Voice Source Register Differences in Female Musical Theatre Singers

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ABSTRACT

Musical theatre singing requires the use of two vocal registers in the female voice. The voice source and subglottal pressure P_s characteristics of these registers are analysed by inverse filtering. The relationship between P_s and closed quotient Q_{closed}, peak-to-peak pulse amplitude U_{p-t-p}, maximum flow declination rate MFDR and the normalised amplitude quotient NAQ were examined. P_s was typically slightly higher in chest than in head register. For typical tokens MFDR and Q_{closed} were significantly greater while NAQ and U_{p-t-p} were significantly lower in chest than in head.

1. INTRODUCTION

Vocal register is a phenomenon of great relevance in vocal art, particularly in female singing. An important task in singing training, regardless of style, is to teach the student how to master the transition from one register to the other with minimal timbral changes. The register used in the lower part and in the adjacent higher part of the female pitch range is here referred to as chest and head, respectively. Vocal registers reflect voice source characteristics, e.g., Q_{closed}, peak-to-peak pulse amplitude U_{p-t-p}, and maximum flow declination rate MFDR. All these parameters are heavily influenced by subglottal pressure P_s and glottal adduction. Hence it seemed reasonable to analyse these parameters. The Normalised Amplitude Quotient NAQ defined as the ratio between $U_{p-t-p}/(T0*MFDR)$ [1] seems related to glottal adduction and is correlated with degree of perceived phonatory pressedness [2].

In classical singing mainly the head register is used while in non-classical styles, like pop, jazz and blues, chest is used more commonly. Musical theatre singing, on the other hand, demands a perfect control of both registers. In this repertoire high subglottal pressures are typically used. Such pressures sometimes jeopardise vocal health. To understand the reason for this, a better knowledge of the register function in female singing is needed. Therefore, the present investigation studies the register function in professional female musical theatre singers by analysing their voice source characteristics, paying special attention to the influence of subglottal pressure on these characteristics.

2. MATERIAL AND METHODS

2.1 Subjects and recording

Seven female singers, all classically trained and working professionally as musical theatre actors, volunteered as subjects. Their ages were between 17-43 years and all, except one, had professional experience for duration of 11 to 25 years. Their task was to sing a sequence of the syllable /pae/ at a pitch where they could use both chest and head register. This pitch varied between C4 and G4 for different subjects. They initiated the sequence at high lung volume and at maximum degree of vocal loudness and continued while gradually decreasing vocal loudness. They were asked to perform this sequence three times first in chest and then three times in head register. The vowel /ae/ was chosen since its high first formant adds to the reliability of inverse filtering and the oral pressure during the p-occlusion allows estimation of P_s.

The flow signal was recorded using the Rothenberg mask, a specially designed pneumotachograph for capturing oral flow. The subject held a plastic tube, inner diameter

4 mm, in the corner of her mouth for recording oral pressure. The audio signal outside the mask was recorded from a microphone at a distance of 30 cm from the lips. All these signals plus an EGG signal (Glottal Enterprises) were recorded on a multi-channel digital recorder [TEAC RD 180 PCM].

2.2 Analysis

The effect of P_s variation on the voice source can be ideally analysed by examining glottal parameters as function of several P_s values. Therefore, for each subject and register ten approximately equidistantly spaced P_s-values were selected. The entire material thus consisted of a total of 140 samples, ten for each register and singer, respectively. Subject MAR produced emphatic /p/ explosions in her head register recordings, as demonstrated by sharply peaked oral pressure peaks [3]. Following the recommendation of Hertegård the estimates of P_s in these cases were taken from the discontinuity appearing in the initial part of the pressure peak.

2.3 Listening test

A computerised listening test (Judge, S.Granqvist) was run with a panel of three voice experts. Their task was to rate along a visual analogue scale how representative the various 280 sung samples (10 degrees of vocal loudness x 2 registers, x two presentations of each sample) were of chest and head register. The subjects were presented with a visual analogue rating scale on the computer display, where 0 marked 'Chest' and 1000 was marked 'Head'. The program recorded all settings on text files. Fig 1 shows the standard deviations as function of the ratings averaged across the three raters. The standard deviations were highest in the center of the scale, as expected. For some singers the chest and head register
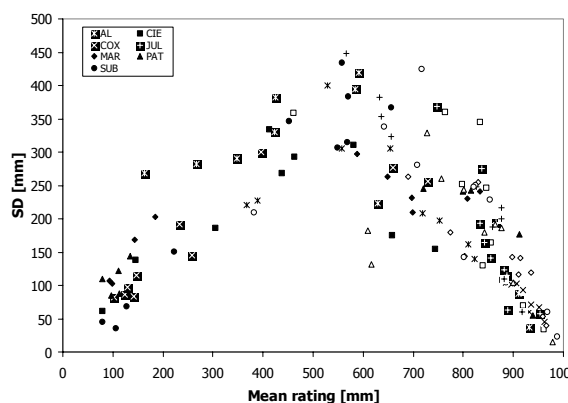

Fig 1. Standard deviations of the three experts' register ratings as function of the averages of these ratings. Symbols refer to singer subjects, and filled and open symbols pertain to chest and head register, respectively.

data are gathered toward the left and right sides of the graph, respectively, indicating that their chest and head register samples were perceived as clear examples of these registers. Singers JUL and AL, in particular, produced samples that differed less clearly. Therefore their data were disregarded.

A total of 16% of the samples received mean ratings in the interval 0 – 250 while 49% of the samples received ratings in the interval 750-1000. The 17 samples that received ratings in the range of 0-250 were thus accepted as 'clear cases of chest register' while the 17 samples that received the highest mean ratings were considered as clear cases of head register.

2.4 Voice source analysis

Flow glottograms were obtained using the DeCap custom-made program (S. Granqvist). The formant frequency values were adjusted such that a ripple- free closed phase was obtained. These values were checked, by using them for synthesising the vowel sound in the custom made MADDE synthesiser (Granqvist).

From the resulting flow glottograms, period time, Q_{closed}, $U_{p\text{-}t\text{-}p}$ and MFDR were measured. In addition the normalised amplitude quotient NAQ was determined. As P_s significantly influences most of these parameters [2] it seemed relevant to examine their variation with P_s for the two registers.

3. RESULTS

3.1 Statistical analysis

A 2-way ANOVA was carried out for the clear cases, with register and singer as factors. Due to a technical problem singer SUB`s recordings had to be excluded from the statistical analysis. Results showed register as highly significant (p=0.01) for all parameters. Factor singer was found to be significant for P_s, $U_{p\text{-}t\text{-}p}$ and MFDR. For MFDR a significant interaction was also found between the two factors. A 2-way ANOVA for all cases showed that register was highly significant for the parameters P_s, Q_{closed} and NAQ, and singer was highly significant for parameter P_s, $U_{p\text{-}t\text{-}p}$, MFDR and NAQ. No significant interaction between register and singer was found for any parameter.

3.2 Acoustic/aerodynamic analysis

Fig 2 illustrates the differences between the registers in terms of the means across the 17 clear cases. The mean and SD of P_s were
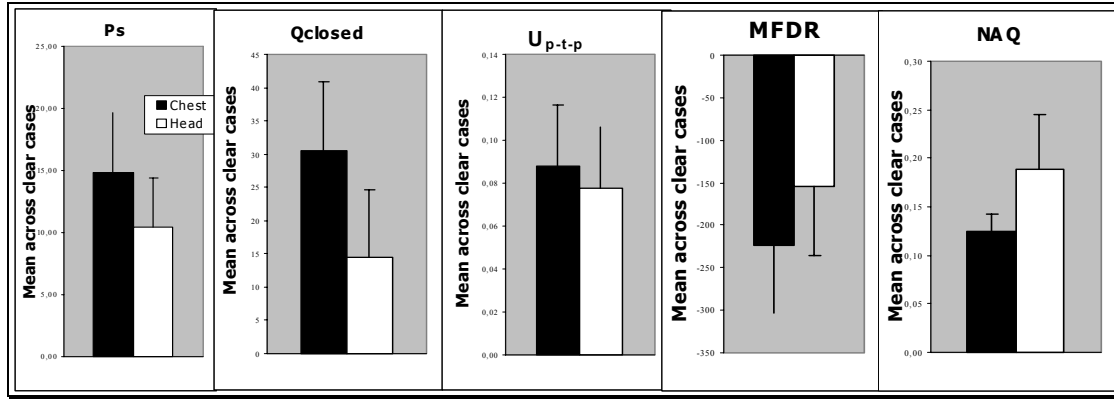
Fig 2. Means of the indicated parameters across singer subjects for the clear examples of the two registers, see text.

higher for the chest register samples, which also had higher Q_{closed}, somewhat higher $U_{p\text{-}t\text{-}p}$ and lower NAQ means. The MFDR values were more negative in the chest. register. Mean P_s values, calculated over each subject's 10 P_s values in each register, showed higher values for chest than for head for all subjects. Fig 3a illustrates the relationship between P_s and Q_{closed}. Chest register phonations tended to show higher Q_{closed} values than head register phonations. The same relationship is illustrated also in fig 3b, showing the relationship between pressure and Q_{closed}, averaged across subjects. Here pressure is given in terms of the normalized excess pressure P_{SEN} [4]. The dashed curves represent an approximation of the data points by means of a power function (Sundberg & al, 1999). The registers differ clearly with respect to the asymptote, reaching 25% and 20% in chest and head registers, respectively. In addition, the growth of Q_{closed} with increasing P_{SEN} is quicker in chest register. These findings strongly suggest that a longer closed phase is typical of chest as compared to head register.

As P_s heavily influences glottal parameters, comparisons at identical P_s values are informative. All singers had used a P_s value of 11 cm H2O, approximately (Fig.s 4a – e). Considering the random variation inherent in the individual data underlying the figure, several surprisingly clear trends can be observed. For all subjects sound level was higher in chest (Fig 4a) apparently supporting the typical observation that head register at low F0 is difficult to combine with loud phonation. Fig 4b shows that the higher sound level in chest corresponded to a more negative MFDR. The closed phase was clearly longer in chest, Fig 4c. While $U_{p\text{-}t\text{-}p}$ did not differ consistently between the registers and varied among singers, Fig 4d, NAQ was consistently lower in chest than in head (Fig 4e). Summarising the P_s difference between the registers cannot account for all of the differences illustrated in Fig 2.

4. DISCUSSION

Several precautions were taken to optimise measurement reliability of the inverse filtering and our results showed a systematic variation with P_s that was similar to that found under more ideal experimental conditions. This suggests that our data were reasonably reliable. The availability of several P_s values seems a strong advantage, providing heavy support for the observation that P_s influences a number of flow glottogram characteristics. For example, the variation of Q_{closed} with P_s was similar to
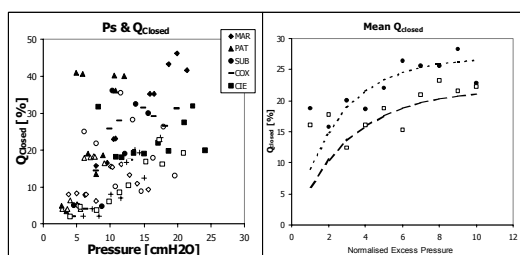

Fig 3. Closed quotient Q_{closed} as function of subglottal pressure P_s (left panel) and normalised excess pressure (right panel). Filled and open symbols refer to chest and head register, respectively. The right panel shows the mean values for all subjects and the dotted and dashed curves represent the power function that best approximates these data points.
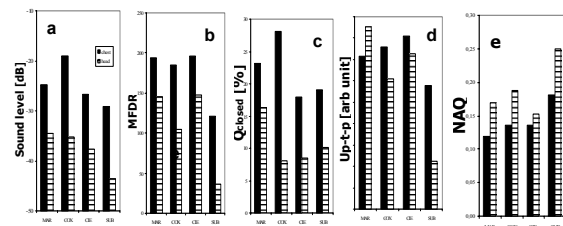

Fig. 4. Sound level, MFDR Q_{closed}, $U_{p\text{-}t\text{-}p}$, and NAQ for the singers' phonations at a P_s of 11 cm H_2O, approximately, in chest and head register.

that found for professional male singer [5]. The listening test showed that no more than 16% of all sung vowels were classified as clear chest register while 49% were classified as clear head register. One possible reason for this bias could be that it is difficult to differentiate registers in this pitch range, particularly in soft phonation. A contributing factor may be that the subjects sang into a pneumotachograph mask that attenuated the higher spectrum components slightly. As chest register typically had a longer closed phase than head, strong higher spectrum overtones should belong to the characteristics of chest register. Attenuation of such overtones can therefore be expected to reduce the timbral difference between the registers.

Our results suggest that modification of P_s and possibly also of glottal adduction are needed for changing from chest to head register or vice versa. As female musical theatre singers use both registers they would need a refined control of both breathing and phonation muscles. According to our observations chest register is characterised by a high P_s and a greater Q_{closed} and by a lower U_{p-t-p} and NAQ. In female untrained voices' chest register Q_{closed} was found to be higher than in head register [6]. Comparing professional baritones', tenors' and counter tenors' modal and falsetto registers Sundberg and Högset [7] found that P_s and Q_{closed} were higher, glottal leakage smaller, and the fundamental was weaker in chest register. These observations are compatible with or similar to the findings of the present study. They suggest that much of the voice source differences, between these registers, can be explained if the vocal folds are assumed to be thicker in the modal/chest register. Thicker folds would be associated with a longer phase lag between the upper and lower margins of the vocal folds, which should cause a more extended closed phase.

5. CONCLUSIONS

The chest and head register voice source in female musical theatre singers differ in several respects. In typical tokens of chest register P_s and MFDR are higher, Q_{closed} is greater while U_{p-t-p} and NAQ are lower than in head register. Register differences are perceptually clearer in loud than in soft phonation. The results also show that P_s has a strong influence on flow glottogram parameters. As NAQ seems

associated with degree of perceived phonatory pressedness, the low NAQ values for chest register suggests a more adducted phonation as compared to head register.

7. REFERENCES

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