Introduction:
It is apparent for singers, that the sensation of self-produced supported voice primarily involves the adjustment of breath structures. At least three different strategies for breath management are known, and Miller and Bianco (1985) found differences in diaphragmatic action among them. Leandersson et al. (1987) found that a co-activation of diaphragm is used by some subjects to reduce expiratory recoil forces and excessive subglotal pressure.

The purpose of this pilot study was to find new evidence of the relationship between transdiaphragmatic pressure, three surface respiratory measurements and acoustic characteristics in various emissions, perceptually judged as supported or unsupported. A particular strategy for breath management was used in order to look for a respiratory pattern. Methods and procedures were tested for their improvement in future replications.

Objectives:
To explore diaphragm activation and thorax-abdominal displacements during singing with and without support.
To assess diaphragm activation through non-invasive surface measures
To study the difference in inhalatory phase just before singing with and without support

Methods, Procedures and materials:
One trained singer soprano, 35 years old, sung eight different melodies with and without support in two different conditions:
  i) with surface and internal measurement devices: Respibands (Respirtrace) and a Catheter balloon system.
  ii) in a natural singing situation.

In this study support technique was referred to the breath technique. The singer explained her breath technique as a maneuver that consists on sustaining her rib cage expanded during singing. The instructions
for singing without support consisted in asking the singer ‘not to do what you think you do for supporting singing’.

It was consider convenient to obtain three surface respiratory measurements: i) Upper chest (TX) -at nipples level-, ii) Apposition area (AP) – floating rib level- and iii) Abdominal wall (AB) – navel level-

A plethysmograph “Respitrace” was used to measure AP and AB displacements. Another tool a neumograph “Samborn 270” was used to measure TX displacements. Figure 1 shows a schematic diagram of the equipment employed. Respitrace bands were placed in singer trunk on apposition area (AP) (lower rib cage) and abdomen (AB); Another band from the neumograph “Samborn 270” was placed in superior rib cage (TX). These devices are able to measure respiratory movements and volume displacements.

Gastric and esophageal pressures were taken through a catheter-balloon-system. Validine MP 45 Differential-Pressure - Transducers were used in order to obtained internal measurements from esophageal and gastric balloons.

A Physiograph MK IV, four channels was used to amplify Validine Mp 45 signal pressure.

A Vetter digital recorder magnetic tape FM 16 channels was used for store the signals for further analysis off line. A converter device A/D and a Sponge V2.1 software were used to allow signal analysis into an IBM PS2 personal computer. Data was analyzed by means of a START program (Inspirational Software, Montreal).

The catheter balloon system was placed through nostrils and connected to pressure transducers.

An esophageal balloon measured the esophageal pressure (PES), this pressure is similar to pleural pressure.
A gastric balloon measured the gastric pressure (PGA), this pressure is similar to the abdominal pressure. Figure 1.

Transdiaphragmatic pressure (PDI) is the difference between de PGA and PES. This measure reflects the diaphragm activation. During inspiration and when the diaphragm is activated, gastric pressure increases and esophageal pressure turns negative, therefore PDI growths. Pressures were measured in cm H2O.

Voice output was recorded in FM magnetic DAT tape in order to accomplish the analysis off line. The analysis of acoustic output for condition i and ii were done by Anagraf Software. This software analyses F0 and formants or armonic spectrum of voice output. Values of total Energy and of partial’s energy were taken through this device. Data files were generated automatically by the software.

B.-DATA VALIDATION PROCEDURE
A panel of seventeen expert listeners evaluated the samples within the conditions i) and ii). And classified then into two categories: supported and unsupported singing voice. The amount of data validated was 67% for condition i and 81% for condition ii.

C.-RESULTS
Acoustical output and respiratory parameters of the validated data were analysed.

1. Analysis of Respiratory parameters:
Surface measures were expressed in arbitrary units reflecting changes in thoracic or abdominal perimeters. Ap and AB measures were related and they are comparable between them because the came from the same Respitrace equipment.
TX measures were taken from other pneumatic and transducer equipment non-related with Respitrace.
Therefore, displacements on each zone (TX; AP or AB) should be compared with displacement variations for the same area in different conditions (supported or unsupported singing).
Each of them must be seen as δ deflection related with itself in two different situations (when singing with or without support). One cannot be compared with the other two. (Table 2)

1.1. Inspiratory Phase analysis:
- Displacement of TX and AP were significantly greater on inhalatory phase before singing with support than without it. Table 2
- There were no significant differences in AB expansion, between inspirations before singing with support than without it. (Table 2)
- PES was much more negative during inhalatory phase previous singing with support than without it. (Table 1)
- PGA was much more positive during inhalatory phase for samples with support than for samples without it. (Table 1)
- It seems that diaphragm was greater activated and there was a higher inhalatory volume previous singing with support.
- By the other hand, a no significant increasing in abdominal wall excursion, suggest a co-contraction of abdominal muscles. (Table 2)
- **PDI** was greater in inspirations before support technique. It shows higher diaphragm activation during inspiration before singing with support. (Table 1)

*This data suggests a greater tidal volume during inhalatory phase.*

### 1.2. Singing Phase analysis:

- **TX, AP** and **AB** showed a greater deflection during singing phase for samples with support than for samples without support. It was probably in accordance with a higher air volume previously inhaled. (Table 2)
- During singing with support, a tendency to sustained Apposition Area’s perimeter was observed. This did not happened for the other two zones. (Table2)
- **PES** (an indirect predictor of subglotic pressure) was greater (more positive) during singing with support. Therefore we could assume that subglotic Pressure was higher during supported singing. (Table 1)
- **PDI** was greater during singing with support technique. It suggests *a higher diaphragmatic activation during singing with support.* (Table 1)

### 2. Acoustical analysis:

The energy of the different harmonics in the spectrum was measured for conditions i and ii. Data's significance level was determined by an ANOVA. LTAS was not used, but its use will be consider for further analysis. *(Figure 2)*

i) Singing with surface and internal measurements devices: no significant differences were found in formant's energy between supported or unsupported emissions.

ii) Singing in a natural situation: significant differences were found in formant's energy between supported or unsupported voice, for F1, F3, F4 and F5. No significant differences were found in F2.
Discussion:
Data suggests a greater tidal volume during inhalatory phase and a higher diaphragmatic activation during singing with support. A tendency to sustain Apposition zone is in accordance with the description singer made about her respiratory technique for support. This tendency was also observed in curves of Respitrace's at the AP Area channel. Displacements of abdominal wall -which suggest a co-contraction of these muscles- should be confirmed by electromyography measurements.
On the other hand, aural test validated the voice output at a higher level when singing was produced without catheter than when it was done with catheter. When the validated data was assessed by software, the results show no significant differences for emissions produced with a naso-esophageal catheter. The software shows significant differences for emissions without catheter. This results would suggest that a human trained ear is able to detect subtle nuances in singing emission. And that is necessary to further explore the boundaries between human perception and objective measurements of the singing voice.

**BIBLIOGRAPHY**

### Table 1. Internal Measurements: In cm H2O. Mean (M), Standard deviation (SD) and Significance Level (Sig.) for Esophageal Pressure (PES), Gastric Pressure (PGA) and Transdiaphragmatic Pressure (PDI).

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Table 1. Internal Measurements: In cm H2O. Mean (M) Standard deviation (SD) and Significance Level (Sig.) for Esophageal Pressure (PES), Gastric Pressure (PGA) and Transdiaphragmatic Pressure (PDI).

### Table 2. Surface Measurements: In arbitrary units. Means (M), Standard Deviation (SD) Significance level for Thorax (TX), Apposition Area (AP) Abdomen (AB) and in singing with and without Support. Addition of three measurements (SUM) represents complete thorax excursion.

<table>
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