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Lungs of Singers

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It is well recognized that the act of breathing provides the energy for voice production and the vocal efficiency rests upon pulmonary function. For this reason, voice researchers have long been interested in various aspects of the pulmonary function of professional singers, the assumption being that the superior vocal ability of the trained singer is due fundamentally to a concommitant superiority in ventilatory capacity, reflecting from an increased lung volume.

Despite this assumed relationship, there has been little concrete evidence adduced to document in a systemic fashion a correlation between ventilatory capacity and long-term vocal training. In particular, there has apparently been no systemic analysis of the effect of voice training upon not only ventilatory capacity, but also of the ability to utilize such capacity in actual voice production. If such a correlation could be decumented, it would be considerable significance in clarifying the specific relationship between respiration and voice production.

The present study indicates that a definite correlation between ventilatory capacity and voice training can be shown and that this relationship is readily discernible in several parameters reflecting aspect of pulmonary function. The purpose here is to describe the design of these studies and the concrete data they have produced.

Certain aspects of this interrelationship have been suggested by a number of previous investigators. As early as 1880, for example, Wassiliew found a large vital capacity in singers than in non-singers. Madoleczny and Luchsinger, similarly, observed significantly larger vital capacity values for professional singers than for untrained persons. Luchsinger further noted that air consumption in the well trained-singer was reduced as pitch rose. Bouhuys et al. reported that in the trained singer the air flow rate increased with an increasing sound level, while, by contrast, a relatively high air flow was required by the inexperienced singer singing the same tone softly. Proctor pointed out that the well-trained singer was able to utilize virtually the full vital capacity in sound production and he therefore urged that voice training should be focused upon the easy and habitual use of the full vital capacity, rather than upon its enlargement.

To determine whethere there is an increased ventlilatory capacity in singers and whether a correlation between this and voice training could be demonstrated, static lung volumes were measured in three groups. Group one consisted of pro-

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fessional singers; Group two was comprised of singing students; Group three included only normal individuals who had had no vocal training.

Methods :

The subjects were 45 adults without pulmonary and/or cardiovascular disorders. The first group (professional singers) was made up of six males and four females, ranging in age from 26 to 55 years. Members of the group had received from 11 to 40 years of vocal training and most were operatic performers deservedly renowned for their vocal abilities. Included in the second group were 15 students, six males and nine females, with an age range of 18 to 28 years and who had received from two to eight years of vocal training. The third group was comprised of ten males and tem females, ranging from 21 to 33 years, none of whom had had any vocal training.

Parameters of the lung volume were obtained from each subject by means of spirometry and body plethysmography. Specific parameters included *Vital Capacity* (VC), *Toal Lung Capacity* (TLC) *Residual Volume* (RV), *Inspiratory Capacity* (IC), *Expiratoy Reserve Volume* (ERV) and *Functional Residual Capacity* (FRC). ERV, IC and VC were measured at least two times, using a Collins 9-liter respirometer; the highest value was taken as the valid one in each instance. Each value was corrected to BTPS (body temparature and ambient saturated with water vapor). FRC was obtained by a plethysmographic method. RV as then calculated by subtracting ERV from FRC, and TLC was obtained by adding FRC and IC. All tests were done with subject in a sitting position.

To minimize the influence of variations due to sex, age and body size, each parameter was expressed as a percentage of the predicted value, using the formula of Goldman et al.

Table 1. Lung Volumes of Professional Singers

Case	Age	Sex	Years of Training	RV/TLC Ratio	RV	VC	TLC
1	29	M	11	20%(75%)	1.61L.(75%)	6.40L.(111%)	8.03L.(106%)
2	35	M	18	22 (78)	1.91 (96)	6.62 (139)*	8.53 (126)*
3	36	M	18	17 (64)*	1.31 (61)*	6.28 (117)	7.59 (106)
4	37	M	16	21 (70)*	1.56 (72)	5.95 (111)	7.51 (93)
5	41	M	22	20 (64)*	1.41 (63)	5.76 (117)	7.17 (104)
6	46	M	27	12 (37)*	0.99 (51)*	7.36 (179)*	8.35 (136)*
7	26	F	16	23 (82)	1.14 (80)	3.68 (104)	4.82 (98)
8	30	F	15	21 (69)	1.18 (57)	4.57 (105)	5.75 (93)
9	32	F	13	20 (66)	0.90 (72)	3.63 (122)	4.53 (106)
10	55	F	40	33 (92)	1.81 (98)	3.62 (114)	5.43 (103)
		Mean		(69.7)	(72.5)	(122.5)	(107.7)
		s.d.		(13.7)	(15.8)	(21.9)	(12.7)

( ) : per cent of the predicted value.
* : outside the two standard deviation from the predicted value.

Results:

VC, TLC and RV (Table 1 and 2);

All of these parameters in the control group, as well as in the students in singing, regularly fell within the normal range.

In contrast with the results in these two groups, however, the professional singers frequently had measurements out-side the normal range. Two subjects (cases 2 and 6) in this group showed VCs that were significantly higher than the normal range (179% and 139%, respectively), while two (cases 3 and 6) showed markedly lower RVs (51% and 61%).

Table 2. The Ratio of the Radidual Volume to the Total Lung Capacity

	The observed values (%)			Per cent of the predicted values		
	Mean	s.d.	Range	Mean	s.d.	Range
Professional Singers	20.9	5.0	12–33	69.7	13.7	37–92
Students in Singing	23.9	4.3	18–32	92.3	12.9	66–113
Controls	27.7	3.4	18–33	105.6	14.4	75–130

Table 3. The Ratio of the Residual Volume to the Total Lung Capacity

	The observed Values (%)			Per cent of the Predicted Value		
	Mean	s.d.	Range	Mean	s.d.	Range
Professional Singers	20.9	5.0	12–33	69.7	13.7	37–92
Students in Singing	23.9	4.3	18–32	92.3	12.9	66–113
Controls	27.7	3.4	18–33	105.6	14.4	75–130

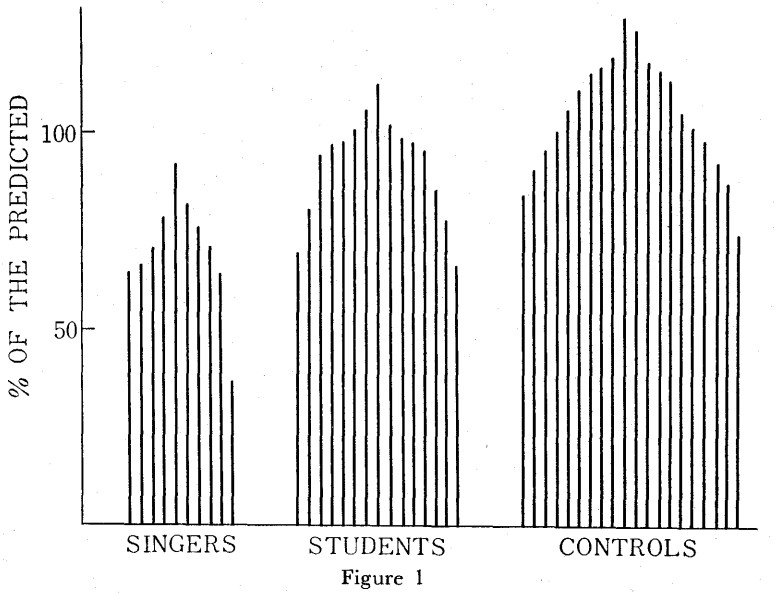

Figure 1

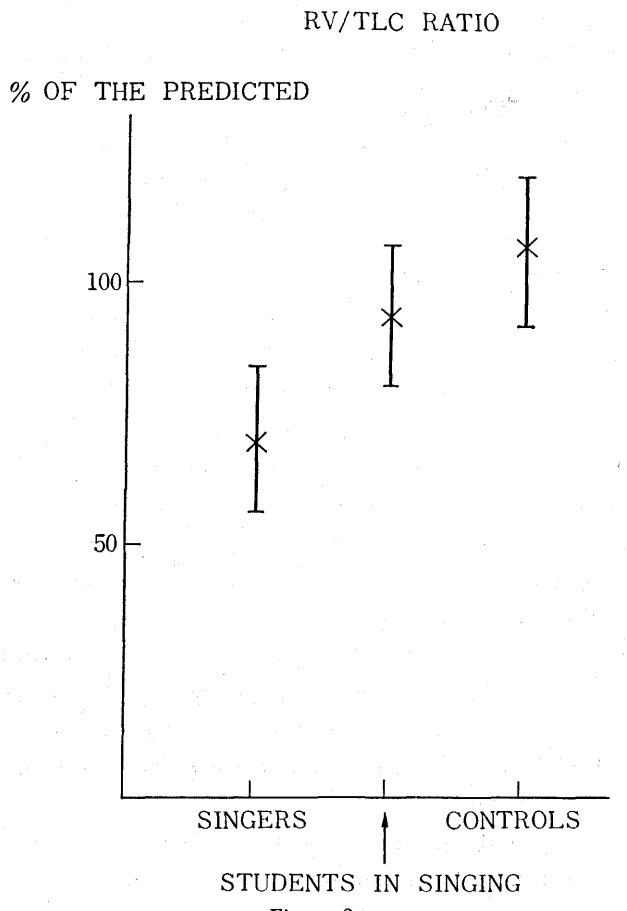

Figure 2

On the other hand, there were no significant differences between the TLC of the professional singers and that of the other two groups. These values in the students in singing fell between those of the other two groups.

RV/TLC Ratio; This parameter is shown in detail in Table 2 and 3, and in Figures 1 and 2. The RV/TLC ratio in the professional singers had extremely low values, while it in the controls and in the students in singing fell consistently within the normal limits. In four of the professional singers (cases 3, 4, 5 and 6) the RV/TLC ratio ranged from 37% to 70%, lower than the normal range. The ratios of the students of voice were between those of the professional singers and the subjects without vocal training.

Discussion :

The importance of dynamic investigation of the respiratory mechanism and its fundamental role in voice production has long been stressed by both clinicians and experimental researchers. In recent years such investigations have been

completed by aerodynamic analyses of the phonatory mechanism. Despite refinements in the latter particularly, however, it still must be recognized that parameters of the static lung volume provide basic information concerning pulmonary function that is unobtainable by alternative methods and that these parameters must form the bed-rock upon which the various elements of dynamic evaluation must rest. Hence, the purpose of this study was not to evaluate the functioning of the respiratory mechanism during singing, but rather to assay the ventilatory capacity of the lungs for such activity, using determinations of the static lung volume as our basic data and point of departure.

As already noted, most parameters of lung volumes vary widely with such factors as sex, age and body size and composite values from a heterogenous group of subjects must accordingly be interpreted cautiously. Goldman et al., for example, reported that the coefficient of variation of the normal RV in females was 24%. On the other hand, ratios between various lung volume subdivisions, particularly RV/TLC ratio, appear to be considerably less variable. Therefore, the RV/TLC ratio might well be a more useful and meaningful indicator of ventilatory capacity than other parameters.

Although there were no strinking difference between the three groups with respect to TLC, the professional singers showed higher VCs and lower RVs than did the other two groups. Both the VC and the RV, on the other hand, have a large standard deviation, and differences in these values among the three study groups cannot be conclusive.

Neverthless, it would appear reasonable to expect the professional singers to have a higher VC than the person without voice training, and this expectation is borne out by analysis of RV/TLC ratio. The RV/TLC ratio of the controls averaged 27.7% (sd: 3.4) at the observed value and this finding is consonant with values reported by other investigations. The professional singers, by contrast, showed quite low RV/TLC ratio, ranging from 12 to 33% at the observed value, with a mean of 20.9%. The RV/TLC ratio is also influenced by sex, age and body size, but to a much lesser degree.

In evaluations of the actual results obtained in comparison with the predicted values, it was found that the percentage of the predicted value for the RV/TLC ratio in the professional singers was highly significantly lower than those of the singing students and of the controls.

It should be noted that these findings are not consonant with those of earlier investigators who have reported no evidence of significant differences between the lung volumes of professional singers and those of untrained control groups. Heller et al., for example, concluded from a study of lung volume in singers a and non-singers that there were no marked differences between the two groups in this respect.

This apparent discrepancy between our findings and those of earlier investi-

gators may arise from a number of factors. It could well be, to cite one such possibility, that the type of professional singer figuring in a study markedly affects the results obtained. There may be a considerable differences between the ventilatory capacity of highly trained operatic singers and that of popular singers who generally receive little or no training. For this reason, it was made a special effort to obtain as subjects operatic performers who had undergone the uniquely rigorous vocal training associated with this profession.

A further factor making for possible discrepancy is the fact that earlier investigators employed, for the most part, parameters known to be highly variable within reasonably homogenous groups and especially so between less homogenous subjects. The present conclusion rests essentially on the RV/TLC ratio, a parameter that appears to be considerably less variable than other indices of ventilatory capacity.

It is clear from the results that many professional singers have a markedly lower ratio of RV to TLC than does the person with no voice training or even the person with training that falls short of that needed for the true professional. In view of the fact that the TLC of the professional singers did not differ from that of the other two groups, this finding suggests that the VC of the professional singers is expanded within the overall limits of the TLC by reduction of the RV. If this is indeed the case, it implies that the impressive singing potential of the professional singers arises fundamentally from the ability to store large volumes of air that is a concomitant of an effective expansion of vital capacity.

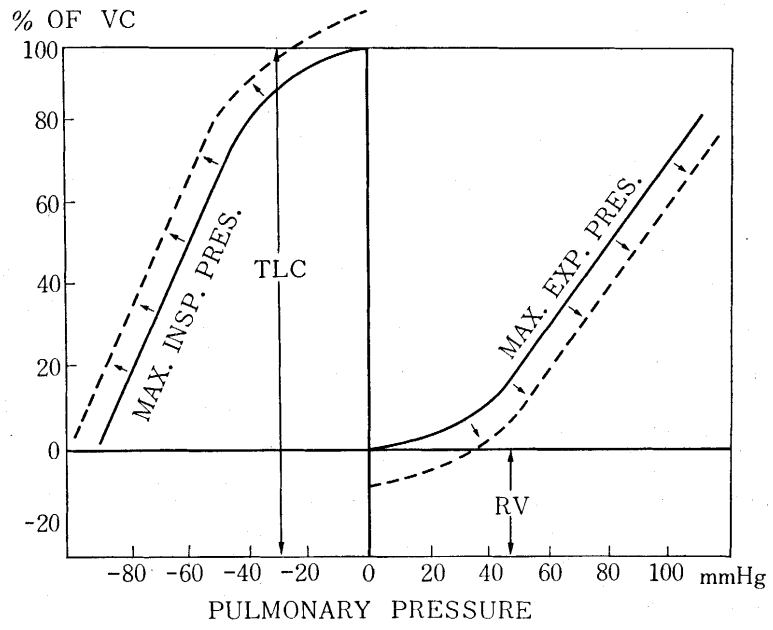

Figure 3

To clarify the mechanism which give rise to the markedly low RV/TLC ratio which was found in the professional singers, one would need to investigate pulmonary function in this group not only statically but also dynamically. But, on the basis of the results we have obtained, it may be hypothyzed that expiratory force is markedly increased in the trained singer as compared with that of the person without rigorous vocal training, and that this increased force, in turn, apparently makes for an augmented total ventilatory capacity, as a result of a reduction in RV. The manner in which this might occur is illustrated in figure 3, showing the relationship between lung volume and pulmonary pressure, measured under static conditions. As a result of training, the curves for the professional singer's maximum expiratory and maximum inspiratory efforts apparently shift, as indicated by the broken lines, giving not only an increase in TLC, but also a marked decrease in the RV/TLC ratio. Such a shift may be dominant in the phase of the maximum expiratory effort, since the markedly low RV/TLC ratio was observed in the professional singers. The shifts mentioned above are entirely consonant with the results of the present study.

Even though the augmented lung volume of the professional singers may in fact stem from long and rigorous trainging, the possibility that the professional singers represent a select group with inherently superior pulmonary function, whether trained or not, must be considered.

It was for this reason that students in singing were selected in this study. The lung volumes of the students fell between those of the professional singers and those of the untrained controls. This suggests that the students were well on the way to acquiring a superior ventilatory capacity.

Conclusion :

In the light of the results in the current studies, it appears reasonable to conclude that the professional singers who have a marked increased potential for singing, as reflected by a lower RV/TLC ratio in comparison with either wholly untrained persons or those with less vocal training. The results further suggest that there may be a specific correlation between the increased ventilatory capacity of the professional singers and their long-term vocal training.

References :

1. Bouhuys, A. et al.: Kinetic Aspects of Singing. J. Appl. Physiol. **21**: 483, 1966.
2. Comroe, J.H. Jr., et al.: The Lung. Year Book Med. Pub. 1970.
3. Goldman, H.I. et al.: Respiratory Function Tests. Am. Rev. Tuberc. **79**: 457, 1959.
4. Heller S.S. et al.: Lung Volume of Singers. J. Appl. Physiol. **15**: 40, 1960.
5. Luchsinger, R. et al.: Voice-Speech-Language. Wadsworth Pub., 1967.
6. Proctor, D.F.: The Physiologic Basis of Voice Training. Ann. N.Y. Acad. Sci. **155**; 208, 1968.
7. Rahn H. et al.: The Pressure- Volume Diagram of the Thorax and Lung. Am. J. Physiol. **146**; 161, 1946.

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