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Exploring age-related changes in acoustic voice analysis parameters: insights from a study on older people

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Objective. Changes in voice in older people impact their ability to use their voice to communicate in all situations and can lead to decreased quality of life. The purpose of our study was to investigate through acoustic voice analysis the vocal parameters, according to sex, of older people who came to observation for dysphonia and subsequent diagnosis of presbyphonia.
Methods. The study was carried out on a group of 15 dysphonic patients (5 men and 10 women, mean age 69 years, range 62-75). The control group consisted of 20 euphonic patients (10 men and 10 women, mean age 68,55, range 62-75). Acoustic analyses were performed with the Multidimensional Voice Program (MDVP).
Results. After the calculation of the Fisher test (with $p < 0.05$) the differences in the vocal acoustic parameters dependent on sex, in the male dysphonic group were: Jitter, Shimmer, and VTI; in the female dysphonic group were FFtr, Fatr, vFo, Shimmer, VTI, FTRI.
Conclusions. Our study provided acoustic data of voice for the dysphonic older patients, which has been scarcely reported in the literature. Voice analysis programs such as MDVP require established norms for both older and younger/middle-aged individuals. This is crucial because the acoustic outputs of older speakers may differ significantly from those of younger and middle-aged speakers due to the natural aging process.

Key words: presbyphonia, voice, dysphonia, MDVP

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INTRODUCTION

The number of older individuals requesting consultations for dysphonia has trended upward in parallel with the aging population. The aging process affects the laryngeal structures, and the series of physiological events associated with voice aging is referred to as presbyphonia. This encompasses morphological changes in the mucosa and cartilaginous muscle coverage, as well as neurological and functional aspects [1]. Molecular and cellular changes due to aging may take place in the laryngeal musculature, the lamina propria, or cartilaginous structures [2]. Patient symptoms are characterized by poor vocal projection, shorter phonation duration, and vocal roughness [2]. Patients may complain that they can't clear their throat' and have difficulty being heard over background noise [3].

The objective assessment of the voice has received considerable attention, because of its comparatively low cost, easy application, and quantitative output.
The various programs available on the market, as Multi-Dimensional Voice Program, provide the possibility to perform a vocal-writing study on the recording made and this allows the extrapolation of acoustic parameters [4].
The purpose of our study was to investigate through acoustic voice analysis the parameters, according to sex, of older patients who came to observation for dysphonia and subsequent diagnosis of presbyphonia. The acoustic voice parameters of the group of presbyphonic patients were then compared to the acoustic voice parameters of a euphonic control group of the same average age.
Our group conducted a study on the changes in the voices of older patients likely prompted by a recognition of the limited understanding of how aging affects vocal characteristics. We have sought to address the gap in knowledge regarding the specific alterations in voice associated with aging, aiming to contribute valuable insights to the field of geriatric voice research. Additionally, understanding these changes could have implications for healthcare, communication disorders, or related fields, motivating the authors to explore and document the impact of aging on voice.

METHODS

The study was carried out on a selected group of 15 dysphonic patients (5 men and 10 women, mean age 69 years, range 62-75).
The inclusion criteria were the following: over or equal to 65 years of age, an adequate degree of collaboration.
The exclusion criteria were the presence of pathologies associated with dysphonia (neurological diseases, neoplastic diseases, muscular diseases, autoimmune and rheumatic diseases). The same protocol was then applied to a group of 20 healthy control individuals, not affected by any pathology related to voice (10 males and 10 females, mean age of 68.55 years, range 62-75).
All subjects were recruited among patients of ENT Department of the Polyclinic Hospital in Bari.
Patients were approached and informed about the study objectives and significance.
All patients who agreed to participate in the study signed an informed consent form, previously approved by the local hospital Ethics Committee.
The patients were excluded if they met any of the following criteria: reporting a condition that might affect the normal voice function, any previous formal voice training or voice therapy, any laryngeal, mouth, or throat abnormality, or any respiratory infection for the last 2 weeks before recording.
Any organic or dysfunctional alterations were ruled out by subjecting the patients to fiber optic laryngoscopic examination and stroboscopy.
Voice signal recording and analysis was carried out with KAY Computer Speech Lab (CSL) (156) model 4300B (Kay Elemetrics Corp., USA), supported by personal computer and basic software CSL5.0, with microphone at 20 cm, angled 45°, in a silent environment (< 30 dB of background noise). All subjects were trained to voice a vocal sample of a sustained /a/, at a conversational voice intensity, always within 55 dB and 65 dB, on average (not including recordings the average intensity of which was out of range), as constant as possible, with no intensity or frequency variation.
Acoustic analyses were performed with the Multidimensional Voice Program (MDVP) (model 5101) . The parameters analyzed were [5]:

- Fo (Hz). Average Fundamental Frequency for all extracted pitch periods;
- Fftr – Fo-Tremor Frequency /Hz/ – The frequency of the most intensive low-frequency Fo-modulating component in the specified Fo-tremor analysis range. The tremor analysis algorithm determines the voice's strongest periodic frequency and amplitude modulation;
- Aftr – Amplitude-Tremor Frequency /Hz/ – The frequency of the most intensive low-frequency amplitude-modulating component in the specified amplitude-tremor analysis range. If the corresponding ATRI value is below the specified threshold, the Fatr value is zero. The tremor analysis algorithm determines the voice's strongest periodic frequency and amplitude modulation;
- Jitt (%). Jitter Percent provides an evaluation of the variability of the pitch period within the analysed voice sample. It represents the relative period-to-period (very short-term) variability.vFo (%). Fundamental Frequency Variation represents the relative standard deviation (SD) of the period- to-period calculated fundamental frequency. It reflects the very long-term variations of Fo for all the analysed voice sample;
- Shim (%). Shimmer Percent provides an evaluation of the variability of the peak-to-peak amplitude within the analysed voice sample. It represents the relative period-to-period (very short-term) variability of the peak-to-peak amplitude;
- vAm (%). Peak Amplitude Variation represents the relative SD of the period-to-period calculated peak to- peak amplitude. It reflects the very long-term amplitude variations within the analysed voice sample;
- NHR. Noise-to-Harmonic Ratio is the average ratio

of the energy of the inharmonic components in the range 1500-4500 Hz to the harmonic components energy in the range 70-4500 Hz. It is a general evaluation of the noise presence in the analyzed signal (such as amplitude and frequency variations, turbulence noise, sub-harmonic components, and/or voice breaks);

- VTI. Voice Turbulence Index is an average ratio of the spectral inharmonic high-frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub-harmonic components are minimal. VTI measures the relative energy level of high frequency noise. It correlates primarily with the turbulence caused by incomplete or loose adduction of the vocal folds;
- SPI. This parameter is not a measurement of noise, but rather the harmonic structure of the spectrum. Soft Phonation Index is an average ratio of the lower frequency harmonic energy (70-1600 Hz) to the higher frequency (1600-4500 Hz) harmonic energy (compare to NHR and VTI). An increased value of SPI may be an indication of incomplete or loosely adducted vocal folds during phonation. SPI is very sensitive to the vowel formant structure because vowels with lower high-frequency energy will result in higher SPI. Only values computed for the same vowel can be compared. The vowel /a/ is recommended;
- FTRI – Frequency Tremor Intensity Index /%/ – Average ratio of the frequency magnitude of the most intensive low-frequency modulating component (Fo-tremor) to the total frequency magnitude of the analyzed voice signal;
- ATRI – Amplitude Tremor Intensity Index /%/ – Average ratio of the amplitude of the most intense low-frequency amplitude modulating component (amplitude tremor) to the total amplitude of the analyzed voice signal;
- DVB (%). Degree of Voice Breaks shows, in percent, the ratio of the total length of areas representing voice breaks to the time of the complete voice sample;
- DSH (%). Degree of Sub-Harmonics is an estimated relative evaluation of sub-harmonic to Fo componentsin the voice sample;
- DUV (%). Degree of Voiceless is an estimated relative evaluation of non-harmonic areas (where Fo cannot be detected) in the voice sample. In the case of non-sustained phonation from the beginning to the end of the data acquisition, DUV will evaluate also the pauses before, after and/or between the voicesample(s);

The sample size was calculated using G*Power.
Statistical analyses were performed using SAS version 9.4.

RESULTS

The data acquired from the dysphonic subjects were collected in Table I (10 male dysphonic subjects) and in Table II (5 female dysphonic subjects).
Table III and Table IV collect the parameters of the control group of euphonic patients.
In Tables V-VI the first statistical values were extrapolated to compare the 4 groups of patients; the minimum and maximum values recorded were identified and the mean standard deviation and median of each individual data group of the dysphonic subjects were calculated.
In Tables VII-VIII the mean, standard deviation and median of the control group were calculated.
Tables IX-X report the calculated values of the confidence and the interval of each parameter of the MDVP in male and female subjects. Confidence was calculated with two different levels of significance ($a < 0.01$ and $a < 0.05$): no statistically significant differences were detected (the same result was obtained for the confidence interval $\alpha < 0.05$).

Table I. Data acquired from the dysphonic male subjects.

Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
65	141,494	14,286	1,342	2,864	2,79	3,472	6,084	0,1584	0,0461	21,6051	0,887	1,185	0	0	0
67	217,421	1,732	1,702	0,69	1,246	4,731	13,07	0,1308	0,003	4,6386	0,489	5,249	0	0	0
81	159,908	1,05	6,061	3,245	4,196	5,968	8,182	0,1176	0,0341	35,3436	0,843	3,417	0	0	0
70	118,103	1,159	5,634	1,414	1,512	4,671	9,424	0,1521	0,421	20,2925	0,35	4,169	0	0	2,041
71	155,21	3,604	2,963	4,041	6,714	8,392	35,793	0,1938	0,0725	12,3069	1,307	5,945	0	2,155	9,02
65	184,598	2.312	1,194	4,934	4,469	6,612	12,708	0,0959	0,0887	21,1503	0,657	4,356	0	0	0
78	122,814	7,547	2,439	7,246	21,085	8,546	28,906	0,3492	0,7321	22,0797	3,84	5,722	1,99	0,649	42,105
70	176,538	4,598	2,941	2,62	5,123	3,887	43,892	0,1421	0,0444	21,7634	1,032	6,969	7,456	0,474	32,154
70	178,903	1,587	3,39	2,481	3,664	7,278	18,664	0,1599	0,0776	19,0147	1,128	7,428	0	4,211	1,042
69	123,376	4,151	4,938	2,416	2,759	5,805	16,235	0,0984	0,0436	36,7942	1,178	9,822	0	0	0

Table II. Data acquired from the dysphonic female subjects.

Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
62	166,41	2,5	1,187	1,097	1,244	2,864	11,204	0,1467	0,0421	28,5605	0,387	3,689	0	1,042	0
65	200,122	4,706	1,22	3,066	21,534	4,183	16,998	0,1546	0,0687	13,4767	6,178	2,557	0	2,247	6,316
75	222,387	1,413	2,198	4,009	3,454	7,609	16,8	0,1524	0,0337	34,9052	0,889	6,216	0	30,526	2,062
71	245,789	1,674	1,023	2,723	4,549	7,616	21,59	0,1671	0,0578	22,802	0,52	11,714	3,078	10,588	13,265
62	233,264	1,156	5,634	1,475	1,875	5,887	15,382	0,1376	0,075	9,3184	0,524	8,572	0	6,452	1,064

Table III. Control group of male subjects.

Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
75	118,899	1,149	6,557	1,922	1,833	8,754	11,943	0,1824	0,0860	6,1651	0,397	3,081	0	0	9,278
72	85,608	7,692	10,524	2,007	3,429	5,339	19,574	0,1166	0,0433	26,2323	1,055	10,879	0	0	1,031
65	92,134	3,226	11,765	1,466	3,955	11,586	17,891	0,3083	0,2119	4,6536	2,663	14,19	0	0	26,882
72	184,333	5,063	3,738	1,489	3,521	7,158	22,48	0,1541	0,0528	14,0295	1,382	9,923	0	5	0
69	116,827	1,036	4,651	0,863	1,359	4,974	9,592	0,153	0,0892	10,5541	0,253	2,567	0	0	1,12464.516
66	114,324	1,05	2,186	1,693	2,494	10,937	26,092	0,1953	0,0879	10,3633	0,201	9,764	0	0	17.0212,128
67	124,882	1,303	1,951	2,363	2,037	14,7	22,741	0,3594	0,1003	7,4675	0,501	9,91	0	0	64,516
67	155,767	2,857	1,465	3,653	4,757	24,821	23,476	0,2445	0,0384	14,9966	2,238	14,468	0	2,5	2,128
76	136,085	2,837	3,774	3,338	4,524	6,778	8,164	0,1382	0,0609	16,822	0,882	3,555	0	2,128	0
72	98,364	8,889	1,031	0,959	1,085	6,277	11,616	0,3185	0,1085	1,1436	0,391	4,664	0	0	13,402

Table IV. Control group of female subjects.

Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
75	185,406	1,569	1,399	0,253	0,744	3,357	15,774	0,1551	0,0461	8,0229	0,208	2,45	0	4,536	0
65	195,912	1,544	1,303	0,679	1,876	3,375	16,659	0,1216	0,0447	9,6011	0,703	4,031	0	0	0
62	225,985	4,832	1,538	0,382	0,827	2,089	7,578	0,1237	0,0415	14,8791	0,083	0,814	0	0	0
63	142,86	1,198	2,963	1,442	4,545	3,225	15,863	0,1331	0,0339	16,8863	2,832	8,403	0	0	0
66	176,886	2,649	1,311	0,491	1,016	2,922	12,331	0,1339	0,0455	3,2054	0,322	3,005	0	0	0
67	244,032	1,633	1,286	0,577	0,728	3,669	12,913	1,1265	0,03	3,4369	0,306	1,175	0	0	0
69	155,791	23,529	1,329	2,966	2,256	3,688	13,324	0,1366	0,0282	26,6359	0,47	3,03	0	0	0
69	294,54	3,704	3,704	1,102	2,108	3,362	16.332	0,1093	0,0367	6,159	0,381	7,518	0	4,255	0
65	147,277	1,212	1,212	2,245	2,345	4,308	12,465	0,164	0,0419	14,6626	0,733	1,507	0	2,062	0
69	207,951	1,515	1,515	0,266	1,095	2,675	17,014	0,1122	0,0302	5,217	0,716	4,056	0	0	0

Table V. Maximum value, minimum value, mean, standard deviation and median of male disphonic group.

	Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Max	81	217,421	14,286	6,061	7,246	21,085	8,546	43,892	0,3492	0,7321	36,7942	3,84	9,822	7,456	4,211	42,105
Min	65	118,103	1,05	1,194	0,69	1,246	3,472	6,084	0,0959	0,003	4,6386	0,35	1,185	0	0	0
Mean	70,6	157,837	4,2026	3,2604	3,1951	5,3558	5,9362	19,2958	0,15982	0,15631	21,4989	1,711	5,4262	0,9446	0,7489	8,6362
SD		32,1993	4,07021	1,74968	1,86061	5,76669	1,7777	12,7233	0,07294	0,23457	9,44311	0,98629	2,37695	2,37181	1,391	15,447
Median		157,559	2,958	2,952	2,742	3,93	5,8865	14,6525	0,1471	0,0593	21,37777	0,9595	5,4855	0	0	0,521

Table VI. Maximum value (Max), minimum value (Min), mean (Mean), Standard Deviation (SD) and Median (Median) of female disphonic group.

	Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Max	75	245,789	4,706	5,634	4,009	21,534	7,616	21,59	0,1671	0,075	34,9052	6,178	11,714	3,078	30,526	13,265
Min	62	166,41	1,156	1,023	1,097	1,244	2,864	11,204	0,1376	0,0337	9,3184	0,387	2,557	0	1,042	0
Mean	67	213,594	2,2898	2,254	2,474	6,5312	5,6318	16,3948	0,15168	0,05546	21,8126	1,6996	6,5496	0,6156	10,171	4,5414
SD		31,2593	1,44185	1,94618	1,18983	8,487	2,10186	3,72452	0,01084	0,01743	10,53	2,51046	3,70797	1,37652	11,9839	5,4340
Median		222,387	1,674	1,22	3,454	3,454	5,887	16,8	0,14464	0,0578	22,802	0,524	6,216	0	6,452	2,062

Table VII. Maximum value (Max), minimum value (Min), Mean (Mean), Standard Deviation (SD) and Median (Median) of male control group.

	Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Max	76	184,333	8,889	11,765	3,653	4,757	14,821	26,092	0,3594	0,2119	26,2323	2,663	14,468	0	5	64,516
Min	65	85,608	1,036	1,031	0,863	1,085	4,974	8,164	0,1166	0,0384	1,1436	0,201	2,567	0	0	0
Mean	70,1	122,722	3,5102	4,7642	1,9753	2,8994	9,1324	17,3569	0,21703	0,08813	11,2428	0,9963	8,3001	0	0,9628	13,538
SD		29,9952	2,83651	3,75396	0,92324	1,31577	3,68262	6,50856	0,08543	0,05286	7,18304	0,85899	4,50429	0	1,71622	20,039
Median		117,863	2,847	3,756	1,8075	2,9615	7,956	18,7325	0,18885	0,0879	10,4587	0,6915	9,837	0	0	5,703

Table VIII. Maximum value (Max), minimum value (Min), Mean (Mean), Standard Deviation (SD) and Median (Median) of female control group.

	Age	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Max	75	294,54	23,529	3,704	2,966	4,545	4,308	4,308	1,1265	0,0461	26,6359	2,832	8,403	0	4,536	0
Min	62	142,86	1,064	1,212	0,253	0,728	0,728	2,089	0,1093	0,0282	3,2054	0,083	0,814	0	0	0
Mean	67	197,66	4,2898	1,756	1,0403	1,754	1,754	3,3052	0,2316	0,03787	10,8706	0,6754	3,5989	0	1,86051	0
SD		47,5203	6,87296	0,85551	1,39574	1,17578	1,17578	0,62575	0,31491	0,00694	11,9463	0,78996	2,55686	0	2,28017	0
Median		190,659	1,601	1,484	0,628	1,4855	1,4855	3,3595	0,1335	0,03304	11,4085	0,4255	3,01750	0	0	0

Table IX. Confidence and confidence interval parameters MDVP male group (Maximum value (Max), minimum value (Min)).

	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Confidence 99%	24,4325	2,31047	3,05778	0,75203	1,07176	2,99967	5,30154	0,06959	0,04306	5,85094	0,69969	3,66897	0	1,39794	16,3235
Max	147,155	5,82067	7,82198	7,82198	3,97116	12,1321	22,6584	0,28662	0,13119	17,0937	1,69599	11,9691	0	2,36074	29,8617
Min	98,2898	1,19973	1,70642	1,70642	1,82764	6,13273	12,0554	0,14744	0,04507	5,39183	0,29661	4,63113	0	0,43514	2,78531
Confidence 95%	18,5909	1,75805	2,32668	0,57222	0,81551	2,28247	4,03397	0,05295	0,03276	4,45201	0,5324	2,79174	0	1,0637	12,4207
Max	141,313	5,26825	7,09088	2,54752	3,71491	11,4149	21,3909	0,26998	0,1209	15,6948	1,5287	11,0918	0	2,0265	25,9589
Min	104.131	1,75215	2,43752	1,40308	2,08389	6,84993	13,3239	0,16408	0,05537	6,79077	0,4639	5,50836		0,1009	1,1175

Table X. Confidence and confidence interval parameters MDVP male group (Maximum value (Max), minimum value (Min)).

	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
Confidence 99%	38,7076	5,59836	0,69685	1,1369	0,95773	0,50971	12,8935	0,25651	0,00565	9,73086	0,64346	2,08269	0	1,85731	0
Max	236,372	9,88816	2,45285	2,1772	2,71173	3,81419	26,9188	0,48811	0,04352	20,6015	1,31886	5,68159	0	3,71782	0
Min	158,956	1,30856	1,05915	0,096598	0,79627	2,79627	1,13175	0,02491	0,03222	1,13976	0,03194	1,51621	0	0,0032	
Confidence 95%	29,4528	4,25982	0,53024	0,86507	0,72874	0,38784	1,80377	0,19518	0,0043	7,40427	0,48961	1,58473	0	1,41324	0
Max	227,117	8,54962	2,28624	1,90537	2,48274	3,69304	15,8291	0,42678	0.04217	18,2749	1,16501	5,18363	0	3,27375	0
Min	168,21111	0,02998	1,22576	0,17523	1,02526	2,91736	12,2215	0,03357	0,03357	3,46635	0,18579	2,01417	0	0,44727	0

Finally, in Tables XI-XII the significance of the samples under examination was calculated with the Student's test and the Fisher test.

The MDVP parameters from the Fisher test of the male dysphonic group were statistically significant for $p < 0.05$ were: Jitter, Shimmer, VTI. In the female dysphonic group, the MDVP parameters at the Fisher test that were statistically significant for $p < 0.05$ were FFtr, Fatr, vFo, Shimmer, VTI, FTRI.

DISCUSSION

The prevalence of vocal disorders in the general population aged 60 years or more ranges from 4.8 to 29.1% [6]. Despite this high prevalence, studies are rare. This shortage of data may be because the sole effect of age on the voice is difficult to determine. Previous studies have demonstrated vocal fold bowing, paralysis, benign vocal fold lesions, voice tremor, and spasmodic dysphonia as the most common diagnoses in the older

Table XI. Statistical significance of parameters MDVP male group.

	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
T-TEST	0,05931	0,25899	0,25899	0,09793	0,24343	0,03626	0,67103	0,07961	0,3693	0,07247	0,71411	0,12379	Not Available	0,74971	0,37753
F-TEST	0,83615	0,29698	0,03282	0,04867	0,19766	0,04101	0,05859	0,64526	0,00031	0,42749	0,68724	0,07051	Not Available	0,54127	0,44996

Table XII. Statistical significance of parameters MDVP female group.

	F0	Fftr	Fatr	Jitt	vF0	Shim	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV
T-TEST	0,27994	0,95401	0,62356	0,02558	0,27667	0,0886	0,30589	0,1032	0,17013	0,03767	0,53096	0,1023	0,3739	0,1857	0,13502
F-TEST	0,43589	0,00871	0,0384	0,47926	0,00688	0,00296	0,49	0,70427	0,02118	0,34901	0,0044	0,32574	Not Available	0,0045	Not Available

patients [7-9]. Furthermore, older patients may suffer from an array of comorbid conditions and take multiple medications: there are many potential adverse effects from common medications prescribed to the aging population that may also affect vocal quality [10] .Respiratory function progressively declines with increasing age in both sexes and it has a great impact on vocal quality [11]. Although all the mechanisms that contribute to the reduction of this activity are not known, the factors that decrease lung elasticity, and muscle strength, and increased chest stiffness certainly play an important role [1]. Studies of the effects of aging on the respiratory system may be difficult to interpret for several reasons. Chronic exposure to environmental pollutants, repeated pulmonary infections, smoking, and differences in lifestyle, working conditions, and socioeconomic factors may cause alterations in the respiratory system that are not easy to distinguish from changes due to aging alone. Awan found that vital capacity was positively correlated with speaking fundamental frequency and maximum phonation time (MPT), and negatively correlated with variations in fundamental frequency [12]. The author specified that this could be the result of the aging process affecting both the respiratory and the laryngeal systems simultaneously. Furthermore, Vaca et al. [11] found that older people who had both a glottal gap and low spirometry values (FVC and PEF < 80% of predicted values) had significantly shorter MPTs, as well as measures related to greater impairment in auditory-perceptual ratings, jitter, and Voice Handicap Index-10 (VHI-10) when compared to participants with a glottal gap but normal spirometry measures. According to the study by Desjardins et al. [1], raw respiratory strength and the amount of air available for phonation were found to be the strongest predictors for physiological voice measures: a lower respiratory function was associated with lower vocal fold pliability and regularity of vibration and with an elevated aerodynamic resistance accompanied by supraglottic hyperfunction, which in turn had an impact on perceived handicap. Desjardins et al. demonstrated also how respiratory function did not have an effect on voice quality (as measured by auditory-perceptual and acoustic measures), which was mostly influenced by the severity of vocal fold atrophy.

The production of the voice also depends on sophisticated and integrated exchanges of sensory and motor information that run along with the nervous networks which with age undergo a general and physiological reduction in conduction speed, resulting in delayed and not always precise muscle coordination [13].

Synaptic connections are reduced in the number and concentration of neurotransmitters [14].

At the periphery, the nerve fibers reduce their diameter due to a thinning of the myelin and the number of nerve axons. Neuromuscular units decrease in number and density on nerve fibers resulting in less vigorous muscle contractions and coarser movements [15,16]. A reduction of nerve cells occurs between 18 and 83 years in the subject's white matter [17], with obvious consequences for the functions regulated therein, such as consciousness, personality, hearing, memory, sight, and motor functions. Furthermore, the discovery that with advancing age the brain reduces its dopamine levels by more than 50% is fundamental [18]. The effects of these "age-related" alterations in the dopaminergic system occur with a substantial deterioration of muscle tone, a weakening of performance, and a reduction in sensory-motor integration that also affects the verbal system, being able to slow down the speed of phonation in the older people [19].

The reduction or change in hormonal balances, both in males and females, plays a key role in the aging of the voice. It has also been reported that the fundamental speaking frequency tends to increase in males with aging whereas it tends to decrease in females, because of the shortening of the membranous vocal fold and increase in stiffness of the vibrating tissue [20].

According to the studies by Hirano et al. [21,22], the vocal fold tended to shorten with age, especially after 70 years. This tendency seems to be more marked in males than in females. In males, the thickness of this layer and the density of elastic fibers tended to decrease with age whereas, in females, no such tendency was observed. Elastic fibers became atrophic and the contour of the intermediate layer which is normally of sickle shape became more or less deteriorated in males. In females, such changes were less marked.

Martins et al. findings showed smaller diameters of vocal muscle fibers in older people when compared to controls, demonstrating the atrophy of the muscle [23].

Pontes et al. [24], comparing morphological and functional aspects of the young adult and the geriatric larynx, noticed that the presence of protuberant vocal process, increased glottic proportion, phase, and amplitude mucosal wave asymmetry and tremor of laryngeal structures were features of old women's larynx, and bowing of the vocal fold membranous portion plus increased glottic proportion characterized the old men's larynx.

Videostroboscopy or other instrumental imaging tests of the larynx can reveal asymmetries in vibration and longer duration in the open phase. In this regard Bloch in 2001 [25] prepared a study of quantitative analysis of the images obtained with videostroboscopy, hypothesizing that the arching of the vocal cords directly correlates with the glottic gap in patients with presbilarynx and that these characteristics could be objectively quantified.

Right now, there are not many studies in the literature regarding the acoustic analysis of the voice in older patients. Devadiga et al. [26] studied a total of 162 participants, in the age range of 60-70 years using the MDVP software: an increase observed for frequency-related perturbation measures with age except for mean Jita was observed. The older participants in the study of Xue et al. [27] had significantly higher VTI, SPI, and NHR than the norms of young and middle-aged adults: although elderly men had higher VTI than young and middle-aged men, this difference was not statistically significant ($p > .05$).

The study by Schaeffer et al. [28] revealed a significant difference at the 0.001 level for mean RAP values between the older and the younger groups. The older participants showed higher mean MDVP values for shimmer and NHR than the younger group . Additionally, males demonstrated greater degrees of shimmer than females.

Unlike previous studies in the literature, our study highlighted alterations specific to sex in vocal parameters between older dysphonic subjects and older non-dysphonic subjects.

With aging, it is, therefore, possible to identify differences in the vocal acoustic parameters dependent on sex, which can add an additional variable to be considered during the diagnosis of presbyphonia.

However, it's important also to underline how the routine acoustic voice assessments in non-gerontologic settings face specific challenges that stem from the complexity of diverse environments and the multifaceted nature of vocal communication. These challenges can impact the accuracy and applicability of voice assessments in various settings, such as educational institutions, workplaces, or clinical environments (Example: Integration with Multidisciplinary Approaches: Voice assessments often benefit from a multidisciplinary approach involving speech-language pathologists, otolaryngologists, and other healthcare professionals. In non-gerontologic settings, achieving effective collaboration between professionals from diverse fields may be hindered by organizational structures, communication barriers, and differences in professional terminology).

Limitations of the study

The small sample size considered may not be representative of the larger population, and the results might be more susceptible to random variations or outliers.

CONCLUSIONS

Our study provided acoustic data of voice based on sex for dysphonic older people, which has been scarcely reported in the literature. In addition, this study also identified several very important implications: acoustic voice analysis programs (like MDVP) need norms for older people as well as for the young and middle-aged because older speakers may have quite different acoustic outputs than young and middle-aged speakers as a result of the natural aging process. If the acoustic analysis programs they use do not provide acoustic voice norms for older persons, practicing speech and hearing clinicians must use caution and discretion when making diagnostic evaluations and clinical judgments of the voices of older patients.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

MLF, VDN: conceptualisation; GC, MLF, VDN: data curation; GC, MLF, VDN: formal analysis; GC, MLF, VDN: writing – original draft; GC, MLF, FB, VDN: writing – review & editing.

Ethical consideration

This study was approved by the Institutional Ethics Committee (Comitato Etico Indipendente Azienda Ospedaliero-Universitaria "Consorziale Policlinico" Bari (prot. 67172/DS, 02/08/2021). The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki. Written informed consent was obtained from each participant/ patient for study participation and data publication.

References

1 Desjardins M, Halstead L, Simpson A, et al. The impact of respiratory function on voice in patients with presbyphonia. J Voice 2022;36:256-271. https://doi.org/10.1016/j.jvoice.2020.05.027

2 Galluzzi F, Garavello W. The aging voice: a systematic review of presbyphonia. Eur Geriatr Med 2018;9:559-570. https://doi.org/10.1007/s41999-018-0095-6

3 McGarey PO Jr, Bitar R, Hughes CK, et al. Correlation of glottic gap and voice impairment in presbyphonia. Laryngoscope 2021;131:1594-1598. https://doi.org/10.1002/lary.29068

4 Keung LC, Richardson K, Sharp Matheron D, et al. A comparison of healthy and disordered voices using Multi-Dimensional Voice Program, Praat, and TF32. J Voice 2022:S0892-1997(22)00011-X. https://doi.org/10.1016/j.jvoice.2022.01.010

5 Di Nicola V, Fiorella ML, Spinelli DA, et al. Acoustic analysis of voicein patients treated by reconstructive subtotal laryngectomy. Evaluation and critical review. Acta Otorhinolaryngol Ital 2006;26:59-68.

6 de Araújo Pernambuco L, Espelt A, Balata PM, et al. Prevalence of voice disorders in the elderly: a systematic review of population-based studies. Eur Arch Otorhinolaryngol. 2015 Oct;272(10):2601-9. doi: 10.1007/s00405-014-3252-7. Epub 2014 Aug 23. PMID: 25149291.

7 Applebaum J, Harun A, Davis A, et al. Geriatric Dysphonia: Characteristics of Diagnoses in Age-Based Cohorts in a Tertiary Voice Clinic. Ann Otol Rhinol Laryngol. 2019 May;128(5):384-390. doi: 10.1177/0003489419826133. Epub 2019 Jan 24. PMID: 30678474.

8 Rapoport SK, Menier J, Grant N. Voice Changes in the Elderly. Otolaryngol Clin North Am. 2018 Aug;51(4):759-768. doi: 10.1016/j.otc.2018.03.012. Epub 2018 Jun 8. PMID: 29887345.

9 Roy N, Kim J, Courey M, et al. Voice disorders in the elderly: a National Database study. Laryngoscope 2016;126:421-428. https://doi.org/10.1002/lary.25511

10 Roy N, Stemple J, Merrill RM, et al. Epidemiology of voice disorders in the elderly: preliminary findings. Laryngoscope 2007;117:628-633. https://doi.org/10.1097/MLG.0b013e3180306da1

11 Vaca M, Mora E, Cobeta I. The aging voice: influence of respiratory and laryngeal changes. Otolaryngol Head Neck Surg 2015;153:409-413. https://doi.org/10.1177/0194599815592373

12 Awan SN. The aging female voice: acoustic and respiratory data. Clin Linguist Phon 2006;20:171-180. https://doi.org/10.1080/02699200400026918

13 Painter MW. Aging Schwann cells: mechanisms, implications, future directions. Curr Opin Neurobiol 2017;47:203-208. https://doi.org/10.1016/j.conb.2017.10.022

14 Smith GS. Aging and neuroplasticity. Dialogues Clin Neurosci 2013;15:3-5. https://doi.org/10.31887/DCNS.2013.15.1/gsmith

15 Rosso AL, Studenski SA, Chen WG, et al. Aging, the central nervous system, and mobility. J Gerontol A Biol Sci Med Sci 2013;68:1379-1386. https://doi.org/10.1093/gerona/glt089

16 Sorond FA, Cruz-Almeida Y, Clark DJ, et al. Aging, the central nervous system, and mobility in older adults: neural mechanisms of mobility impairment. J Gerontol A Biol Sci Med Sci 2015;70:1526-1532. https://doi.org/10.1093/gerona/glv130

17 Bendlin BB, Fitzgerald ME, Ries ML. et al. White matter in aging and cognition: a cross-sectional study of microstructure in adults aged eighteen to eighty-three. Dev Neuropsychol 2010;35:257-277. https://doi.org/10.1080/87565641003696775

18 Hornykiewicz, O. Dopamine changes in the aging human brain: functional considerations. In Agnoli et al., Eds. Aging 1983;23:9-14.

19 Seidler RD, Bernard JA, Burutolu TB, et al. Motor control and aging: links to age-related brain structural, functional, and biochemical effects. Neurosci Biobehav Rev 2010;34:721-733. https://doi.org/10.1016/j.neubiorev.2009.10.005

20 Eichhorn JT, Kent RD, Austin D, et al. Effects of Aging on vocal fundamental frequency and vowel formants in men and women. J Voice 2018;32:644.e1-644.e9. https://doi.org/10.1016/j.jvoice.2017.08.003

21 Hirano M, Kurita S, Sakaguchi S. Ageing of the vibratory tissue of human vocal folds. Acta Otolaryngol 1989;107:428-433. https://doi.org/10.3109/00016488909127535

22 Hirano M, Sato K, Nakashima T. Fibroblasts in geriatric vocal fold mucosa. Acta Otolaryngol 2000;120:336-340. https://doi.org/10.1080/000164800750001215

23 Martins RH, Benito Pessin AB, Nassib DJ, et al. Aging voice and the laryngeal muscle atrophy. Laryngoscope 2015;125:2518-2521. https://doi.org/10.1002/lary.25398

24 Pontes P, Yamasaki R, Behlau M. Morphological and functional aspects of the senile larynx. Folia Phoniatr Logop 2006;58:151-158. https://doi.org/10.1159/000091729

25 Bloch I, Behrman A. Quantitative analysis of videostroboscopic images in presbylarynges. Laryngoscope 2001;111(11 Pt 1):2022-2027. https://doi.org/10.1097/00005537-200111000-00029

[26] Devadiga DN, Bhat JS, Guddattu V. Perturbation-related measures of voice in geriatrics: a normative using multidimensional voice profile. Int J Otorhinolaryngol Clin 2019;11:34-37.

[27] An Xue S, Deliyski. Effects of aging on selected acoustic voice parameters: preliminary normative data and educational implications. Educational Gerontology 2001;27:159-168.

[28] Schaeffer N, Knudsen M, Small A. Multidimensional voice data on participants with perceptually normal voices from ages 60 to 80: a preliminary acoustic reference for the elderly population. J Voice 2015;29:631-637. https://doi.org/10.1016/j.jvoice.2014.10.003