

## **Correlation between acoustic measures, voice handicap index and GRBAS scales scores among Moroccan students.**

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### **Abstract**

**Purpose:** The purpose of this paper is to explore students' perceptions of voice handicap and to analyze their acoustic parameters to determine whether acoustic measures of students' voice would correlate with their perceptions of voice handicap assessed by Arabic version of Voice Handicap Index (VHI), and with the perception of the listener assessed by the scale of Grade, Roughness, Breathiness, Asthenicity and Strained (GRBAS scales). This study will also check the correlation between GRBAS scales results and VHI scores.

**Method:** 371 students (204 girls and 167 boys), underwent 3 kinds of communication disorders assessment: vocal assessment that included the Arabic version of VHI-30, acoustic measures and perceptual analysis of dysphonia which was performed by 2 speech language therapists using the GRBAS scale. The control group consisted of a group of students selected based on VHI-30 scores cut off. The correlations were assessed using the Pearson correlation coefficient. The differences were assessed using Mann Whitney U Test. The difference is significant if  $p\text{-value} < 0.05$  and the correlation is strong if the correlation coefficient  $r$  is bigger than 0.7.

**Result:** For all subjects and male gender, low positive correlations were found between the total VHI score and Shimmer local, number of voice breaks and jitter local. It was revealed high correlations ( $r > 0.72$ ) between total VHI-scores, functional VHI score, emotional VHI score and the overall severity resulted from GRBAS subscales. However, a moderate correlation ( $r = 0.61$ ) was resulted between physical VHI and the overall severity of GRBAS subscales. We noticed that B subscale is highly correlated ( $r > 0.75$ ) with all subscales of VHI. Moderate to high correlation was revealed between respectively the numbers of voice breaks, jitter (local), shimmer (local) and GRBAS subscales. However, little correlation between Mean pitch, maximum pitch, fraction of locally unvoiced frames respectively and GRBAS subscales.

**Conclusion:** VHI, GRBAS scales and acoustic measures are assessing two different levels of activity according to the World Health Organization classification of Impairment, Disabilities, and Handicaps. Thus, these three types of assessment tools may be used as separate procedures in one test battery to reach a comprehensive evaluation of voice disorders in different populations.

**Keywords:** VHI-30, Acoustic analysis, GRBAS scale, Voice disorders.

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### **Introduction**

The World Health Organization's (WHO) International Classification of Impairments, Disabilities, and Handicaps identifies handicap as limitations in individual activities through the disorder and the personal and environmental

factors that might change the individual's perceptions of his/her disorder [1].

As described in the report of 2014's survey on handicap in Morocco [2]; seven categories define a handicap situation:

Motor impairment, hearing impairment, visual impairment, visceral and metabolic impairment, mental and psychic impairment, esthetic impairment and speech and language disorders defined also as communication disorders which are the focus of the present paper.

### ***Communication Disorders Statistics in Morocco***

Based on the results of Moroccan survey, it was estimated that 1.38% of Moroccan population had communication disorders, 0.6% of the 1.38% are from university studies, which represents 0.008% of Moroccan students; and 1.6% of the 1.38% are following primary studies, which represents 0.02% of teenagers [2].

Regarding the ages, among the 1.38%; 0.34% are less than 15 years old; which represent 0.0047% of the entire population less than 15 years old; and 0.85% are between 15 years old and 59 years old, which represent 0.01% of the population between 15 years old and 59 years old. According to a recent academic study, students who answered as having serious communication disorders were ranked according to type of disorder [3]: hearing problems represent 10.5%; voice disorders represent 9.3%; followed by dyslexia with 7.7% and stuttering with 7.1%.

Another recent study based on an online survey was conducted among a fairly representative sample of Speech-Language Therapist (SLT) covering 15 major cities of Morocco and questionnaires were completed by 68 SLTs [4]. Within the studied sample, results revealed that 53.8% show oral communication disorders; 16.7% have written communication disorders, 11.2% show disabilities (deafness, autism, mental disability and other Rare Diseases), 10.5% have Ear-Nose-Throat (ENT) disorders and the rest (7.8%) has communication neurological disorders. It is estimated that 5.62% of the Moroccan population are affected with speech disorders, 1.74% are unable to communicate in writing, 1.17% are disabled, 1.09% are affected with ENT disorders, and 0.81% have neurological disorders. Thus, in this study, we found that the estimated prevalence of communication disorders were 10.43% for the overall population, among them speech disorder found to be very prominent.

Communication disorders may not only have an impact on the general health condition but also bring about employment-related problems, which was estimated in the survey by 11.5% (compared with employment-related problems of ear disorder: 9.4%, and the employment-related problems of eye disorder: 14.5%) [2].

### ***Voice Disorders Measurements: Objective and Subjective Tools***

In order to quantify the severity of communication disorders; significant efforts have been made to develop objective measures as crucial instruments in addition to the subjective ones [5,6].

One of the most common subjective instruments of self-assessment that has been designed to evaluate the quality of life specific to voice disorder is the Voice Handicap

Index (VHI). This scale has been shown to have construct validity and reliability [7,8].

VHI permits the person to describe the sensations their voice gives. It is a questionnaire that reviews situations grouped into three areas (functional, physiological and emotional) and gives an idea of the subjective impact that a vocal problem produces in a specific individual. The VHI was translated in many languages, French, Chinese, Portuguese, Spanish and Arabic [9].

As the VHI identifies persons' diverse individual perceptions and needs subjectively, acoustic measures give objective data of voice quality for individuals with voice disorders.

Some acoustic measures taken into account in previous studies:

- Fundamental frequency (Mean Pitch): This measures the number of cycles of vocal fold vibration per second.
- Jitter%: This reflects the change of frequency (cycle-to-cycle frequency perturbation) from one successive period to the next.
- Shimmer%: This indicates the percent of small changes in cycle-to-cycle amplitude of the vocal fold signal.
- Signal to noise ratio (SNR) which is a ratio measure of the energy in the voice signal over the noise in the voice signal.

Less shimmer% and jitter% reflect more stability of cycle-to-cycle vocal fold vibration. On the other hand, greater SNR indicates better voice quality.

The GRBAS scales, as described by Hirano, are semi objective tools to assess communication disorders in addition to the objective tool (acoustic measures) and subjective tool (VHI) [10].

However, neither the objective evaluation via acoustic or aerodynamic measurements nor the technologically advanced images of the voice production system make it possible to assess the level of handicap that a person experiences as a result of voice disorders [11].

### ***Voice Handicap Index: VHI-30***

In our study, in order to quantify students' opinion as to the impact caused by communication disorder, the Voice Handicap Index has been employed to assess the impact communication disorders have had on students' quality of life [2,3,12-14]. The VHI is the Students' self-perception form. VHI entails a functional (functional/ VHI-F), physical (physical/VHI-P) and emotional (emotional/ VHI-E) subscale with 10 sub questions per category. The student rates his/her answer from 0 to 4 (0=never; 1=almost never; 2=sometimes; 3=almost always; and 4=always), and the total score is calculated between 0 and 120 and for each subcategory between 0 and 40. A low total VHI score (VHI-T: score 0–30) relates to light voice problems,

a score of 30–60 represents a medium-to-heavy handicap level and a score ranging from 61 to 120 indicates severe voice disorders.

All subjects were instructed to answer the VHI-Arab, a version of the original VHI [9]. A perceptually normal voice had a VHI score 11.5. This particular VHI cutoff score was selected because had reported that the upper limit of the 95% confidence interval for VHI scores in subjects with healthy voices was 11.5 [15]. In this paper, the control group was constructed based on cut off value of VHI-30.

### **Acoustic Analysis**

At the time of recording, participants did not have any cold or flu symptoms and had no prior history of voice related systemic diseases.

We reminded students that the procedure was not an examination of their vocal abilities but for the purposes of data collection. All the participants were subjected to acoustic voice analysis; Audio recordings of the speech signal were conducted through a Dictaphone Sony [ICD-PX333], Situated at 5 cm of the students' mouth while they emitted the "sustained a" sound at comfortable intensity and pitch levels, as long as they could.

The sampling rate was set at default (22.050 kHz) for all recordings. The speech samples were directly input into audacity software (Audacity 2.1.2 version) then into Praat (version 6.0.16) [16,17]. The computer used was an Intel® Core™ i7 CPU M640 @ 2.8 GHZ 2.8 GHZ with 4 Go of RAM The sampling frequency was 44,100 Hz. The acoustic analysis was performed using Praat software (version 6.0.16) for Windows 7. Once the signal was digitized, Praat calculated the acoustic parameters: Median pitch: Mean pitch (Hz); Minimum pitch: Mean pitch; Maximum pitch; Fraction of locally unvoiced frames; Number of voice breaks; Jitter (local); Jitter (local, absolute) ; Jitter (rap); Jitter (ppq5); Jitter (ddp); Shimmer (local); Shimmer (local, dB); Shimmer (apq3); Shimmer (apq5); Shimmer (apq11); Shimmer (dda); Mean autocorrelation; Mean noise-to-harmonics ratio; Mean harmonics-to-noise ratio (dB). Based on correlation scores, Mean pitch (Hz); Fraction of locally unvoiced frames; Number of voice breaks; Jitter (local); Shimmer (local) are not correlated.

The following acoustic cited parameters of sustained vowel/a/phonation were assessed.

### **GRBAS Scales (Grade, Roughness, Breathiness, Asthenicity and Strained)**

Perceptual analysis of dysphonia was performed using the GRBAS scale [18]. Two experienced professionals evaluated the recorded voice samples simultaneously, classifying each sample from 0 to 3 (0=normal, 1=mild, 2=moderate, 3=severe). The severity of hoarseness is quantified under the parameter G (grade), which represents overall voice quality. B (breathiness): audible impression of turbulent air leakage through an insufficient glottic closure, which may include short aphonic moments (unvoiced segments).

R (roughness or harshness): audible impression of irregular glottic pulses, abnormal fluctuations in mean pitch. A (asthenicity): impression of weakness in the spontaneous phonation, hypokinetic or hypofunctional voice. S (strain, vocal tension): auditive impression of excessive force or tension associated with spontaneous phonation.

### **Correlations between Acoustic Measures, VHI Scores and GRBAS Scales Scores**

Several studies have been carried out regarding the correlation of acoustic and aerodynamic measures to the VHI [19,20].

The study of [18] reported no significant correlation between vocal fatigue and acoustic measures (fundamental frequency or mean pitch, jitter%, shimmer%).

Similar findings were identified by Lehto et al. [21] who reported no correlation was established between acoustic measures such mean pitch and self-rate of voice symptoms. Jonsdottir et al. [22] reported that increased mean pitch might suggest ample vocal adaptation to excessive voice use and not phonatory degradation.

On the other hand, Schmidt et al. [23] found inconsistent correlation between people's perception of effectiveness measures and different acoustic measures.

As previous studies Stemple et al. [24] showed indecisive results, there is a need to investigate further the relation, if any, between acoustic measures and subjective measures (i.e., VHI-30, GRBAS scales). Such a correlation, if found, may help clinicians follow up their clients progress using different tools interchangeably.

## **Proposed Method**

### **Aim of this Paper**

The aim of the present study was to examine the correlation between the VHI and objective voice measurements to find whether the self-rating scales of the VHI-30 would be verified by acoustic measures.

In addition to that examine the correlation if any between GRBAS scale scores and VHI, and find out whether there is a difference between the dysphonic group and control group in terms of VHI-30, acoustic measures and GRBAS scales scores.

### **Subjects**

A total of 371 students participated in the study, (167 boys and 204 girls) (mean age 22.35 and standard deviation 2.10). The sample insures a confidence level of 95% and confidence interval of 5 [25].

Participants were randomly recruited, following the ethical standards of anonymity, confidentiality, and consent, from faculty of science Ben M'sik, Casablanca, Morocco.

## **Materials and Methods**

Method combines objective and subjective evaluation and is constituted from the steps listed below:

- The students fill Arabic version of VHI-30 (the validated VHI- Arabic was used in this study [9].
- Recording of sustained /a/ utterances.
- GRBAS scale evaluation by two speech languages therapists.
- Acoustic parameters extraction based on recording of /a/ utterances.
- A correlation study was done in order to reduce the acoustic parameters to the relevant and independent ones.
- Based on the cut off values of VH-30, we construct the control group and dysphonic one.
- Correlation between the three components: acoustic parameters scores, VHI-30 scores and GRBAS scale scores.
- Mann Whitney test evaluation to reveal the difference in gender and in age and between control group and dysphonic one.

We mention in one hand that the thresholds of acoustic parameters are different from paper to paper, and in the other hand that GRBAS scales scores are related to the perception of the listener.

Thus, for these limitations related to GRBAS-scales scores and acoustic parameters ones we take into account the cutoff of VHI in this study in order to build control group and dysphonic one.

### Statistical Analysis

Statistical analysis was performed using the SPSS software Version 18.0 [26]; the correlations were calculated with Pearson's coefficient and  $p < 0.05$  was considered the level of significance, [27].

The correlations tests were conducted to find out any possible relation between students' scores on the VHI-Arab and their results on acoustic parameters and GRBAS scale scores.

The correlations coefficients of 0.00–0.30 represent “little if any correlation,” those of 0.30–0.50 are “low,” those of 0.50–0.70 are “moderate” and  $>0.70$  are “high” to “very high” in terms of effect size magnitude [28].

The differences were calculated using the Mann Whitney test.

The statistical differences were considered significant when  $P$  was lower than 0.05.

## Results and Discussion

- The overall internal consistency is 0.97%.
- The internal consistency of GRBAS scores, VHI-30 and acoustic analysis results are respectively 0.98%, 0.97% and 0.96%.

### VHI-30 Scores

The two groups of students (the dysphonic group and the control one) were identified based on the cutoff of VHI scores.

Table 1 shows the averages obtained from the “Voice Handicap Index” questionnaire in the functional, physical and emotional scales in both groups, as well as the calculated total score which is the sum of functional, physical and emotional subscales scores.

Based on Table 1 results:

- On comparing the VHI scores obtained in both groups (the control group and dysphonic one), there were statistically significant differences ( $p\text{-value} < 10^{-4}$ ).
- Upon completing the comparison between the two groups, the statistical difference is significant, in favor of the dysphonic group in all subscales as well as the global scores.
- We note that the total VHI scores were over 3 times as high as in control group.
- In our study, low scores, classified as mild-disability; were obtained for dysphonic group in the three scales, functional, physical and emotional. This could imply reduce impact in the quality of life of studied sample of students.
- The statistically significant differences are more important in emotional scales ( $p=4.10^{-6}$ ) although less important in physical scale ( $1.310^{-5}$ ): This result indicates that students have a somewhat high perception of voice handicap, which was expected because students are not considered professional voice users, with heightened perception of voice use, compared with a study on teachers which are considered professional voice users [29-31].
- It should be noted here that, according to the original VHI, the physical subscale includes statements describing the sensation related to the vocal output (pitch, loudness and quality), and the emotional subscale includes statements describing

**Table 1.** Evaluation of VHI-30, scores and differences between control group and dysphonic group using Mann Whitney test

VHI-30	Dysphonic group	Control Group	p-value
Functional VHI	14.1	4.5	$8.10^{-5}$
Physical VHI	15.21	4.8	$1,5. 10^{-5}$
Emotional VHI	11	3	$4. 10^{-6}$
Total VHI	40.3	12.3	$1,3. 10^{-5}$

the affective impact of the voice on the subject. It is expected that students, will be more caring regarding their vocal health. An unhealthy voice might mean the end of their academic career and their social being.

- The functional subscale was found also statistically significant. The functional subscale includes statements describing the impact of the voice on daily activities. This is important for daily life of a student.

Table 2 lists the means and standard deviations of the dysphonic group and the control group's total scores on the VHI-Arab along with the physical, functional, and emotional subscales scores.

As shown in Table 2:

- Regarding gender, for both groups, no significant differences (p-value<0.05) were found among students in the three VHI subscales, and the total score.
- Regarding the means of total VHI and their subscales, for female the mean values of total VHI score and their subscales are higher than male, however the means are slightly higher for boys in the control group.
- The no significant differences are more apparent in control group than dysphonic group.
- Russel et al. [32] found that women are more prone to voice problems compared with men, which is consistent with our finding.

- A closer look at the data reveals that p-value=0.1; is the lowest value (the nearest value to 0.05) which is related to physical VHI.

Based on Table 3 results:

- As for students' age, no significant differences were found between dysphonic group and control group.
- The no significant differences are more apparent in control group than dysphonic group for physical subscale.
- For dysphonic group, Spearman's r test reveals a moderate correlation between age and VHI scores.
- For the control group, Spearman's r test reveals no correlation between age and VHI scores: This result means that for this particular group of students, all participants had a somewhat equal perception of voice handicap.

**Acoustic Analysis**

Based on the correlation between acoustic parameters listed by Praat; we define these parameters as independent if the correlation coefficient is greater than 0.7. By looking at Table 4:

There was no significant divergence between the parameters: fundamental frequency (mean pitch), (p-value=0.35), maximum pitch (p-value=0.29) and number of voice breaks (p-value=0.055) on comparing both groups. However, there were significant differences in the jitter (p-value=1.5.10<sup>-5</sup>), shimmer (p-value=0.0002), NHR (Noise to Harmonic Ratio) (p-value=0.0002) and fraction of locally unvoiced frames (p-value=0.018).

**Table 2.** VHI, measurement of comparison between gender and individual domains and total VHI scores in the dysphonic students and control group using Mann Whitney test

VHI-30	Gender	Mean		Standard Deviation		p-value	
		Dysphonic Group	Control Group	Dysphonic Group	Control Group	Dysphonic Group	Control Group
Functional VHI	Male	13,1	4.6	6,64	3.66	0.46	0.71
	Female	23	4.14		2.68		
Physical VHI	Male	14	5	6,32	3.92	0.1	0.45
	Female	26	4.21		2.91		
Emotional VHI	Male	10	3.1	4,44	3.06	0.14	0.37
	Female	20	2.5		2.62		
Total VHI	Male	37,1	12.68	17,22	10.34	0.16	0.67
	Female	69	10.85		7.68		

**Table 3.** VHI, measurement of correlation between age and VHI (all subscales and total) scores in dysphonic group and control group using Spearman rank correlation coefficient

VHI-30	r Value		p-value	
	Dysphonic group	Control group	Dysphonic group	Control group
Functional VHI	0.5	-0.12	0.39 (>0.05)	0.34 (>0.05)
Physical VHI	0.57	-0.05	0.31 (>0.05)	0.71 (>0.05)
Emotional VHI	0.52	-0.12	0.36 (>0.05)	0.39 (>0.05)
Total VHI	0.67	-0.11	0.21 (>0.05)	0.35 (>0.05)

- For dysphonic group, the values of acoustic parameters exceed the norms reported in multiple studies which are an indication of vocal abuse/misuse [33].

We notice that:

- Shimmer% results may be affected by environmental factors (such as the time of day the recording was obtained, noise level, etc.)
- The control group has more stable voices and a better vocal quality.
- The greater values of NHR are a sign of a relatively stable acoustic measure.

As shown in Table 5:

- Significant differences were found among female and male students in mean pitch (max pitch included) (p-value=0.003) and fraction of locally unvoiced frames (p-value=0.0052).
- The significant difference between male and female in fundamental frequency is an indication of possible abuse and misuse of voice.

**GRBAS Scales Scores**

For the internal consistency Cronbach’s alpha GRBAS is equal to 0.97, if S is missed the Cronbach’s alpha value will increase to be 0.98; and if G, R, B or A is missed, the value will decrease to be (0.9); which revealed the impact of the subscales G, R, B, A compared with the impact of

S subscale.

Perceptual dysphonia analysis scores in Table 6 show the results obtained using GRBAS scale on students. As shown in Table 6:

- In the average 2.6% of the studied sample are classified with severe level.
- Low scores are revealed for S subscale, and high scores are for G, R and A subscales. In Table 7:
- Significant differences between the two groups in all GRBAS scales (p-values<0.05)
- The difference is more significant in G and R (p-value=1.4.10<sup>-5</sup>); and is less apparent in S scale (p-value=0.0034).
- We noted obviously that low scores are revealed in control group.
- On comparing the results obtained in the G domain of the GRABS scale, a significant difference was found between the two groups (p-value=1.4.10<sup>-5</sup>). In the study by Tamura et al. [34] there were no significant differences found between the two groups on comparing the scores obtained using the G parameter of the GRABS scale, which corresponds to the degree of dysphonia.

However in this study we revealed significant differences between both groups in all subscales of GRBAS.

**Table 4.** Acoustic analysis data: Mean standard deviation and p-values for control and dysphonic group (using Mann Whitney Test)

Acoustic Parameter	Dysphonic Group	Control Group	p-value
Mean pitch	148,04 ± 35.37	158.51 ± 42.75	0,35
Jitter	1.2% ± 0.45%	0.4% ± 0.17%	1,5. 10 <sup>-5</sup>
Shimmer	12.69% ± 2.92%	8.89% ± 2.18%	0,0002
Noise to harmonic ratio (NHR)	0.35 ± 0.17	0.16 ± 0.08	0,00022
Number of voice breaks	1.7	0,36	0.055
Fraction of locally unvoiced frames	11.10%	6,57%	0.018
Maximum pitch	210.84 ± 84.88)	198.79 ± 84.06	0.29

**Table 5.** Acoustic, difference in gender if<0.05 (U Mann Whitney Test)

Between Female and Male	Mean Pitch	Maximum Pitch	Fraction of Locally Unvoiced Frames	Number of Voice Breaks	Jitter Local	Shimmer Local
p-value	0.003	6*10 <sup>-5</sup>	0.0052	0.28	0.04	0.11

**Table 6.** GRBAS results of students (n=371)

	0	1	2	3	4
G	38%	34%	20%	5%	3%
R	38%	34%	20%	5%	3%
B	38%	50%	8%	2%	2%
A	40%	50%	3%	4%	3%
S	56%	39%	1%	3%	1%

- The differences are significant in G and R parameters.
- Other studies such as failed to find statistically significant differences on comparing GRABS scales [35,36].

**Correlation between Acoustic variables and VHI-30 Arabic Version**

As shown in Table 8:

- For all subjects and male gender, low positive correlations were found between the total VHI score and Shimmer local; and between Number of voice breaks and jitter local.
- For female gender, a negative low correlation was revealed between mean pitch and total score of VHI. In addition to that, a positive low correlation was set with shimmer and number of voice breaks.
- We noticed that for female gender, the jitter is not correlated with the total score of VHI.
- Man Whitney U test revealed statistically significant differences between the student’s group and the control group in terms of three acoustic measures: jitter (p-value=1.5.10<sup>-5</sup>), shimmer% (p-value=0.0002) and Fraction of locally unvoiced frames(p-value=0.018) but not mean pitch (p-value=0.35), number of voice breaks(p-value=0.055) and maximum pitch (p-value=0.29).
- Significant differences in mean pitch (p-value=0.003) between boys and girls in both groups but also in maximum pitch (p-value=6\*10<sup>-5</sup>), fraction of locally unvoiced frames (p-value=0.0052) and jitter local (p-value =0.04) with no significant difference

in shimmer local (p-value=0.11) and number of voice breaks (p-value=0.28).

- Maximum pitch was the most statistically significant differences between male students and female students.

As mentioned in Table 9:

- For the control group; low moderation was set between shimmer local and total score of VHI, functional VHI, and physical VHI. In addition to that, for the emotional VHI scale, low moderation was revealed with number of voice break, jitter local and shimmer local.
- The analysis of the relationship between the acoustic parameters (Number of voice breaks, Jitter local, and Shimmer local) and the VHI score in dysphonic students yielded a significant correlation, both with respect to the total VHI and with respect to the score on any subscale (functional, emotional or physical). This correlation was confirmed using Pearson’s coefficient. Such a correlation has not been observed in control group.

When the relationship between the acoustic parameters and VHI-T score was analyzed, a positive significant correlation was found in dysphonic students for the frequency perturbation parameters (jitter local). These findings also referred to the amplitude perturbation parameters (shimmer local).

Such correlations have not been observed in controls. No significant relationship between the number of voice breaks, shimmer, jitter and the total score of VHI could be found. The analysis of the relationship between the acoustic parameters and the particular VHI subscales revealed the correlations noted in Table 9. As regards the control group,

**Table 7.** GRBAS scale data: Mean, standard deviation and p values (t-test two independent samples) for control and dysphonic group

GRBAS scales	Dysphonic group		Control group		p-value
	Mean	Standard deviation	Mean	Standard deviation	
Grade	2,70	0,82	0,75	0,78	1.4.10 <sup>-5</sup>
Roughness	2,70	0,82	0,75	0,78	1.4.10 <sup>-5</sup>
Breathiness	2,40	1,17	0,64	0,63	0.0009
Asthenicity	2,40	1,17	0,78	0,58	0.0016
Strained	1,90	1,10	0,56	-	0.0034

**Table 8.** Evaluation of acoustic parameters and spearman rho (rs) correlations for acoustic variables obtained from sustained vowel/a/ versus VHI total score\*\* p-value<0.01, \* p-value<0.05: correlation (p-value)

Acoustic variables	All subjects, rs		Males, rs		Females, rs	
	rs	p-value	rs	p-value	rs	p-value
Mean pitch	-0,14	0,26	0,02	0,86	-0,49	0,06
Fraction of locally unvoiced frames	0,19	0,14	0,21	0,14	-0,15	0,68
Number of voice breaks*	0,54	0,015	0,51	0,052	0,63	0,25
Jitter (local)**	0,39	0,0008	0,47	0,0003	0,018	0,95
Shimmer (local)**	0,52	5. 10 <sup>-6</sup>	0,56	1.10 <sup>-5</sup>	0,48	0,07

no significant correlations were found between acoustic parameters and VHI-30 scores. For the dysphonic group, a significant correlation could be observed between number of voice breaks, jitter and shimmer respectively and total VHI-score.

A closer look revealed that the correlation test showed no significant correlation between students' scores on the VHI-Arab (physical, emotional, functional, and total) and their results on acoustic measures (mean pitch, maximum pitch, fraction of locally unvoiced frames). Table 9 presents these correlations. For dysphonic group, strong correlation between number of voice breaks ( $r=0.97$ ,  $p\text{-value}=0.031$ ), jitter local ( $r=0.86$ ,  $p\text{-value}=0.0015$ ) shimmer local ( $r=0.71$ ,  $p\text{-value}=0.023$ ) and total VHI-30. For the functional subscale, a strong correlation between it and the cited acoustic parameters.

However for the physical and emotional subscale the strong correlation is limited to jitter and shimmer. For the control group, the local shimmer is weakly correlated with VHI total score ( $r=0.35$ ,  $p\text{-value}=0.008$ ), functional subscale ( $r=0.34$ ,  $p\text{-value}=0.0011$ ), physical subscale ( $r=0.34$ ,  $p\text{-value}=0.0011$ ). For the emotional subscale, a weak correlation with jitter local ( $r=0.33$ ,  $p\text{-value}=0.028$ ), shimmer local ( $r=0.37$ ,  $p\text{-value}=0.013$ ).

Scores on the VHI-Arab showed no correlation with acoustic measures, which agrees with the previous studies [33,37-39]. These acoustic parameters also significantly correlated with the score on the functional and emotional subscales, but rarely with the physical subscale of the VHI. Roy et al. [31]; Rusell et al. [32]; Colton et al. [33]; Tamura et al. [34]; Loughran et al. [35]; Sittel et al. [36] investigated the relationship between voice laboratory

measures and the VHI and found a poor correlation between them. Similar results were obtained by Wheeler et al. [40]. Who correlated acoustic measures to the VHI and found that those measures could predict neither the overall VHI score nor the individual VHI items.

Also found a poor correlation between the harmonic-to-noise ratio and the VHI [16]. Regarding gender, the effect on VHI as VHI total increases is unpredictable as shown in Table 10. By comparing both groups, for dysphonic group shimmer is proportional to VHI total as shown in Table 10. For the control group, the evolution of the total scores is unpredictable function of acoustic parameters values.

**Correlation between GRBAS Scales Scores and Voice Handicap Index (VHI-30 Arabic Version)**

As shown in Table 11, it was revealed high correlations ( $r>0.72$ ) between total VHI- scores, functional VHI score, emotional VHI score and the overall severity resulted from GRBAS subscales.

However, a moderate correlation ( $r=0.61$ ) was resulted between physical VHI and the overall severity of GRBAS subscales.

We noticed that B subscale is highly correlated ( $r>0.75$ ) with all subscales of VHI.

The functional VHI high-correlates with G, R, and B ( $r>0.75$ ); however it correlated moderately ( $r=0.69$ ,  $r=0.54$ ) with A and S subscales.

And regarding physical VHI and emotional – VHI, they respectively high-correlated with B, A, and S subscales, besides they moderately correlate with G and R.

**Table 9.** Correlation between VHI scores and acoustic parameters in control group and dysphonic group

Parameters		Total VHI		Functional VHI		Physical VHI		Emotional VHI	
		Correlation	p-value	Correlation	p-value	Correlation	p-value	Correlation	p-value
Mean pitch	Control group	-0,042	0,75	-0,066	0,63	-0,076	0,58	-0,011	0,94
	Dysphonic group	0,091	0,80	0,091	0,80	0,13	0,72	0,012	0,97
Maximum pitch	Control group	0,053	0,69	0,018	0,89	0,018	0,9	0,095	0,54
	Dysphonic group	-0,03	0,93	-0,024	0,95	-0,019	0,96	-0,121	0,74
Fraction of locally unvoiced frames	Control group	0,026	0,86	0,019	0,9	0,084	0,58	0,059	0,73
	Dysphonic group	0,47	0,20	0,48	0,19	0,48	0,19	0,49	0,18
Number of voice breaks	Control group	0,24	0,37	0,26	0,33	0,26	0,33	0,3	0,26
	Dysphonic group	0,97	0,031	0,97	0,028	0,91	0,09	0,92	0,08
Jitter local	Control group	0,15	0,24	0,17	0,21	0,17	0,21	0,33	0,028
	Dysphonic group	0,86	0,0015	0,84	0,0023	0,79	0,0067	0,83	0,0032
Shimmer local	Control group	0,35	0,008	0,34	0,011	0,34	0,011	0,37	0,013
	Dysphonic group	0,71	0,023	0,62	0,055	0,60	0,065	0,71	0,021



**Table 10.** Evolution of VHI total, function of acoustic parameters values, for male and female gender, and for control group and dysphonic one

Effect on VHI	Gender	Mean pitch (Hz)	Fraction of locally unvoiced frames	Number of voice breaks	Jitter (local)	Shimmer (local)
As VHI total increases	Male	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓
	Female	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓
As VHI total increases	Control group	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓
	Dysphonic group	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↓ ↗ ↓	↗

↓ Variable decreases                      ↑ variable increases

**Table 11.** Correlation between the GRBAS scales and VHI voice handicap index

GRBAS	Functional VHI		Physical VHI		Emotional VHI		Total VHI	
	r	p-value	r	p-value	r	p-value	r	p-value
Overall severity	0.82	3.17. 10 <sup>-14</sup>	0.61	4.9. 10 <sup>-6</sup>	0.73	7.6. 10 <sup>-7</sup>	0,91	1.9. 10 <sup>-22</sup>
G	0.78	1.9. 10 <sup>-10</sup>	0.65	1.12. 10 <sup>-6</sup>	0.64	3.9. 10 <sup>-5</sup>	0.83	1.10 <sup>-12</sup>
R	0.78	1.9. 10 <sup>-10</sup>	0.65	1.12. 10 <sup>-6</sup>	0.64	3.9. 10 <sup>-5</sup>	0.83	1.10 <sup>-12</sup>
B	0.76	1.27. 10 <sup>-9</sup>	0.86	3.5. 10 <sup>-14</sup>	0.77	1.25. 10 <sup>-7</sup>	0.77	3.2. 10 <sup>-10</sup>
A	0.69	4.7. 10 <sup>-9</sup>	0.86	1.8. 10 <sup>-14</sup>	0.75	2.5. 10 <sup>-7</sup>	0.7	3.6. 10 <sup>-9</sup>
S	0.54	0.0002	0.75	2.6. 10 <sup>-7</sup>	0.99	3.9. 10 <sup>-53</sup>	0.53	0.0002

\* r: spearman’s correlation coefficient  
 \*p-value: statistically significant (p-value<0.05)

We noted that the emotional VHI has the highest value of correlation with S subscale of GRBAS (r=0.99).

The total VHI score high-correlated with the overall severity of GRBAS, and with G, R, B and A subscales. However, a moderate correlation is revealed with S scale(r=0.53).

Regarding overall severity, it high correlated with functional VHI, emotional VHI, but it correlated moderately with physical VHI.

In dysphonic group, the correlation between VHI and GRBAS is high (r=0.71, p-value=0.02) which means that all are functional apparent to the perceiver; as shown in Table 12.

However, for the control group, a low correlation(r=0.36, p-value=0.11) is revealed between GRBAS scores and VHI-30 ones.

**Correlation between GRBAS Scales Scores and Acoustic Parameters**

As shown in Table 13:

- Moderate to high correlation between respectively the numbers of voice breaks, jitter (local), shimmer (local) and GRBAS subscales. However, little correlation between Mean pitch, maximum pitch, fraction of locally unvoiced frames respectively and GRBAS subscales.
- A closer look to the correlations scores, revealed a

**Table 12.** Correlation between GRBAS and VHI

VHI Versus GRBAS		
	Spearman correlation coefficient	p-value
Control group	0.36	0.11
Dysphonic group	0.71	0.02

**Table 13.** Correlation between GRBAS subscales and acoustic parameters

	Mean pitch	Maximum pitch	Fraction of locally unvoiced frames	Number of voice breaks	Jitter (local)	Shimmer (local)
G	-0.09	0.14	0.23	0.69	0.67	0.58
R	-0.09	0.14	0.23	0.69	0.67	0.58
B	-0.08	0.13	0.27	0.71	0.72	0.61
A	-0.05	0.11	0.34	0.70	0.71	0.54
S	0.02	0.16	0.31	0.66	0.63	0.46

high correlation between number of voice breaks and B subscale of GRBAS ( $r=0.71$ ); and moderate correlations which varied between 0.66 to 0.69; between number of voice breaks and the other subscales of GRBAS.

- For the local jitter parameter, correlation tests revealed high correlations with A, and B (respectively,  $r=0.7$  and  $r=0.71$ ) and moderate correlations with the other subscales (G, R and S).
- The shimmer local low-correlated with S subscales and moderate-correlated with the other subscales.
- For Mean pitch and maximum pitch, no correlation was revealed with GRBAS subscales. And for Fraction of locally unvoiced frames, it low-correlates with A subscale ( $r=0.34$ ); however no correlation was found with the other subscales.

**Conclusion**

The low scores obtained for VHI show reduced impact of communication disorders in the quality of life of studied sample of students. We noticed that the functional subscale was found statistically significant as it is important for daily life of a student. Regarding age, our results mean that for this particular group of students, all participants (all ages) had a somewhat equal perception of voice handicap. And regarding gender, the significant difference between male and female in mean pitch is an indication of possible abuse and misuse of voice inside the studied sample.

We noticed that the correlation between VHI-30 and GRBAS is strong which means that all disorders are functionally apparent to the perceiver. The correlation between objective voice parameters and VHI scores is obtained among the students, however indecisive correlation between GRBAS and acoustic parameters is revealed.

In order to reach a comprehensive evaluation of voice disorders, we need to combine objective and subjective tools. Thus, acoustic measures assessment, self-rated scales (VHI-30) and GRBAS scales assessment.

As a future work, we suggest to define the control group based on cutoff of acoustic threshold defined in the literature and on results of GRBAS scale in order to evaluate consistency and sensitivity of the two approaches and compare it with VHI cutoff approach.

The results confirmed that VHI-30 can be a valuable tool for assessing students with speech and language disorders and should be incorporated in multidimensional voice assessment.

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