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# Voice Sequelae Following Recovery From COVID-19

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**Summary: Introduction.** Covid-19 is an infectious disease with a different symptomatic implication depending on each person. There are sequelae in the nervous, cardiovascular, and/or digestive system that involve the approach and multidisciplinary work of different health professionals where the speech therapist is included. In this way, we can speak of a direct relationship between speech therapy and Covid-19; especially in those patients with serious sequelae such as the inability to eat and/or speak and the loss of voice. The damage caused to the laryngeal mucosa triggers the loss of some of the qualities of the voice, limiting oral communication. That is why we can find dysphonias caused by a great weakness, by a continuous overexertion or because of a paralysis of the vocal cords.

**Objectives/Hypothesis.** The objective of this study was to identify the patterns of behavior in the biomechanical correlates of people who passed Covid-19 symptomatically with sequelae in voice.

**Methods.** An experimental study with a total of 21 participants (11 women and 10 men) with sequelae in voice post Covid-19 is presented. Voice samples were collected and biomechanical correlates were analyzed through the Voice Clinical Systems program.

**Results and Conclusions.** The results show different altered biomechanical patterns between men and women that correlate with other infectious diseases.

**Key Words:** Biomechanical correlates—Covid-19—Voice analysis—Vowel sounds.

## INTRODUCTION

For the last 2 years, Covid-19 has been the main protagonist of our lives. Due to its high infection rate, to date, 388 million cases of coronavirus (SARS-CoV-2) have been recorded in the world. Although this virus presents a wide spectrum of clinical symptoms, it mainly affects the respiratory system; where the lungs, airways, and muscles of the respiratory tract are included. In addition to cough, fever, muscle pain, headache, loss of smell, and taste, patients who have been symptomatic have also reported changes in their voice; even inability to produce it.<sup>1</sup> The process of phonation in humans is the main source of vocalization in the production of sound sounds. A complex biomechanical process that is highly sensitive to changes in the respiratory parameters of the speaker.<sup>2</sup> Considering this definition and taking into account that Covid-19 mainly affects the respiratory tract, one would expect the voice to experience irregularities after passing the disease. In this line, the audio signals generated by the human body (e.g., breathing, coughing, speech) have been used as diagnostic indicators of diseases or as values to evaluate their progression.

Although there are few studies that have investigated the impact of Covid-19 on the voice, the vocal cords of these people have been shown to exhibit abnormalities in their oscillation patterns during phonation.<sup>2</sup> Other work has shown interesting results in the detection of diagnostic signs of Covid-19 from voice and cough. In fact, the work

published in this area has focused on demonstrating that voice analysis could be used as a tool for the early detection of Covid-19.<sup>1–3</sup> Next, the main findings related to Covid-19 and voice will be reviewed.

The study of Dash et al.<sup>3</sup> focused on investigating the Mel frequency coefficient (MFCC) of the voice signal. This tool allows to analyze the characteristics of speech signals and demonstrates that these characteristics vary from one disease to another. With this premise, the authors showed that patients with Covid-19 had a new speech signal characteristic, which they called the COVID-19 Coefficient (C-19CC). In this way, they concluded that detecting Covid-19 by means of the speech signal could serve as a cost-effective tool. These results are convergent with the results of the theoretical review by Deshpande et al.<sup>4</sup> The authors offer an overview of research into human audio signals where they use “artificial intelligence” techniques to detect, diagnose, monitor, and spread awareness about Covid-19.

For their part, in the work of Brown et al.<sup>5</sup> they used coughing and breathing to study how discernible the sounds of Covid-19 patients are versus patients with asthma and healthy controls. Their audio results showed that Covid-19 patients present with different breathing patterns from people with asthma or healthy controls, so the authors suggest that respiratory pattern analysis could be used to aid early diagnosis of Covid-19. In Ismail et al.'s research<sup>2</sup> they used voice signals from Covid-19 patients to analyze vocal cord oscillations. The results showed the existence of unique biomarkers in these patients. Specifically, they showed that Covid-19 interrupts the dragging of the vocal cords during phonation and causes asymmetries in their movement. Similar findings found Verde et al.,<sup>6</sup> who through voice signals identified that there are unique vowel sounds affected in Covid-19 patients. In addition, they demonstrated that the evaluation of the vowel /e/ allows to detect the effects of Covid-19 more accurately than other vowels.

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In summary, this set of scarce, but solid results show that the analysis of voice signals contributes to improving the early diagnosis of Covid-19. However, this proposed screening measure is limited as it is not effective in cases of asymptomatic patients. What does seem to be clear is that suffering from Covid-19 in a symptomatic way causes changes in the voice. That is why the objective of this study is to identify patterns of behavior in the biomechanical correlates of people who have passed Covid-19 symptomatically.

Biomechanical analysis of the voice, which evaluates the dynamics of the vocal folds during phonation from a sample of the patient's voice, has recently been introduced in the evaluation of vocal pathology.<sup>7</sup> The voice is the final result of a biomechanics developed by the vocal folds and the biomechanics developed by the vocal folds is a consequence of functional and structural factors dependent on the histology of the vocal folds themselves.

The biomechanical study of the voice signal analyzes the mechanical and structural factors involved in the development of the movement of the free edge of the vocal folds, reflecting the patient's vocal production model and the structure of the vocal folds; both will vary due to the existence of the disease.<sup>7</sup> In this way, the *Voice Clinical Systems* tool approaches this biomechanics from the analysis of a sample of the signal radiated at the level of the lips and extracts correlates that allow the biomechanics of the vocal folds during phonation to be inferred with great precision.

To carry out the voice analysis, 4 seconds are recorded that the *App* automatically registers from the vowel /a/, which in Spanish corresponds to the most open vowel and least influence of the vocal tract. This is important for establishing correlates with the dynamics of the free edge of the vocal folds, that is, with the glottic source.

Biomechanical correlates include information related to Cycle Phases, GAP, Mass Effect, Mucosal Wave Correlates, Tension, Glottic Force, etc. and they offer key information for the screening and characterization of voice pathology associated with a lesion or functional alteration of the vocal cords. Despite being a recent tool, the *Voice Clinical Systems* is included in the list of validated applications for smartphones for clinical practice.<sup>8</sup> In addition, various investigations have shown the effectiveness of this tool for screening patients with vocal pathology.<sup>9-13</sup>

Using this tool, in the present study, voice samples were collected from patients who passed Covid-19 symptomatically in order to identify irregularities in the biomechanical correlates.

## MATERIALS AND METHODS

### Participants

Voice recordings were obtained from 21 adult participants (10 men, 11 women), aged between 23 and 59 years, all of them Spanish native speakers. All participants were outpatients diagnosed with Covid-19 in primary care of the Canary Islands Health Service. Specifically on Tenerife

Island, in Spain. Patients met the inclusion criteria: (1) have passed Covid-19 symptomatically, (2) have not been intubated, (3) have not received speech therapy rehabilitation, (4) have no previous voice pathology. Voice samples were collected between June 2020 and March 2021; months corresponding to the first wave of Covid-19, so no participant was vaccinated. In addition, voice samples were collected between 1 and 3 months after Covid-19 had passed. Participants signed an informed consent document about the study.

### Materials

Due to the pandemic situation and the recommendations to avoid social contact, the data was collected online. That is, all participants received instructions and did the tests described below at home.

Following the list of symptoms proposed by the World Health Organization (WHO), the symptoms experienced by patients during the days they were sick with Covid-19 were collected.<sup>14</sup> The list of symptoms was translated into Spanish and written on the Google Forms platform. Each participant was sent a link with the list for them to respond.

The Voice Handicap Index (VHI): Development and Validation questionnaire<sup>15</sup> was used to assess the sequelae of the voice after passing the disease. Precisely, the version translated into Spanish<sup>16</sup> of adaptation and validation of the vocal disability index in its complete version (VHI-30) was used. This questionnaire is a validated instrument to quantify the impact perceived by the patient affected by a vocal disorder in the areas of the vocal function itself, in the physical capacity related to it and in the emotions caused by the dysphonia. The questionnaire is made up of 30 statements grouped into three blocks of 10 statements. These blocks are called the physical (I-F), functional (II-F), and emotional (III-E) subscale. Each statement is assigned a score from 0 to 4 depending on the degree of perceived disability (0 = never, 1 = Almost never, 2 = Sometimes, 3 = Almost always and 4 = Always). The maximum possible score is 120 points and the degree of disability is divided into mild (less than 30 points), moderate (between 31 and 60 points), severe (between 61 and 90 points), and severe (between 91 and 120 points).<sup>16</sup> Again, this questionnaire was submitted through the *Google Forms* tool.

The sampling of the vocal signal was carried out using an *iPhone* device (8, XR, X), since the microphones of this telephone brand are validated by the *App Online Lab* tool. The biomechanical analysis was carried out through the *App Online Lab* tool provided by *Voice Clinical Systems*, version 1.4.0. for Apple device.

All participants had an *iPhone* brand device at home. Participants were instructed to download the *Online Lab App* and were provided with the researchers' specialist code. In this way, the participants accessed the App, indicated their participant code, their gender, their age and proceeded to take a voice sample. Participants were instructed to record in a closed room, without noise.

## Procedure

First, the participants were given a sheet containing a list of symptoms proposed by WHO.<sup>14</sup> Participants had to mark the symptoms they experienced during the days they were sick with Covid-19. In second place, participants then completed the full version of Adaptation and validation of the voice disability index to Spanish (VHI-30).<sup>16</sup>

Following the protocol established by the developer of *Voice Clinical Systems*, with the App Online Lab application open, the mobile phone was placed at a distance of about 20–30 cm from the patient's mouth and asked to emit a phonation /a/ in its natural tone for 4 seconds, at a comfortable intensity and tone, monitoring that the amplitude of the signal varied around 50%. Once the sample was collected, the R3 biomechanical complete report was requested, from which a quantitative assessment of 22 biomechanical parameters was obtained, whose range of normality is established according to age and sex.<sup>7</sup>

R3 is the most complete report that the App offers on the biomechanics of the vocal folds during phonation. It includes three studies: (1) pathology profile, (2) alteration indices, and (3) biomechanical profile. It also includes the analysis of 22 parameters that accurately describe all biomechanics, in addition to the biomechanical wave. The R3 report is essential for the characterization of voice pathology.<sup>7</sup>

## RESULTS

Table 1 shows the percentage of patients who reported having experienced any of the symptoms on the list proposed by WHO. It should be noted that 66.67% reported having had dysphonia during the days they were infected.

The mean score of the VHI-30 questionnaire was 11.19 (range between 0 and 29, standard deviation = 8.07). Regarding the degrees of vocal disability of the patients, 85.71% presented a mild disability; while 14.29% did not

present disability. There were no participants with moderate, severe, or severe disabilities.

In women, the mean score of the VHI-30 questionnaire was 11.18 (range between 0 and 29, standard deviation = 9.58). Only two women scored 0 on the questionnaire. That is, 81.81% of women have mild disability. In men, the mean score of the VHI-30 questionnaire was 11.2 (range between 0 and 29, standard deviation = 6.55). Only one man scored 0 on the questionnaire. That is, 90% of men have mild disability.

Table 2 shows the results obtained in the biomechanical parameters of the sample of women; while Table 3 shows the biomechanical parameters of the sample of men.

First, the analysis of the results obtained in the biomechanical parameters of the sample of women, highlight that they present alterations in the parameters Pr01, Pr09, and Pr21. The rest of the means in the parameters were maintained at normal intervals. The fundamental frequency (Pr01) varied between 192.6 Hz and 312.8 Hz, leaving 100% of women above the normal range. In the parameter Pr09 that indicates the strength of the glottic closure, we found that 54.5% of the participants had excess glottic strength. In the Pr21 parameter, 63.7% of the participants presented structural imbalance.

Secondly, the analyses of the results obtained in the biomechanical parameters of the sample of men present alterations in the parameters Pr10 and Pr21. In the Pr10 parameter that evaluates the ability of the vocal folds to perform an opening that allows sufficient air passage and optimal glottic closure for voice production, 50% of men show inefficiency scoring below the normal range. Regarding the Pr21 parameter, 90% of men show structural imbalance; 70% of the participants being above the normal range; while 20% are below the normal range.

At the same time, the possible relationship between the parameters of interest was studied according to the gender variable. A Pearson correlation analysis was performed for parameters Pr01, Pr09, and Pr10 for women and parameters Pr10 and Pr21 for men.

Data on correlations between parameters of interest to women are shown in Table 4.

The results showed a significant negative correlation [ $r = -0.64$ ,  $n = 11$ ] between the fundamental frequency and the efficiency index. Indicating that as the fundamental frequency in Hz increases there is a decrease in the opening capacity of the vocal folds with which there is no optimal opening or optimal glottic closure in the production of the voice. Other correlations were also found that did not reach a significant relationship, but clinical trends that allow us to relate other biomechanical parameters of the voice in women. For example, a negative correlation was also found between the fundamental frequency and the strength of the glottic closure [ $r = -0.25$ ,  $n = 11$ ]. At the same time a positive correlation was found between the fundamental frequency and the structural imbalance index [ $r = 0.16$ ]. A positive relationship was found between the strength of the glottic closure and the efficiency index [ $r = 0.36$ ,  $n = 11$ ].

**TABLE 1.**  
Percentage of Patients Who Report Symptoms of Covid-19 During the Disease

| Symptoms            | Percentage |
|---------------------|------------|
| Headache            | 66,67      |
| Fever               | 76,19      |
| Runny nose          | 52,39      |
| That                | 76         |
| Diarrhoea           | 33,33      |
| Vomiting/nausea     | 19,04      |
| Chest pain          | 33,33      |
| Fatigue             | 71,43      |
| Shortness of breath | 28,57      |
| Loss of smell       | 57,15      |
| Earache             | 9,52       |
| Hearing loss        | 0          |
| Sore throat         | 76,19      |
| Dysphonia           | 66,67      |

**TABLE 2.**  
**Data Obtained in the Biomechanical Parameters of the Index of Alteration for the Women Sample**

| No   | Biomechanical Parameter                      | Normal Interval in Women | Outcome in Women (X) | No. Patients in Normal Interval | N Low Range | N Over Range |
|------|--|--------------------------|----------------------|---------------------------------|-------------|--------------|
| Pr01 | Fundamental frequency (Hz)                   | 160–206                  | 233,75               | 0                               | 0           | 11           |
| Pr02 | List of cycles in closing CVD/CVI (UR)       | 0,50–0,33                | 0,95                 | 11                              | 0           | 0            |
| Pr03 | % asymmetry                                  | 0                        | 13,95                | 8                               | 0           | 3            |
| Pr04 | Duration of the closed phase (%)             | 50–75                    | 55,11                | 8                               | 3           | 0            |
| Pr05 | Duration of the open phase (%)               | 25–50                    | 44,89                | 8                               | 0           | 3            |
| Pr06 | Duration opening (%)                         | 15–40                    | 32,22                | 7                               | 1           | 3            |
| Pr07 | Duration closing (%)                         | 6,5–12,5                 | 11,74                | 6                               | 0           | 5            |
| Pr08 | Voltage index (UR)                           | 0,46–44                  | 39,03                | 8                               | 0           | 3            |
| Pr09 | Glottic closure force (UR)                   | 40–1360                  | 2309,87              | 5                               | 0           | 6            |
| Pr10 | Efficiency index (UR)                        | 1–2,3                    | 0,75                 | 4                               | 7           | 0            |
| Pr11 | Breadth of gap (UR)                          | (–0,005)                 | –0,01                | 8                               | 3           | 0            |
| Pr12 | Gap size (%)                                 | 1–32                     | 8,25                 | 10                              | 0           | 1            |
| Pr13 | Instability index (UR)                       | <21                      | 3,97                 | 10                              | 0           | 1            |
| Pr14 | Amplitude index (UR)                         | <1                       | 0,83                 | 9                               | 0           | 2            |
| Pr15 | Vibration lock index                         | 0                        | 0                    | 11                              | 0           | 0            |
| Pr16 | Closing amplitude index (UR)                 | 0,09–2,2                 | 2,71                 | 7                               | 0           | 4            |
| Pr17 | Adequacy of the OM in the closed phase (UR)  | 130–370                  | 169,60               | 7                               | 4           | 0            |
| Pr18 | Adequacy of the OM in the opening phase (UR) | 10–100                   | 85,26                | 6                               | 0           | 5            |
| Pr19 | OM adaptation closing                        | (–40)-90                 | –6,09                | 7                               | 4           | 0            |
| Pr20 | Adequacy OM opening                          | 200                      | 81,82                | 11                              | 0           | 0            |
| Pr21 | Structural imbalance index                   | 75–85                    | 73,21                | 0                               | 4           | 7            |
| Pr22 | Mass alteration index                        | 0                        | 0,38                 | 10                              | 0           | 1            |

**TABLE 3.**  
**Data Obtained in the Biomechanical Parameters of the Alteration Index of the Male Sample**

| No   | Biomechanical Parameter                      | Normal Interval in Men | Result in Men (X) | No. Patients in Normal Interval | N Low Range | N Over Range |
|------|--|------------------------|-------------------|---------------------------------|-------------|--------------|
| Pr01 | Fundamental frequency (Hz)                   | 95–159                 | 122,83            | 10                              | 0           | 0            |
| Pr02 | List of cycles in closing CVD/CVI (UR)       | >0.33                  | 0,88              | 10                              | 0           | 0            |
| Pr03 | % asymmetry                                  | 0                      | 3,18              | 9                               | 0           | 1            |
| Pr04 | Duration of the closed phase (%)             | 28–77                  | 62,11             | 9                               | 0           | 1            |
| Pr05 | Duration of the open phase (%)               | 22–71                  | 37,89             | 10                              | 0           | 0            |
| Pr06 | Duration opening (%)                         | 8–35                   | 26,68             | 9                               | 0           | 1            |
| Pr07 | Duration closing (%)                         | 4–37                   | 11,24             | 9                               | 1           | 0            |
| Pr08 | Voltage index (UR)                           | 0,69–45                | 59,14             | 6                               | 1           | 3            |
| Pr09 | Glottic closure force (UR)                   | 43–2100                | 3720,53           | 6                               | 1           | 3            |
| Pr10 | Efficiency index (UR)                        | 1–2,7                  | 1,15              | 5                               | 5           | 0            |
| Pr11 | Breadth of gap (UR)                          | (–0,013)               | –0,001            | 9                               | 1           | 0            |
| Pr12 | Gap size (%)                                 | 1–35                   | 6,7               | 9                               | 0           | 1            |
| Pr13 | Instability index (UR)                       | < 30                   | 2,31              | 10                              | 0           | 0            |
| Pr14 | Amplitude index (UR)                         | < 1                    | 0,57              | 8                               | 0           | 2            |
| Pr15 | Vibration lock index                         | 0                      | 0,18              | 9                               | 0           | 1            |
| Pr16 | Closing amplitude index (UR)                 | 0,1–2,2                | 3,05              | 7                               | 0           | 3            |
| Pr17 | Adequacy of the OM in the closed phase (UR)  | 90–630                 | 324,97            | 9                               | 1           | 0            |
| Pr18 | Adequacy of the OM in the opening phase (UR) | 7–155                  | 113,59            | 8                               | 2           | 0            |
| Pr19 | OM adaptation closing                        | (–56)-90               | 0,64              | 9                               | 0           | 1            |
| Pr20 | Adequacy OM Opening                          | 200                    | 190               | 6                               | 0           | 4            |
| Pr21 | Structural imbalance index                   | 75–85                  | 75,23             | 1                               | 2           | 7            |
| Pr22 | Mass alteration index                        | 0                      | 0,84              | 8                               | 0           | 2            |

**TABLE 4.**  
Correlation Analysis Between Altered Parameters in Women

|      | Pr01   | Pr09 | Pr10  |
|------|--------|------|-------|
| Pr09 | -0.25  |      |       |
| Pr10 | -0.64* | 0.36 |       |
| Pr21 | 0.16   | 0.32 | -0.18 |

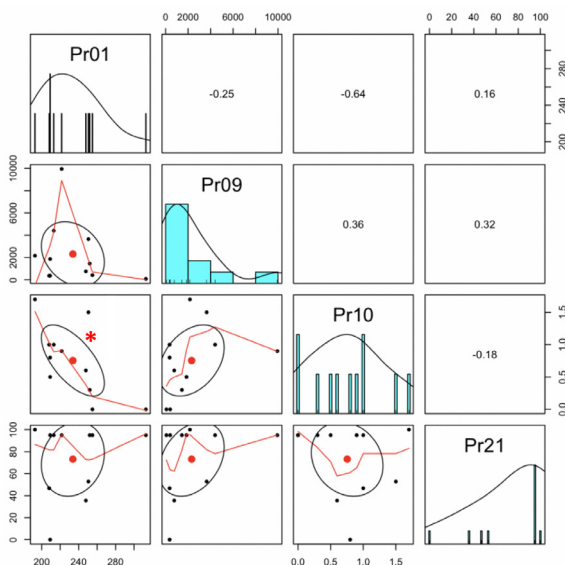
Note: Pr01 "Fundamental Frequency in Hz". Pr09 "Strength of the glottic closure". Pr10 "Efficiency Index". Pr21 "Structural imbalance index".

\*  $P < 0.05$ .

The sense of the relationship shows us that the strength of the glottic closure is positively related to the efficiency index. Likewise, the correlation between the strength of the glottic closure and the structural imbalance index was positive [ $r = 0.32$ ]. Finally we found a negative correlation value between the efficiency index and the structural imbalance index [ $r = -0.18$ ]. Increased structural imbalance implies less optimal opening of vocal folds and less glottic closure. [Figure 1](#) shows the linear relationship between the parameters through a dispersion graph and the histogram of the distribution of the parameters of interest in the subsample of women (see [Figure 1](#)).

The analysis of the relationships of interest in the case of men focused on the relationship between the efficiency index and the structural imbalance index. In this case, a nonsignificant low correlation was found between them [ $r = -0.18$ ,  $n = 10$ ].

Finally, the Pearson correlation was computed between the scores of the VHI-30 questionnaire and the altered parameters in women (see [Table 5](#)).



**FIGURE 1.** Linear relationship and histogram of distribution for parameters of interest. Note Pr01 "Fundamental Frequency in Hz". Pr09 "Strength of the glottic closure". Pr10 "Efficiency Index". Pr21 "Structural imbalance index". \*  $P < 0.05$ .

**TABLE 5.**  
Pearson Correlation Between Altered Parameters and VHI-30 Questionnaire in Women

|        | Pr01    | Pr10   |
|--------|---------|--------|
| Pr10   | -0.641* |        |
| VHI-30 | 0.462   | -0.201 |

Note: Pr01 "Fundamental Frequency in Hz". Pr10 "Efficiency Index".

The results showed positive correlation [ $r = 0.462$ ,  $n = 11$ ] between the VHI-30 questionnaire and the Pr01 parameter. As the Fundamental Frequency (Pr01) increases, the rate of vocal incapacity increases. The results also showed a significant negative correlation [ $r = -0.201$ ,  $n = 11$ ] between the VHI-30 questionnaire and the Pr10 parameter. The higher the score on the VHI-30 questionnaire (greater vocal disability), the lower the vocal efficiency index (Pr10).

[Table 5](#) shows the meaning of the relationship between VHI-30 and the parameters of interest. Although these relationships are not significant, they do show us the tendency of them. Finding a positive relationship between VHI-30 and Pr01 ( $r = 0.463$ ) and a negative relationship between VHI-30 and Pr10 ( $r = -0.20$ ).

## DISCUSSION

The investigations of Covid-19 and voice initially reviewed, demonstrated the existence of exclusive acoustic parameters in Covid-19 patients. Supported by the literature,<sup>1-6</sup> this study expected to identify unique irregularities in the biomechanical correlates of people who were sick with Covid-19.

First of all, it should be noted that 66.7% of the participants reported having had dysphonia during the days they were sick with Covid-19. Second, the results of the VHI-30 questionnaire showed that 86% of the participants perceived a mild disability of their own vocal function after having overcome the disease, that is, that most of the participants were left with sequelae in the voice.

Regarding the results of the biomechanical parameters of the participants, it was found that the alterations presented were compensated and reflected in different ways in men and women. On the one hand, the women showed alterations in four biomechanical parameters; increase in the fundamental frequency (Pr01), increase in the glottic closing force (Pr09), decrease in the efficiency index (Pr10) and increase in the structural imbalance index (Pr21). It should be noted that the GAP indices (Pr11 and Pr12) were within the range of normality (phonation without air leaks). As there was no alteration in these parameters, it was confirmed that the participants had a voice without pathology before suffering from Covid-19. From the results of the correlation analyses of the altered parameters, it was observed that women make a compensatory effort, that is, that the increase in glottic strength and the maintained tension

values are produced by the increase in fundamental frequency; which produces an alteration in the free edge.

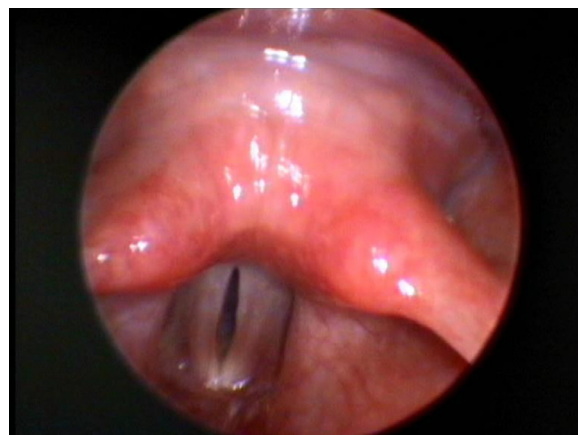
The correlation analysis between the VHI-30 questionnaire and the altered biomechanical parameters in women showed the expected trends of relationship between Pr01 and Pr10 with the VHI-30 questionnaire. As the vocal disability index (IHV-30) increases, the fundamental frequency increases. Likewise, the increase in the rate of vocal disability implies the decrease in the efficiency index (Pr10). Therefore, the significant relationship found in the parameters Pr01 and Pr10 in the sample of women is reflected in the perception that women have about their vocal disability (81.81% of women showed mild disability).

On the other hand, the men only showed alterations in two parameters; decrease in the efficiency index (Pr10) and increase in the structural imbalance index (Pr21). However, in the analysis of relationships, a nonsignificant low correlation was found between them. The rest of the parameters were within the normal ranges. Note here that in the parameters Pr08 and Pr09 four participants were outside the normal range, indicating three of them increase in the index of muscle tension and glottic closure strength. In addition, these participants also presented alterations in the Pr20 parameter, indicating a greater mucosal wave effect. This could be because men do not compensate with the increase in fundamental frequency. In both men and women the Pr21 parameter was found to be altered, which means that there is a nonsignificant or compensated glottic impact.

In the case of men, the absence of significant correlation between the parameters of interest of biomechanical analysis does not imply that the perception they have about their vocal disability shows that 90% of men express having a mild vocal disability. It seems that this perception has no significant reflection between the relationship of the parameters of interest, nor between these and the VHI-30.

It appears that the VHI-30 in this sample implies differences in voice perception between the sexes. To solve these doubts, it would have been interesting to administer other questionnaires to measure the vocal disability of patients, such as the GRABS scale. This scale is applied by the voice professional, so it has a more objective judgment than the patient himself can have about his voice.

Covid-19 is an infectious process that can occur with inflammation of the respiratory tract and laryngitis. What differentiates Covid-19 from a rhinovirus, adenovirus, or influenza virus is the microbiological study, the clinic and the evolution of them. From the point of view of histopathological involvement, all these viruses would occur in a similar way creating an inflammatory response of the affected mucosa. In this way, it is impossible to differentiate from the acoustic point of view the aphonia secondary to an influenza or Covid-19 infection. What is possible, which is what this work tries to do is to describe the clinic observed in the voice of patients who have been infected by Covid-19. [Figure 2](#) shows the nasofibroscope image of a patient with acute laryngitis with GAP. The image does not allow to differentiate if it is an infection by Covid-19, bacterial or viral.



**FIGURE 2.** Image provided by the otolaryngology service of the Vithas Nuestra Señora de América Hospital in Madrid.

However, the patient's clinic helps establish that differentiation. The effect on the voice is the same, typical of an infectious process.

In summary, the clinical voice of patients who have passed the Covid-19 at the biomechanical level does not show a reflection of parameters exclusive to Covid-19. What was found is that at the biomechanical level, a Covid-19 infection affects in the same way as other infectious processes.

One of the limitations of this study is the small sample. Voice samples were collected during the first wave of the pandemic and none of the participants were vaccinated. During that time, no more patients were found who met the inclusion criteria. It was also not possible to continue collecting data due to the rapid start of the vaccination process.<sup>17,18</sup> Although no side effects of vaccines on the voice have yet been reported, other side effects called systemic adverse reactions have been found, such as headache, nausea, vomiting, fatigue, diarrhea, skin reactions, and mild pain at the prick site.<sup>19</sup> In this sense, it was decided not to collect voice data from vaccinated people, since the exact influence of vaccines on the voice is not known. Note here that although the sample of this study is small, it is a homogeneous sample that yields pure results.

There is currently a lot of talk about *persistent Covid*. This refers to the persistence of symptoms. However, the definition is not yet agreed. In fact, several definitions have been given, leaving it in consensus that it is a multiorgan syndrome, in which the elapsed time exceeds 12 weeks after infection, where more than 200 symptoms are described.<sup>19</sup> In this line, mention that it was also proposed to retest the voices of the participants after 3 months to see if they continued to present alterations in the same biomechanical correlates. A second test was not carried out due to the above mentioned start of the vaccination process. We assume that if we had carried it out, we would have stayed with a heterogeneous group of participants and could not accurately interpret whether the altered patterns in the biomechanical analysis were altered by side effects of vaccines such as

muscle fatigue (which would affect the larynx), or if they would actually be altered by Covid-19.

Another reason why no more samples were collected was due to the appearance of the different strains of the virus (Delta and Omicron). Again, we assumed that by mixing infected patients of different strains we would be left with a heterogeneous group that would not allow us to extract reliable results. In this regard, emphasize that in speech therapy consultations are beginning to arrive patients who have passed the Covid-19 with the Omicron strain who report persistent alterations in the voice. Are we facing a *persistent Covid* situation? It would be interesting to continue with this line of research and thus clarify with more robust results the effects of Covid-19 on the voice.

### CONCLUSIONS

Although other studies have shown the existence of exclusive acoustic parameters in patients with Covid-19, the results of this work show that the alterations in the biomechanical parameters of the voice in people who have passed Covid-19 are similar to the alterations found in people with other infectious processes such as laryngitis.

### DECLARATION OF COMPETING INTERESTS

The authors have no competing interests to declare.

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