# Respiratory and Acoustical Differences Between Belt and Neutral Style of Singing

*,†Johan Sundberg and †Margareta Thalén, *†Stockholm, Sweden

**Summary: Objectives.** Belt is a style of singing commonly used in nonclassical genres. Its respiratory, phonatory, and resonatory characteristics are unclear.

**Design.** Basic research.

**Methods.** Six female singers, professionally performing in the belt styles since many years, sang an excerpt of a song in belt and nonbelt/neutral style, two times with the lyrics and two times replacing the lyrics with /pae/ syllables. On separate channels, recordings were made of audio, oral pressure, and rib cage and abdominal wall movements, as picked up by respiratory inductive plethysmography. Lung volume and breathing patterns during inhalation and phonation were normalized with respect to duration and averaged. Voice source was analyzed in terms of flow glottograms derived from the audio signal by inverse filtering.

**Results.** Belt was produced with higher pressures and yielded higher sound levels, but no consistent breathing pattern was observed, neither for the belt, nor for the neutral style. Voice source differences suggested that belt was produced with firmer glottal adduction than neutral. Also, in four of the singers, the first formant was closer to a spectrum harmonic in belt than in neutral.

**Conclusions.** Belt style of singing is not associated with a characteristic breathing behavior but is produced with higher subglottal pressures, higher sound levels, and firmer glottal adduction than a neutral style of singing.

**Key Words:** Voice source–Formant frequency–Subglottal pressure–Respiratory inductive Plethysmography–Breathing pattern.

## INTRODUCTION

The human voice has been used as a music instrument in singing in all times and in all cultures but the styles of singing differs radically both between and within cultures. The Western classical operatic style has developed over several centuries. During the last century, a number of other singing styles have developed, eg, in the areas of musical theater and the so-called contemporary commercial music (CCM). Also acoustic documentation has been available since the beginning of the 20th century. For example, a gramophone recording of the *Crazy Blues* song, performed by the female singer Mamie Smith, was released in 1920.

In recent years, nonclassical styles of singing have caught the interest of voice researchers, and some important investigations have been published. Several of these have dealt with the so-called belt style of singing, commonly used both in musical theater and CCM. Estill[1] published both electromyographic and electroglottographic (EGG) data on belt voice that suggested a high degree of activity in laryngeal muscles and long contact phase of the vocal fold vibration, approximately 70% of the cycle. According to Lawrence,[2] belting is typified by "a relatively high laryngeal position, essentially closed ventricular spaces, constricted pharyngeal diameters… (an) epiglottis often tilted over the larynx and an often elevated tongue base." He also describes the vocal tract as "constricted" during belting. According to Miles and Hollien,[3] belt is produced in chest register and with strong high frequency partials. In a single subject study, belt voice was found to be associated with high subglottal pressures, high sound levels, and strong glottal adduction.[4] In another single-subject study, Bestebreurtje and Schutte[5] found that, in belt, voice formants were tuned to spectrum partials. They also found that the EGG contact phase was long, greater than 52%. Sundberg et al[6] analyzed the voice source and formant frequencies in several different substyles of belt voice. They found that "heavy belt" was produced with high subglottal pressures, long closed phase, and with a weak voice source fundamental. All these observations are in agreement with the assumption that belt voice is produced with an elevated degree of glottal adduction.

Among singers, voice pedagogs and clinicians, it is commonly assumed that respiratory behavior strongly influences voice function. A likely reason for this is the tracheal pull, ie, the caudally directed force that the respiratory system exerts on the larynx. This force tends to be stronger at high than at low lung volumes, and according to Zenker and Zenker,[7] it is associated with a widening of the glottis. Such a widening is likely to affect phonation. When glottal adduction is strong, the closed phase of the glottal vibratory cycle tends to be long and the amplitude of the transglottal air pulses low, being typical of hyperfunctional/pressed phonation. Hence, a less forceful glottal adduction promotes a more neutral or, in the extreme, even a breathy type of phonation. The dependence of phonation type on lung volume was corroborated in a series of investigations of untrained singers.[8] Thus, untrained voices showed signs of increasing glottal adduction when lung volume decreased. This effect could not be observed in professional opera singers,[9] who also showed intraindividual and highly consistent breathing patterns, thus strengthening reasons to assume that

Accepted for publication September 15, 2014.

This investigation was supported by the University College of Music Education, Stockholm, Sweden.

From the *Department of Speech Music Hearing, School of Computer Science and Communication, KTH, Stockholm, Sweden; and the †SMI (University College of Music Education), Stockholm, Sweden.

Address correspondence and reprint requests to Johan Sundberg, Department of Speech Music Hearing, School of Computer Science and Communication, KTH, SE-100 44 Stockholm, Sweden. E-mail: pjohan@speech.kth.se

Journal of Voice, Vol. 29, No. 4, pp. 418-425

0892-1997/$36.00



http://dx.doi.org/10.1016/j.jvoice.2014.09.018

breathing patterns are relevant to phonation. On the other hand, the interindividual variation was substantial.

Using respiratory inductive plethysmography, Monika Hein[10] studied rib cage and abdominal wall movement patterns in subjects commercially performing in popular music and/or musical theater styles. She also measured their subglottal pressures captured as the oral pressure during the occlusion for the consonant /p/. The singers' task was to sing the same material in belt voice as well as in a more neutral, "legit" type of singing. She found that the subglottal pressures in belt were clearly higher. In her dissertation, Hein also included breathing patterns in an appendix. Although she refrained from commenting on these data, it is clear that the lung volume decrease was surprisingly small during belting but also during these singers' legit singing. The movements of rib cage and abdominal wall showed a great interindividual variation, but within a singer, the behavior was mostly similar in belt and legit. During inhalation, several subjects first expanded and then contracted the abdominal wall, but one did the opposite, first contracting and then expanding the abdominal wall (AW). Thus, the subjects showed consistent breathing behaviors, which however varied between the singers.

There are reasons to assume that for a given style, professional singers use similar breathing patterns. For example, in a style requiring an elevated degree of glottal adduction, a contracted abdominal wall during the phrases may be advantageous because it would tend to promote glottal adduction; a contracted abdominal wall raises the diaphragm, and this reduces the tracheal pull, which, in turn, should promote phonation with an elevated degree of glottal adduction. It is possible that also the breathing behavior during inhalation is relevant to glottal function; an expansion of the abdominal wall during inhalation may promote a different glottal tuning than inhalation with a contracted abdominal wall.

Based on these ideas, we hypothesized that in belt compared with a neutral style of singing,

1. rib cage rather than abdominal wall expansion dominates inhalation
2. high lung volumes are avoided
3. belly-in posture during phrases is typical
4. an elevated degree of glottal adduction is used.

## METHOD

Six female singers volunteered as subjects, age range 23–42 years. They had been performing popular music professionally in belt as well as in other styles of singing between 4 and 25 years. They were asked to sing an excerpt of a song two times in belt style and two times in a neutral, nonbelt style of singing (Theme from *New York New York* by Fred Ebb and John Kander), Figure 1. They first sang the song with the original lyrics and then replaced the syllables of the lyrics with the syllable /pae/.

All recordings were made in a sound-treated studio, about 3 × 4 × 2.5 m, using the Soundswell signal workstation with four tracks, all accepting both AC and DC (alternating and direct current, respectively) signals. The audio was picked up by a headworn omnidirectional electret microphone located at a measured distance from the mouth. Sound level was calibrated by recording a sine tone, the sound pressure level (SPL) of which was measured at the recording microphone by means of an OnoSokki (Yokohama, Japan) sound level meter. The SPL reading was announced on the tape. Oral pressure during the p-occlusion in the /pae/ syllables was recorded by means of a Glottal Enterprises (Syracuse, NY, USA) pressure transducer connected to a thin plastic tube, the end of which the subjects held in the corner of the mouth. The recorded pressure signal was calibrated by exposing the transducer to pressures measured by means of a manometer. The pressure values were announced in the recording.

Breathing movements were recorded using a Respitrace equipment. One respiband was placed around the rib cage at the level of the nipples and the other around the waist at the level of the navel. The signals from these respibands were recorded on separate tracks by the Soundswell system.

The calibration of the respibands was derived from three exercises. First, their sensitivity to volume was calibrated by means of isovolume maneuvers, Figure 2, left panel; the subjects were asked to alternately expand and contract the abdominal wall while keeping glottis closed. Second, the subject made at least three maximally deep inhalations followed by maximally deep exhalations, thus documenting her vital capacity (VC), Figure 2 middle panel. Finally, the subject performed a set of relaxed sighs, such that the resting expiratory level (REL) could be determined, Figure 2 right panel.

The Respitrace signals from the second take of all conditions were transferred to Excel files. Each inhalation and each phonation episode was marked in the file, and then these episodes were sampled at 1000 points, equidistant in time. This yielded two columns in the excel file, where each line corresponded to the respiband values during one thousandth of the duration of the total episode. The excerpt recorded contained three or four inhalations. The breathing patterns during inhalations and phonations were averaged.

The analysis of the data involved several steps. First, the amplitude of one respiband signal was adjusted to be equal to

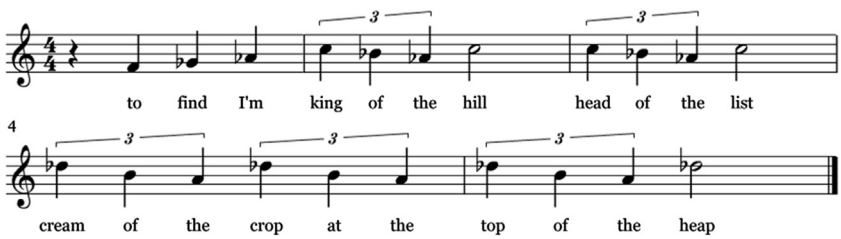


**FIGURE 1.** The music excerpt analyzed, adapted from the theme of the movie "*New York New York*", performed by Liza Minnelli.