed in previous studies. The mix register configuration in this study most often found the larynx at the same height or higher than head register, but there are few data available on this particular type of sound quality, as used by musical theater women, to use for comparison. The belting quality for our subjects was also produced similarly to singers in other studies with the two previously mentioned distinctions, which may be significant.

This study has validated that it is possible for singers to sing various register and sound qualities while being observed with both a rigid and flexible endoscope. It created a rating system based on physiologic movement. It has looked at a small group of singers, rather than at just one. It has sought to establish some relationship between tonal quality, voicing gestures, vocal tract changes, and endoscopic observation. The singers were able to produce natural sounds in response to objective criteria. The data suggest that vocal quality changes caused certain observable physiologic responses.

Sundberg[1] stated, "the singer can be assumed to have mastered the system more efficiently than the non-singer. The individual differences between subjects may lead them to devise different strategies for utilizing their vocal musculature."

It was strongly suggested that this population was able to do just that. There was great variability in executing tasks but each singer had her own way of achieving the desired result. It was not part of this study to evaluate each participant's accuracy over an extended period of time. During the study, however, singers often repeated a task more than once, attempting to more accurately accomplish the requested vocal gestures, sometimes exclaiming, "No, wait, I can make that more 'mixy,'" or "I can make that a

brighter /a/." Each singer seemed to know in her own mind exactly what she had not accomplished and what to aim for in making improvements on the next attempt. Accuracy over time within each singer must be added to the protocol for all additional tests.

As previously mentioned, there was unexpected behavior in laryngeal lowering for belt in several singers and unchanged laryngeal height for two, as well as stable opening or widening of the pharyngeal walls, which must be investigated further. Perhaps this suggests that singers had learned to lower general tension levels through training. It is well known that the most relaxed position for singing is one in which the larynx remains comfortably low. Even if one realizes that the sound quality being produced will incline the larynx to rise, striving for a "low larynx position" when studying may produce behaviors that compensate for tension.

Because all of these subjects are or have been paid to sing in highly competitive commercial markets, we can assume that they have been singing in a fashion that allows them to sound appealing, stay healthy, and do the job for which they were hired. Their ability to produce appropriate sounds could make or break being given or keeping a job, so they would be strongly motivated to learn to sing efficiently and consistently.

CONCLUSIONS

Singers do indeed adjust the tongue, palate, and oral pharynx in response to the expected vocal gesture, based on the tonal quality. There was systematic adjustment of the vocal tract, larynx, hypopharynx, oral pharynx, and oral cavity. Some conclusions were expected, such as the lowered larynx and decreased tension in head register production, and the smaller oral cavity for brighter vowels sounds. Some conclusions were surprising, such as lowered or unchanged larynx height and widened pharyngeal walls for belting quality. This may be due to training and experience gathered by the singers in the course of their careers. The data presented here give only a glimpse of what is happening. The data do suggest that different vocal qualities cause adjustments that may be more than accidental or random in the oral cavity and vocal tract; and that these changes are variable from singer to singer.

REFERENCES

1. Sundberg J. *The Science of the Singing Voice.* DeKalb, Ill: Northern Illinois Press; 1987:50.
2. Sataloff R. *Professional voice: The Science and Art of Clinical Care.* New York, NY: Raven Press; 1991:31-33.
3. Vennard W. *Singing: The Mechanism and the Technique.* New York, NY: Carl Fischer; 1967:88.
4. Reid C. *The Free Voice.* New York, NY: Patelson; 1972:32-33.
5. Bunch M. *Dynamics of the Singing Voice.* Vienna: Springer-Verlag; 1982:69.
6. Estill J. Belting and classic voice quality: some physiological differences. *Med Probl Perform Art.* 1988;3:37-43.
7. Appleman R. *The Science of Vocal Pedagogy.* Bloomington: Indiana University Press; 1967:87.
8. Miller R. *The Structure of Singing.* New York, NY: Schirmer Books; 1996:290.
9. Husler F, Rodd-Marling Y. *Singing the Physical Nature of the Vocal Organ.* 2 ed. London: Hutchinson; 1976:18.
10. Sundberg J, Gramming P, Lovetri J. Comparisons of pharynx, source, formant, and pressure characteristics in operatic and musical theater singing. *J Voice.* 1993;4:301-310.