

Acoustic characteristics of speech in adolescents with suicidal attempt.

Voice, speech and suicidal behaviour

*Características acústicas del habla en adolescentes con intento de suicidio.
Voz, habla y comportamiento suicida*

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Abstract

Introduction: Suicide represents the second leading cause of death among adolescents. There are studies that link voice to suicidal risk.

Methods: The research was conducted through a cross-sectional study, and the sample was selected through non-probability sampling, which included 40 adolescents between 16 and 19 years old from the city of Temuco. After the identification of suicidal attempts, the participants underwent voice and speech acoustic evaluation.

Results: A parameter that showed differences was Jitter ($p < 0,05$). As to the spontaneous speech tasks assessment, it was possible to observe differences in the formants concerning the vast majority of the vowels measured ($p < 0,05$). Some voice and speech indicators differ depending on the group and the task requested.

Conclusion: Therefore, these indicators might provide useful information for assessing suicidal behavior.

Key words: Voice, suicidal attempt, suicide.

Resumen

Introducción: El suicidio representa la segunda causa de muerte entre los adolescentes. Hay estudios que relacionan la voz con el riesgo de suicidio.

Material y métodos: La investigación se realizó a través de un estudio transversal, y la muestra fue seleccionada a través de un muestreo no probabilístico, que incluyó a 40 adolescentes entre 16 y 19 años de la ciudad de Temuco. Tras la identificación de los intentos de suicidio, los participantes fueron sometidos a una evaluación acústica de la voz y del habla.

Resultados: Un parámetro que mostró diferencias fue el Jitter ($p < 0,05$). En cuanto a la evaluación de las tareas de habla espontánea, fue posible observar diferencias en los formantes relativos a la gran mayoría de las vocales medidas ($p < 0,05$). Algunos indicadores de voz y habla difieren según el grupo y la tarea solicitada.

Conclusión: Por lo tanto, estos indicadores podrían proporcionar información útil para evaluar la conducta suicida.

Palabras clave: Voz, intento de suicidio, suicidio.

Introduction

In 2012, 804.000 deaths caused by suicide were registered worldwide, which represents a global annual suicide rate, age-adjusted, of 11,4 per 100.000 inhabitants - 15,0 regarding men and 8,0 regarding women¹. All over the world, facing the effect that the COVID-19 pandemic will generate, an increase in suicides in the short or long term is expected².

Generally, suicide rates differ between genders and throughout life, while methods differ among different countries. Suicides are the second leading cause of premature death among fifteen to twenty-nine-year-old individuals, while traffic accidents are the main cause³.

As it happens in many countries, the increase in mortality among adolescents caused by external causes is especially worrying in Chile as well. Within the 15 to 29-year-old group, suicide rates increased from 10.9 per 100.000 in the year 2013 to 11 per 100.000 in the year 2017. Moreover, the national suicide rate increased from 9.9 to 10.2 per 100.000 during the same period⁴. This doesn't include suicidal attempts, which are up to 20 times more frequent than consummated suicide cases⁵.

Non-fatal suicidal thoughts and behavior (named "suicidal behavior" from this point on) are more specifically classified into three categories: suicidal ideation, which refers to thoughts about ending one's life; suicide plan, which refers to planning a specific method through which it is intended to die; and suicidal attempt, which refers to the participation in potentially self-injurious behavior in which there is at least some intention to die and ends in consummated suicide^{6,7}.

Suicidal behavior represents a unique study opportunity within the framework of suicide prevention, given that there is a relation between non-mortal suicidal behavior and consummated suicide⁸.

The effective evaluation of suicidal risk depends on the availability of sensitive and specific measures of long-term risk factors, short-term warning signs, and recognition of the complexity and variability of suicidal risk over time. Unlike many procedures that evaluate relatively stable phenomena, yet there is no proof or test panel that precisely identifies the emergence of a suicidal crisis⁹. For that reason, many health and education professionals don't have the skills required to effectively interact with suicidal teens¹⁰. Furthermore, most parents don't even have knowledge concerning suicidal thoughts, which causes that many adolescents go unnoticed, with the consequent risk that this implies¹¹. Currently, the emergence of new technologies allows generating new ways of intervening online. However, these must have systems in place to ensure that online providers can assess the suicidal risk. Therefore, developing new

assessment and knowledge systems for the infant-juvenile population might contribute to decreasing suicidal behavior¹². In this respect, voice and speech-based technology has been described as a useful tool for recognizing suicidal risk¹³.

Phonatory system

The voice is defined as the principal form of communication of the human being. Its characteristics are: pitch, quality and intensity, which provide an acoustic declaration of personal, physical and psychological identity, and even people's emotional state¹⁴⁻¹⁶.

Scherer, (2003) states that voice is part of the motor component of the expression of emotions and, therefore, the determinants of some types of voice modifications are the physiological changes that accompany emotions. Emotions must be considered as a complex functional system, being so complex that emotional responses have physiological components of the voice in order to correctly manifest the emotional behavior¹⁸.

The voice is produced through the combined action of the phonatory system, respiratory system, resonance system, postural system and regulatory systems such as the endocrine, gastrointestinal and auditory system, whose combination allows oral production. Lastly, the role of both central and peripheral nervous system cannot be forgotten since they control, coordinate and regulate the functions of these systems in our organism, and allow the execution of voluntary and involuntary actions¹⁹.

From a physiological point of view, regarding voice production, the myoelastic-aerodynamic theory considers that the aerodynamic properties of exhaled air are the most important motor elements for chordal oscillation, in interplay with the elasticity of the laryngeal muscles tissues²⁰.

The sound produced by the larynx is a complex wave, the same for all vowels, but when crossing the oropharyngeal pavilion from the glottis to the lips, the initial sound modifies its timbre acquiring the vowel color that it has when it comes out of the mouth. This is caused by the shape and dimension of the vocal tract²⁰. The resonators modify the fundamental tone; in the human body, these are found above the vocal cords (epilaryngeal tube, pharynx, mouth and nasal cavity), acting as a filter, enriching some harmonics that are multiples of the fundamental frequency, and damping others, thus producing the acoustic phenomena that we know as human voice²¹.

At the same time, this process is regulated through somatosensory zones of the thalamus that are transmitted to several parts of the cortex and basal ganglia²². Thereby, the phonation process is related to the central and peripheral nervous system, which controls and verifies

that the functions of the effector muscular system are completely fulfilled, referring to the structural and functional components of the larynx and the phonatory system.

Speech

Following the dual flow model, the act of speech is a complex conduct, integrated by linguistic and high-level motor control cognitive mechanisms. The genesis of speech starts with the communicative intention, which leads to the transformation of lexical units that need the production of vowels in a specific temporary organization. At the same time, these units must be adjusted to the context in terms of rhythm, intensity and prosody²³.

The final stages require the coordination of several sensorimotor systems, including phonation. Thereby, the complexity of speech production is subject to the interaction of sensorimotor systems with linguistic processes, which include grammatical, syntactic, semantic and cognitive processes; within the latter, we can find executive function processes such as verbal memory and audiovisual attention²³.

Voice and speech in suicidal behavior

Complementing the last idea, the behavior of some voice and speech traits have been described as indicators that provide information for the detection of suicidal crisis and depressive states, constituting background to be considered by health personnel²⁴⁻²⁶.

In this sense, the changes in acoustic parameters can be explained in view of the fact that objectively measuring the acoustic signal caused by speech and voice production, the observable and measurable output of the behavior of neurological and physiological subsystems that coordinate to create oral emission and its respective articulation is being quantified^{27,28}.

Therefore, the consideration of voice and speech as an indicator of emotional state can contribute to the knowledge of the great public health problem that suicide represents¹. Although there have been up to now extensive attempts to determine the factors that lead a person to kill themselves, the study of these elements alone have not resulted in an integral model of suicidal behavior, neither has this knowledge contributed to a greater capability of health professionals to predict suicide⁹.

For all of these reasons the research of new ways to evaluate suicidal behavior will allow developing vocal biomarkers that account for physiological processes, representing a fast, non-invasive and objective evaluation alternative. Thereby, delving into the study of voice and speech opens new possibilities for the prevention and treatment of the suicidal risk population. It is important to highlight that this evaluation method does not pretend to replace other professionals and mechanisms that already

exist, but providing a tool that complements assessment, offering an interdisciplinary outlook for approaching these types of disorders.

Due to the above, the objective of this research was to determine the relationship between acoustic parameters of voice and speech and the presence/absence of suicidal attempt (SA) in adolescents from Temuco, Chile.

Materials and Methods

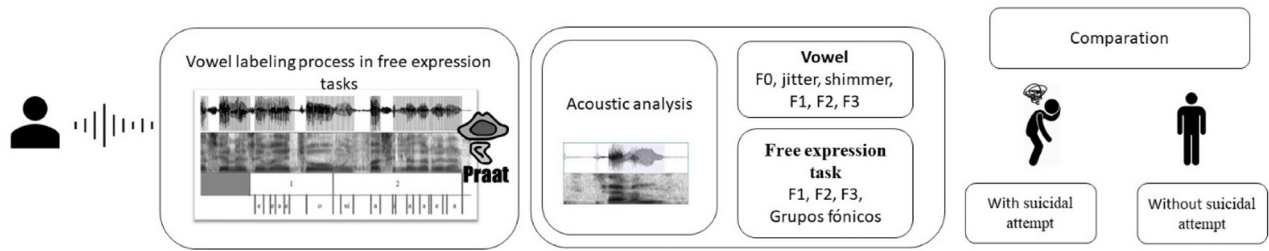
The study was based on a cross-sectional design. The sample was selected through non-probability sampling which was composed of 40 adolescents whose ages ranged from 18 to 19 years old, all of them regularly attended secondary schools in the city of Temuco, Chile. The adolescents were divided into two groups: 1) Group 1 composed of adolescents who reported at least one suicide attempt (N=20), 2) Group 2 composed of adolescents who did not report any suicidal attempts within the last 12 months (N=20). As to inclusion criteria, the following were considered: 1) Being sixteen years old or younger, 2) Being a regular student in an educational establishment, and 3) Self-reporting good health conditions. The exclusion criteria were: 1) Having been medically diagnosed with a speech and/or voice neurological disorder, 2) Background of cardiac pathology, 3) Having been diagnosed with a voice disorder, 4) Consumption of medication that affects voice and speech production, 5) Daily tobacco consumption, 6) Having an influenza virus infection at the time of the evaluation.

Regarding instruments, anamnesis and the Okasha Suicidality Scale was applied to every participant²⁹. It is an instrument that has validity criteria for the Chilean population³⁰, also a self-administered scale, and identifies individuals with suicide risk³⁰. On the other hand, the voice and speech of the participants were assessed through: 1) Production and sustaining of the vowel /a/; 2) The answer to two open questions, specifically "What is the best that has happened to you recently?" and "What is the worst that has happened to you recently?".

Acoustic analysis

In order to measure the voice acoustic parameters, a sustained vocalization —checking maximum phonation time at comfortable pitch and intensity— was recorded. Regarding the connected speech samples, the participants were asked two questions: "What is the best that has happened to you recently?" and "What is the worst that has happened to you recently?". Concerning the quantitative processing of voice data, audio signals manipulation, and observation of voice emission parameters characteristics, the PRAAT® free software was used (Boersma & Weenink, 2018), installed in an HP notebook (Pavilion model, and connected to a SCARLETT 212 GD MK2 Focusrite interface. (shown in **figure 1**).

Figure 1: Process of analysis of the voice and speech.



An ECM8000 ultra-linear condenser microphone installed on a pedestal placed 15 centimeters away from the participants' mouths was used. The recordings were performed in a previously calibrated Eckel Noise Control Technologies ® CL-13 model sound-cushioned camera.

The study variables linked to the voice's acoustic characteristics were:

- Presence of suicide attempts, sorting the subjects between two groups: the first one includes the students with at least one suicide attempt and the second one includes the students without suicide attempts.

As to phonatory tasks, the variables were the following (See **table I**):

1. Emission and sustaining of the vowel /a/, checking maximum phonation time at comfortable pitch and intensity

- Average value of fundamental frequency (F0)
- Minimum and maximum values of fundamental frequency
- Frequency perturbation (Jitter ppq5)
- Duration of the emission
- Formants values (F1, F2, F3)
- Connected speech through free expression
- Fundamental frequency
- Formants
- Intonation phrase
- Numbers of vowels

Table I: Summary of speech and voice phonatory tasks and their methods of measurement.

Phonatory tasks		
Variable	Concept definition	Method of measurement
Fundamental frequency	Voice fundamental frequency (f0) is defined as the first harmonic. It is physiologically determined by the number of glottal cycles performed by the vocal folds in 1 second and it is the natural result of these structures' duration. (Oliveira, Gama, & Magalhães, 2019)	This variable was assessed through the sustained emission of the vowel /a/, using the PRAAT software which was installed in an HP notebook connected to an interface (SCARLETT 212 GD MK2 Focusrite).
Formants	Resonance of the vocal tract. When the sound of the voice goes through the vocal tract it undergoes some changes, that is to say, the attenuation or amplification of determined harmonic groups in order to define some relative amplitude maxima within the spectrum, which are called formants ⁵² .	This variable was assessed through a phonatory task that requested the sustained and comfortable production of the vowel /a/. The formant values were collected by the broadband spectrogram obtained through the Praat software.
Jitter (ppq5)	Unit of measurement of frequency perturbation obtained through the average of 5 consecutive periods.	This variable was assessed through the sustained emission of the vowel /a/ at comfortable pitch and intensity, using the PRAAT software which was installed in an HP notebook connected to a SCARLETT 212 GD MK2 Focusrite interface.
Duration of the emission	Amount of time a person can sustain the sound of the vowel /a/ when produced after one deep breath at comfortable pitch and intensity.	This variable was assessed through the sustained emission of the vowel /a/ at comfortable pitch and intensity, using the PRAAT software which was installed in an HP notebook connected to a SCARLETT 212 GD MK2 Focusrite interface.
Connected speech tasks through free expression		
Variable	Concept definition	Method of measurement
Intonation phrase	The portion of speech between two successive pauses of articulation, which involves several intensity groups but can also be reduced to only one word ⁵³ .	This variable was assessed through the identification of intonation phrase and their vowels, using the PRAAT software through a script.

It is relevant to clarify that some studies, such as the one conducted by Baken y Orlikoff³¹, point out that preliminary evidence suggests the possibility that adult women might have more vocal jitter than men, at least concerning some vowels. The vowel /a/ is used in order to circumvent this drawback as it avoids the effects that the vocal tract could cause on the vibratory pattern of the vocal folds. The beginning and end of the emission are deleted, only considering the most stable region for analysis. Lastly, jitter (ppq 5) was calculated, which is recommended for research due to its softening effect as, with it, the frequency variability does not reach significance between genders³².

Results

The pilot study group was composed of 20 adolescents with suicidal attempt (SA) and 20 adolescents without suicidal attempt (SA). The group with SA was composed of 18 women and the group without SA was composed of 13 women. The age median was 18 years old (16-19) for the group that reported SA and 19 years old (17-19) for the group that did not report SA.

As to the results of the voice and speech assessments, it was observed that the parameters that showed significant differences were: Jitter ($p < 0,05$) and maximum phonation time ($p < 0,05$). Concerning Jitter, it was observed that the group of adolescents that did not report previous SA showed a lower Jitter. With respect to maximum phonation time, it was observed that the maximum phonation time was greater within the group with SA (see **table II**).

Regarding the report of formants, it was possible to observe that facing the question "What is the best that has happened to you recently?", the group that reported committing SA presented significantly greater formant values when compared to the group that did not report SA within the last 12 months. (**Table III**)

As to the comparison of intonation phrase within the female group, it was possible to observe that the emitted intonation phrase were significantly lower within the group with SA ($p < 0,05$). Concerning the assessments associated with the group of vowels per phonic group, it was possible to observe that the fundamental frequency

Table II: Comparison of voice and speech acoustic parameters in accordance with the presence or absence of suicidal attempt (SA) in the vocalization task.

		Without SA		With SA		T test	p
N		20		20			
Variables	^a V. task	\bar{x}	σ	\bar{x}	σ		
F1 normalized	/a/	696.23	89.23	763.61	98,10	-67,38	.027*
N		Without SA		With SA		Man Whitney U test	p
N		20		20			
		Me	Range	Me	Range		
F2 Normalized	/a/	1393.79	790.25	1431.10	454.22	182	.465
F3 Normalized	/a/	2542	1166.35	2574.22	3058.04	200	.794
Maximum phonation time	/a/	6.093	20.10	3.20	8.2	82.00	.001**
Jitter (local)	/a/	0.17	1.63	0.28	.54	85	.001**
Shimmer (local)	/a/	2.74	0.176	.030	.1455	163.00	.327

^a Vocalization task

Table III: Description and comparison of Formants in accordance with the presence of suicidal attempt (SA) in the free expression task.

What is the best that has happened to you recently?							
		Without SA		With SA		T test	p
N		20		20			
Variables	Vowel	x	σ	Me	σ		
F1 normalized	/a/	563	139	643	168	-4,47	0,000**
F2 normalized	/a/	1538	243	1659	282	-3,83	0,000**
F3 normalized	/a/	2507	272	2616	282	-3,345	0,001**
F1 normalized	/e/	466	135	521	136	-3,645	0,000**
F2 normalized	/e/	1729	324	1917	331	-5,13	0,000**
F3 normalized	/e/	2597	287	2753	297	-4,78	0,000**
F2 normalized	/i/	1943	396	2119	326	-2,77	0,006**
F2 normalized	/u/	1379	292	1438	400	-0,624	0,535
F3 normalized	/u/	2538	259	2755	287	-2,834	0,006**
		Me	IQ	Me	IQ	Man Whitney U test	
F1 normalized	/i/	380	115	421	133	1623	0,009**
F3 normalized	/i/	2602	425	2843	433	1409	0,006**
F1 normalized	/o/	467	123	499	163	7111	0,006**
F2 normalized	/o/	1320	343	1450	402	6810	0,001**
F3 normalized	/o/	2511	386	2645	346	6462	0,000**
F1 normalized	/u/	382	107	451	82	215	0,025*

of the vowel, vowel minimum, and vowel maximum were greater within the group with SA. However, these differences were not significant. (Table IV)

compared to the group that did not report SA within the last 12 months; these differences were observed for every vowel but not for every formant (Table V).

Regarding the report of formants, it was possible to observe that facing the question "What is the worst that has happened to you recently?", the group that reported committing SA showed greater formant values when

As to the results of intonation phrase within the female group, facing the question "What is the worst that has happened to you recently?", it was observed that the number of Intonation phrase was significantly lower

Table IV: Comparison of speech parameters in accordance with the presence of suicidal attempt (SA). Women.

Open question: What is the best that has happened to you recently?						
N ^a	Without SA		With SA		Man Whitney U test	p
	659		436			
Variables	Me	Range	Me	Range		
N° of IF ¹	4	16	3	13	113230,50	,00**
\bar{x} F0 IF ²	180,25	235,50	210,24	277,24	86716,00	,00**
\bar{x} F0 Vowel ³	207,92	37	210,17	46	5507,000	0,930
Vowel a						
F0 Min. Vowel	200,62	38	204,75	47	5266,000	0,528
Vowel a						
F0 Max. Vowel	215,83	47	222,22	53	5407,000	0,754
Vowel a						
\bar{x} Vowel ³	210,83	45	215,87	40	6700,000	0,910
Vowel e						
F0 Min. Vowel	201,65	47	208,70	39	6465,000	0,568
Vowel e						
F0 Max. Vowel	227,08	43	222,69	43	6358,000	0,436
Vowel e						
\bar{x} F0 Vowel ³	206,23	34	212,31	31	928,000	0,987
Vowel i						
F0 Min. Vowel	200,81	36	205,94	28	928,000	0,987
Vowel i						
F0 Max. Vowel	211,00	36	221,67	35	892,000	0,750
Vowel i						
\bar{x} F0 Vowel ³	210,37	43	222,30	45	3945,000	0,584
Vowel o						
F0 Min. Vowel	203,65	40	215,00	44	3965,000	0,6221
Vowel o						
F0 Max. Vowel	210,63	46	228,38	55	4137,000	0,991
Vowel o						
\bar{x} F0 Vowel ³	210,34	44	204,87	38	106,000	0,851
Vowel u						
F0 Min. Vowel	205,03	43	203,24	35	109,000	0,950
Vowel u						
F0 Max. Vowel	215,43	45	214,13	37	103,000	0,754
Vowel u						

N^a: Number of vowels per record; ¹Number of Intonation phrase, ²Mean of the Intonation phrase Fundamental Frequency, ³Mean of the Vowel Frequency.

Table V: Description and comparison of Formants in accordance with the presence of suicidal attempt (SA) in the free expression task.

What is the best that has happened to you recently?							
N	Vowel	Without SA		With SA		Man Whitney U test	p
		20		20			
Variables		Me	IQ	Me	IQ		
F1 normalized	/a/	592	187	677	267	23002	0,000**
F2 normalized	/a/	1515	286	1612	385	27064	0,001**
F3 normalized	/a/	2512	365	2738	516	23325	0,000**
F1 normalized	/e/	468	116	488	153	46516	0,013*
F2 normalized	/e/	1819	440	1961	540	40795	0,000**
F3 normalized	/e/	2610	439	2846	427	35534	0,000**
F1 normalized	/i/	410	103	401	87	8814	0,386
F2 normalized	/i/	2153	534	2261	840	8261	0,087
F3 normalized	/i/	2887	462	2964	504	7615	0,007**
F1 normalized	/o/	495	123	517	172	18718	0,211
F2 normalized	/o/	1298	449	1333	468	18199	0,090
F3 normalized	/o/	2600	413	2655	535	17356	0,016**
F1 normalized	/u/	449	105	438	97	1714	0,276
F2 normalized	/u/	1281	474	1192	342	1807	0,529
F3 normalized	/u/	2574	498	2763	430	1353	0,004**

within the group with SA ($p < 0,05$). Concerning the assessments associated with the group of vowels, the fundamental frequency of the vowel, vowel minimum, and vowel maximum were significantly greater within the group with SA ($p < 0,05$), for the vowel /o/ and the vowel /i/ (Table VI).

Discussion/Conclusion

Suicidal behavior is composed of different stages that can go from the wish to die to consummated suicide³³⁻³⁵. This behavior is steadily increasing, especially among adolescents and children³⁶. Suicidal behavior -alongside other mental states such as depression- are complex phenomena to study since they are influenced by several factors, among which social, familial, personal, and biological factors can be found. Therefore, the knowledge and exploration of new tools that account for this phenomenon is fundamental⁹.

In this sense, voice production is a complex system that is sensitive to mild physiological and cognitive changes which, at the same time, causes noticeable acoustic changes³⁷. Consequently, the present research

assessed the association between voice and speech characteristics regarding a group of patients with suicidal attempts. Among the results, it was found that the voice and speech of patients with suicidal attempts differ concerning some variables when compared to patients without suicidal attempts.

As to assessments associated with the Fundamental frequency of vowels, it was observed that this was greater within the group that presented suicidal attempts. Regarding this matter, it becomes of great importance to point out that impulsive suicidal behavior has been linked to dopamine signaling mechanisms³⁸, which influences the information processing in the prefrontal cortex and, at the same time, regulates the functional balance between direct and indirect basal ganglia circuits; therefore, the dopaminergic function might be associated with voice modifications presented in psychiatric problems³⁹.

The findings of this research complement other studies that have found lower fundamental frequencies concerning depressive and suicidal speech^{25,40}. On the other hand, it is relevant to mention that there are studies where no significant correlation between F0 variables, depression, and other mental alterations is reported^{27,41,42}.

Table VI: Comparison of speech parameters in accordance with the presence of suicidal attempt (SA). Women.

Open question: What is the worst that has happened to you recently?						
N ^a	Without SA		With SA		Man Whitney U test	p
	659		436			
Variables	Me	Range	Me	Range		
N° of PG ¹	6	7	5	5	101933	,000**
\bar{x} F0 PG ²	210,20	43	214,96	41	109327	,000**
\bar{x} F0 Vowel ³	207,92	37	210,17	46	8370,000	0,201
Vowel a						
F0 Min. Vowel	200,62	38	204,75	47	8627,000	0,377
Vowel a						
F0 Max. Vowel	215,63	47	222,22	53	8062,000	0,79
Vowel a						
\bar{x} F0 Vowel ³	210,83	45	215,87	40	10468,000	0,195
Vowel e						
F0 Min. Vowel	201,65	47	208,70	39	10195,000	0,098
Vowel e						
F0 Max. Vowel	227,08	43	222,69	43	11373,000	0,914
Vowel e						
\bar{x} F0 Vowel ³	206,23	34	212,31	31	1606,000	0,049**
Vowel i						
F0 Min. Vowel	200,81	36	205,94	28	1738,000	0,182
Vowel i						
F0 Max. Vowel	211,00	36	221,67	35	1420,000	0,004**
Vowel i						
\bar{x} F0 Vowel ³	210,37	43	222,30	45	3390,000	0,000**
Vowel o						
F0 Min. Vowel	203,65	40	215,00	44	3502,000	0,000**
Vowel o						
F0 Max. Vowel	219,63	46	228,38	55	4510,000	0,198
Vowel o						
\bar{x} F0 Vowel ³	210,34	44	204,87	38	717,000	0,796
Vowel u						
F0 Min. Vowel	205,03	43	203,24	35	733,000	0,923
Vowel u						
F0 Max. Vowel	215,43	45	214,13	37	742,000	0,996
Vowel u						

N^a: Number of vowels per record; ¹Number of Intonation phrase , ²Mean of the Phonic Group's Fundamental Frequency, ³Mean of the Vowel Frequency.

When trying to answer why this happens, literature leads us to the heterogeneous nature of the symptoms associated with suicidal behavior, being necessary to understand that FO is a marker of the physical state of the vocal folds and a marker of the emotional state of the speaker but that, alongside many other factors, it does not only depend on the gender or the lack of standardization of FO extraction techniques but also on other biological and physical factors⁴³.

For that reason, the differences obtained between different studies may occur because individuals with depression, suicidal ideation and suicidal attempts can differ with respect to their personality traits in many ways⁴⁴. Therefore, FO can be influenced by mood changes, agitation, anxiety and the speakers' personality⁴³.

Concerning the results obtained on the short-term frequency perturbation measurements, the Jitter values were significantly lower within the groups with suicidal attempts. These results differ from other studies that present slightly greater values for patients with suicide risk, which can be attributed to anxiety²⁵. Physiologically, there are factors that influence the short-term variability of the fundamental frequency. One of the factors described is the cardiovascular mechanism, which causes the systematic variation of the fundamental frequency during the cardiac cycle, i.e., heart rate variations alter the systole period, thus altering the vibratory cycles of the speaker; this is one of the reasons for greater short-term vocal fluctuation in patients with suicide attempts. The second factor is the neuromuscular mechanism, which causes the inherent muscle noise generated by the imperfect integration of individual motor units due to the sustained contraction of the laryngeal musculature. These mechanisms, when under emotional stress due to the influence of the sympathetic and parasympathetic activation of the autonomic nervous system, cause changes in the muscular tone which, at the same time, alters the vibration of the vocal folds²⁵. However, although one of the most used measures regarding speech in people with depression and suicide attempt includes the Jitter, the lack of standardization of extraction techniques influences the values and makes comparing results between studies very difficult^{45,46}. Another factor of confusion when using the Jitter is the type of voice signal from which the measure is extracted, being possible to observe two types of tasks: 1) sustained vocalization and 2) connected speech (Laver et al., 1992); this can be explained since, due to its periodicity, the use of sustained vowels allows a simpler extraction of these characteristics but leaves them exposed to errors because of the different sound pressure levels between and within individuals, which potentially turns it unreliable for clinical analysis⁴⁵. Accordingly, the connected speech analysis is harder than the sustained vowel analysis due to the problems

associated with the search for suitable sound sections in a given emission⁴⁷.

Another variable that showed significant differences was formants, as the group with suicide attempts obtained greater values than the control group. Physiologically, this can be explained by muscle tension alterations caused by the autonomic and somatic nervous system (Scherer, 1986), as well as the neurotransmitter function, as it has been observed that the GABA neurotransmitter has been linked to changes in muscle tension⁴⁸. These changes modify the configuration and dynamics of the vocal tract, which, at the same time, are susceptible to being captured by formant characteristics that are related to the acoustic characteristics of the vocal tract⁴³.

It is important to state that the limitations of this study are related to sample size since there is no formal record of the adolescents with suicidal attempts in the establishments, thus, the way of researching is through assessments for every subject, and, thereby, the selection of individuals with suicidal attempts is reduced to a figure close to 15%⁴⁹. On the other hand, researching adolescents with suicidal risk requires a multidisciplinary work team that can take on the attention of these teens. It is well known that our country invests very little of its GDP in mental health, so mental health programs have been poorly implemented, being unable to address this problem in the affected population⁵⁰.

Among the possible explanations for the conflicting results obtained with respect to other studies, it is possible to observe: 1) lack of heterogeneity of the parameters studied, 2) their evaluation methods, 3) instruments used, 4) possible non-declared comorbidities, 5) non-declared use of medication that affect voice and speech production. All of these circumstances represent potential confounding factors for the results.

Lastly, the findings of this research suggest that voice and speech are signs that must be assessed in the population with suicidal risk. However, it is necessary to continue assessing the acoustic characteristics based on the profiles of suicidal behavior, as it seems that ideation and attempt —with or without depression— are manifested with different characteristics in the voice and speech of adolescents.

It is considered that voice and speech as indicators of emotional state can contribute to suicidal behavior knowledge. This research concludes that the acoustic parameters of voice and speech represent an assessment measure for the adolescent population with suicidal behavior. Despite this conclusion, it is still necessary to continue developing studies in the same line in order to correct the effect of the profiles and sample sizes.

Statements

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Statement of Ethics

The research presented in the manuscript was conducted ethically in accordance with the World Medical Association Declaration of Helsinki and the appropriate guidelines for human studies and was approved by Scientific Ethical Committee of The University of La Frontera with number (109-9).

Parents and adolescents have given their written informed consent. Besides, the schools have given their consent to recruit the adolescents at their facility.

Conflicts of Interest Statement

The authors have no conflicts of interest to disclose.

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