REVISTA CEFAC
SPEECH, LANGUAGE, HEARING SCIENCES AND EDUCATION JOURNAL
Rev. CEFAC. 2022;24(2):e6821 https://doi.org/10.1590/1982-0216/20222426821

Original articles

Dermatoglyphic and acoustic analysis of singing voices: a multiple case preliminary report

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Conflict of interests: Nonexistent

ABSTRACT

Purpose: to identify genetically enhanced physical skills (speed, strength, endurance and motor coordination), provided by the dermatoglyphic method and to analyze the preliminary correlation between dermatoglyphic and acoustic data of lyrical and pop singers.

Methods: the study was approved by the Ethics and Research Committee. Four male singers were evaluated (two lyrical and two pop singers), 31-53 years old. Data collection and analysis procedures comprised (1) Survey -Self-Perception of Vocal Characteristics in Singers (vocal habits, voice performance and phenotypic characteristics); (2) Dermatoglyphic Profile (fingerprint image digitalization: predominance of digital drawings (Arch, Loop and Whorl); scores of deltas (D10); the Total Ridge Count (TRC); digital formula and dermatoglyphic profile (aerobic, anaerobic and mix)); (3) Acoustic Analysis (the Expression Evaluator script application to the audio recordings: f0, intensity, spectral slope and long-term average spectrum – LTAS values); and (4) Integrated (Statistical) Analysis; cluster analysis.

Results: correlations were found between dermatoglyphic variables (Arch, Loop, Whorl, D10, TRC) and acoustic parameters (f0 (median); intensity (asymmetry); spectral slope (mean); and LTAS (SD)). The dermatoglyphic profile did not segregate singing styles.

Conclusion: the dermatoglyphic profiles showed a preliminary correlation with the acoustic vocal measures, especially f0 and LTAS measures.

Keywords: Linguistics; Phonetics; Dermatoglyphics; Speech Acoustics; Voice Quality

Received on: August 31, 2021
Accepted on: July 21, 2022

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INTRODUCTION

The field of Speech and Voice Sciences has been dedicating part of its studies to the various sound effects that the vocal apparatus can produce by modulating the expiratory airflow for the production of both spoken and singing voices.

Compared to speech, singing voices require more specific and specialized adaptations with regard to respiratory, laryngeal and supra-laryngeal settings, according to the need of the singing style and expressive effects[1,2]. Due to the higher specialization of singing voice production, it is desirable to investigate some physiological counterparts, like genetically determined physical skills, and try to correlate them to some acoustic indexes.

Speech and voice have increasingly been considered important biomarkers in different populations, including during the COVID-19 pandemic. Therefore, the association between the study of genetically determined markers and voice quality has been gaining recognition in the development of voice assessment, qualification and rehabilitation strategies[3].

Acoustic analysis is an instrumental resource for research, clinical therapy and voice pedagogy practices because it can lead to inferences about the vocal production mechanism in both speaking and singing productions[1,4]. Acoustic analysis can also integrate physiological and perceptual arenas in voice and speech investigations.

Some physiological information about voice can, potentially, be provided by Dermatoglyphics, the science that studies fingerprints, which originate in the ectoderm, the same embryonic leaflet as the nervous system. A fingerprint is seen as a genetic mark, and can indicate physical skills such as strength, speed, endurance and motor coordination.

For many decades, the dermatoglyphic method has been applied to the field of Sport, aiming at identifying athletes' motor talent, as well as assisting in exercise prescription[5-11]. These steps are part of an investigation protocol proposed by Fernandes Filho[7], with the potential to be adapted to Speech Therapy and Voice Pedagogy practices. According to the method, the examiner must identify the predominance of Arch (A), Loop (L) or Whorl (W) digital patterns as shown in Figure 1.

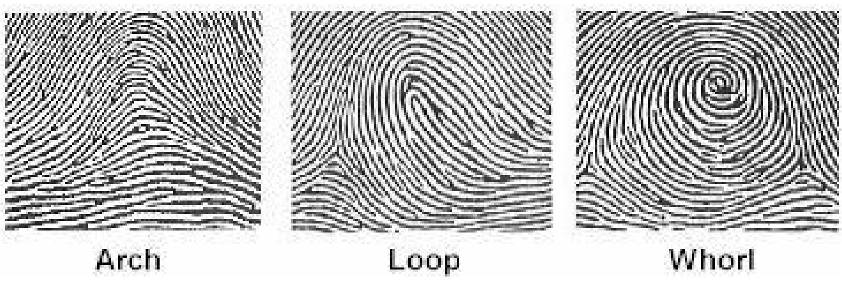


Figure 1. Image of fingerprints collected digitally: Arch (A), Loop (L) and Whorl (W)

The first dermatoglyphic step is based on digital pattern analysis, in which Arch (A) predominance is related to the genetic predisposition to pure strength; Loop (L) predominance points to a genetic predisposition to faster muscle contraction; and Whorl (W) predominance is associated with a genetic predisposition to motor coordination and endurance. If an individual has a genetic predisposition to endurance and motor coordination, he or she fits the aerobic profile. Otherwise, a genetic predisposition to pure strength and speed fits the anaerobic profile. If someone has a genetic predisposition for both pure strength and speed, as well as for endurance and motor coordination, he or she fits the mixed profile[6,7].

In addition to digital patterns, dermatoglyphic evaluations focus on the study of the number of Deltas (D10), the Total Ridge Count (TRC), the physical skills that have been leveraged (pure strength, speed, endurance, motor coordination) and the definition of the dermatoglyphic profile (aerobic, anaerobic or mixed). High levels of D10 identify maximized motor coordination and high levels of TRC point to maximized endurance[6,7].

In this sense, Dermatoglyphics is not concerned with the study of muscle fibers typology and functions, which originate in a different embryonic leaflet, the mesoderm. Furthermore, fingerprints are considered immutable – even if they are affected by events during the lifetime cycle, such as an accident, cut or bruise, genetic information is not altered. On the other hand, muscle fiber type can be transformed according to training needs.

For Speech Language Therapy, the dermatoglyphic parameters (digital pattern predominance, D10 and TRC quantities, genetic predisposition in endurance, speed, pure strength and motor coordination, and dermatoglyphic profile), allied to the result of the speech language assessment, could help in the selection of appropriate training/exercise prescriptions. In other words, if the therapeutic goal for a supposed client A is to develop muscular endurance performance (this is the phenotype, a favorable stimulus environment for skill development) and if the speech therapist identifies that he/she is predisposed to this skill through the dermatoglyphic result (this is the genotype), then the prognosis will become favorable as the therapist will prescribe personalized training to achieve this goal and this client will achieve the expected result, probably faster than a supposed client B, who does not have this genetic predisposition, for instance. Therefore, singer B will possibly need more attention from the therapist in terms of activities that train muscular endurance, since he/she has no genetic predisposition for such ability and the chance of him or her going into muscle fatigue is greater.

In sports applications, football for example, offensive positions require players with a predisposition for speed, as opposed to their defensive counterparts, in which muscular endurance is needed.

Since 2015, the scientific literature has associated dermatoglyphic profile analyses with voice quality and vocal acoustic analyses[12,13], in addition to a review article[14] identifying genetic syndromes that cause communication disorders, in which dermatoglyphics integrated the differential diagnosis.

Recently, a study characterized the dermatoglyphic profile (digital pattern, TRC, D10 and aerobic, anaerobic or mixed profiles) and its relationship with the acoustic vocal measures (f0, intensity and cepstral peak prominence - CPP) of teachers and singers. For the comparison of acoustic variables across the subjects' dermatoglyphic profiles, higher values of F0, intensity, and CPP were found for the group of anaerobics (individuals that present small genetic predisposition for muscular endurance). The results suggested that dermatoglyphics could be implemented in the science of voice as a complement to the voice assessment and allows for care and a better understanding of the performance of voice (speaking or singing) professionals[15].

Although such studies indicate a potential contribution of dermatoglyphic analysis to Speech Therapy as an evaluative resource, and also as a support for therapy, dermatoglyphics is still not widespread, especially for voice studies.

The authors wonder if differential genetically abilities detected by dermatoglyphic analysis, such as speed, strength, endurance and motor coordination could be related to skills in singing styles (lyrical and contemporary commercial music – CCM), particularly pop theater singing styles, and if there is any correspondence to acoustic indexes. Our hypothesis is that lyrical singing is associated with muscular endurance and motor coordination profiles, and pop singing with muscular speed and strength.

Since dermatoglyphics identifies genetic indexes, which are triggered by elements such as quality of life, age, gender and habits, knowledge about these markers can contribute to the development of a counseling program for singing voice professionals.

This study aimed at identifying genetically enhanced physical skills (speed, strength, endurance and motor coordination) of lyrical and pop singers, using the dermatoglyphic method, and searching for preliminary correlations with acoustic vocal parameters (fundamental frequency (f0), intensity, spectral slope and Long-Term Average Spectrum - LTAS).

METHODS

The study, with preliminary character, was approved by the Ethics and Research Committee of the Pontifical Catholic University of São Paulo, Brazil, under number 1.398.242.

Four male singers were selected and evaluated (two lyrical singers and two pop singers), aged between 31 and 53 years old, distributed equally by musical styles, named respectively singers 1 and 2 (lyrical) and 3 and 4 (contemporary commercial music, particularly musical theater).

Inclusion criteria for participants were related to gender (male), length of professional experience (over five years) and professional profile of "high-performance" singers, that is, those who perform on consecutive days, singing and/or choreographing for many hours, and also best represented their musical performance style as recommended by a conductor or singing teacher.

Exclusion criteria included self-reported vocal complaints, otorhinolaryngological and / or speech-language diagnosis of laryngeal and / or voice disorders, as well as failure or absence of digital patterns on the ends of the fingers.

Data collection procedures comprised (1) the application of a questionnaire (*Self-Perception Vocal Characteristics in Singers)* about vocal habits and phenotypic characteristics; (2) Dermatoglyphics - the collection of the fingerprints; (3) the audio recordings. The data collection session took place in the city of Rio de Janeiro, in an acoustically treated environment. The data analysis took place at Integrated Acoustic Analysis and Cognition Laboratory – Pontifical Catholic University of São Paulo.

(1) Self-Perception Vocal Characteristics in Singers Survey

Information regarding training, professional practice of singing voice, vocal habits and phenotypic characteristics were collected by means of a survey ("Self-Perception of Vocal Characteristics in Singers"), elaborated for this study, which is in Appendix.

(2) Dermatoglyphics

Collection of fingerprints (each of the ten hands fingers) was carried out using a Crossmatch Technologies scanner, Verifier 320LC model, digitalized in a Lenovo X200 notebook computer running Windows 7 as its operating system.

(3) Audio Recordings

Voice samples were audio recorded with a Tascam microphone, model im2 and Tascam iXZ audio interface adapter attached to an iPad 2. The recordings were sampled in 22,050 Hz, 16 bits and wav extension and stored on the Soundcloud virtual platform.

The *corpus* comprised the phonatory tasks described in Figure 2, like sustained utterances, vowel [a] in staccato and excerpt from a song from the singer's repertoire. Participants were instructed to produce the sustained vowel at the habitual speech frequency. In order to produce the staccato vowel, participants were instructed to choose note ranges according to their vocal classification in singing, as follows: Bass (from G#1 to C2 or from E2 to G#2); Baritone (from C2 to E2 or from G#2 to C3) and Tenor (From E2 to G#2 or from C3 to E3). This singer vocal classification has been previously defined by an experienced lyrical singing teacher, who teaches classes at the School of Music of the Federal University of Rio de Janeiro.

ORDER	PHONATORY TASK	OBJECTIVE	REASON
1	Sustained utterances: [a] in Brazilian Portuguese, performed very softly, with very little sound, that is, pianissimo.	To check vocal endurance ability	Vocalis muscle (thyroarytenoid- TA) competence, composed of two bundles: 1. Internal: predominance of red fibers (endurance); 2. External: predominance of white fibers (speed).
2	Utterances: Vowel [a] in Brazilian Portuguese, in staccato.	To check muscle contraction speed ability.	Vocalis muscle (thyroarytenoid- TA) competence, composed of two bundles: 1. internal: predominance of red fibers (endurance); 2. external: predominance of white fibers (speed).
3	Sustained utterances: [a] in Brazilian Portuguese, performed very softly, with very little sound, that is, pianissimo.	To check vocal endurance ability. After the script has been run, tasks 1 and 3 were presented in sequence in order to verify if the laryngeal adjustment had been maintained.	Vocalis muscle (thyroarytenoid- TA) competence, composed of two bundles: 1. internal: predominance of red fibers (endurance); 2. external: predominance of white fibers (speed). To compare with result of task 1, confirming or not muscular endurance ability.
4	Stretch of lyrical or pop singing of participant's choice.	To evaluate speed and muscular endurance skills, in singing voice tasks, using utterances based on the vowel [a].	To compare with the findings of tasks 1-3.

Figure 2. Corpus design for sample collections from lyrical and pop singers

Data analysis procedures comprised *(1) self-reported* vocal habits and phenotypic in "Self-Perception of Vocal Characteristics in Singers survey"*, (2) Dermatoglyphic Profile* (based on fingerprint image digitalization)*, (3) Acoustic Analysis (*based on audio sample recordings) and *(4) Integrated (Statistical) Analysis*.

(1) Self-Perception Vocal Characteristics in Singers survey

Survey data were analyzed together with dermatoglyphic profile data and vocal acoustic data.

(2) Dermatoglyphic Profile

The ten digitalized fingerprinting/ images of each singer were analyzed qualitatively and quantitatively. The qualitative analysis was based on the identification of the elements Arch (A), Loop (L), Whorl (W). The quantitative analysis was conducted by the computation of the number of deltas (D10) and the Total Ridge Count (TRC) and the computation of a digital formula, resulting in a profile: aerobic, anaerobic or mixed.

The dermatoglyphic profiles (aerobic, anaerobic or mixed) of each singer were composed based on the following:

- Predominance of types of finger patterns (six or more fingers with A, L or W);
- Digital Formula.
  - The predominance of digital design A and/or L on the fingers corresponds to an anaerobic profile. Thus, the digital formulas can be: $A + L > W$; $A = L$; 10L; 10A; $L > W$; or $A > W$;
  - The predominance of the digital pattern W places the participant in an aerobic profile: 10W; $W > L$; $W > L + A$ and
  - A mixed profile integrates both aerobic and anaerobic profiles and is equivalent to digital formulas $L = W$ or $A + L = W$.
- D10 - number of Deltas of all digital designs of the ten fingers (obtained through the formula $D10 = \Sigma L + 2 (\Sigma W)$); and
- TRC - Total Ridge Count of ten fingers.

The combination of low levels of D10 and TRC, increased number of simple designs (A and L) and decrease in complex designs (W) represents a striking characteristic of subjects who develop pure strength and speed in performing the muscular task, albeit with a low level of motor coordination and endurance. On the other hand, high levels of D10 and TRC, absence or decreased amount of digital design A and increased amount of digital pattern W characterize individuals with high muscular endurance and motor coordination[6,7].

(3) Acoustic Analysis

Audio recordings were segmented, annotated and analyzed by the application of the ExpressionEvaluator script[16,17] to the open-access software PRAAT, which automatically extracts f0, intensity, spectral slope and Long-Term Average Spectrum (LTAS) values. With regard to such measurements, f0 median (considered an approximate measure of the usual f0 of the emission, which avoids detection errors due to sudden changes in the f0 of singers in short periods of time), intensity asymmetry (normalized intensity measure, based on the proportion of intensity in the frequency range of 0,0-1000Hz/1000-4000Hz, allowing samples to have their intensity estimated, even those that have not been captured with a fixed distance between the singer's mouth and the microphone), spectral slope mean (mean of intensity proportion values in the intervals of 0,0-1000Hz/1000-4000Hz, an important measure of laryngeal tension level) and LTAS standard deviation (standard deviation of the normalized measures of intensity, along the frequency intervals of the sound spectrum) were utilized.

These groups of acoustic measures were interpreted in terms of particular muscular adjustments implemented by singers (especially regarding laryngeal tension, and thus, indirectly, the vocal folds adduction mechanism) and the singularities of vocal extension inherited from the lyrical and CCM, particularly musical theater, singing styles.

(4) Integrated (Statistical) analysis

Two approaches were designed for statistical analysis. *Self-Perception of Vocal Characteristics" questionnaire, the dermatoglyphic profile and the acoustic data of lyrical and pop singers were submitted to* Pearson's Correlation Test (SPSS 20.0 - Statistical Package of Social Sciences and System Portable d'Analise des Donnés). *Statistical analysis of Dermatoglyphic* A, L, W, D10 and TRC) *and acoustic* (f0, intensity, spectrum slope and LTAS) *data of lyrical and pop singers* were submitted to Agglomerative Hierarchical Cluster Analysis SPAD 8.0

RESULTS

The results are presented in terms of the (1) Self-Perception of Vocal Characteristics; (2) Dermatoglyphic profiles; (3) Acoustic analysis; and (4) Integrated (statistical) analysis.

(1) Self-Perception of Vocal Characteristics (training, professional practice of singing voice, vocal habits and phenotypic characteristics)

The singers ranged from 7 to 20 years of training and professional experience. In terms of classification, singers 1, 2 and 3 were baritones and singer 4 was a tenor. All singers believed that the quality of the singing voice is the result of a combination of talent and technique. Singers 1 and 3 believed that their abilities were related to muscular endurance; singers 2 and 4 believed that their skills were linked to the speed of muscle contraction.

(2) Dermatoglyphic Profiles

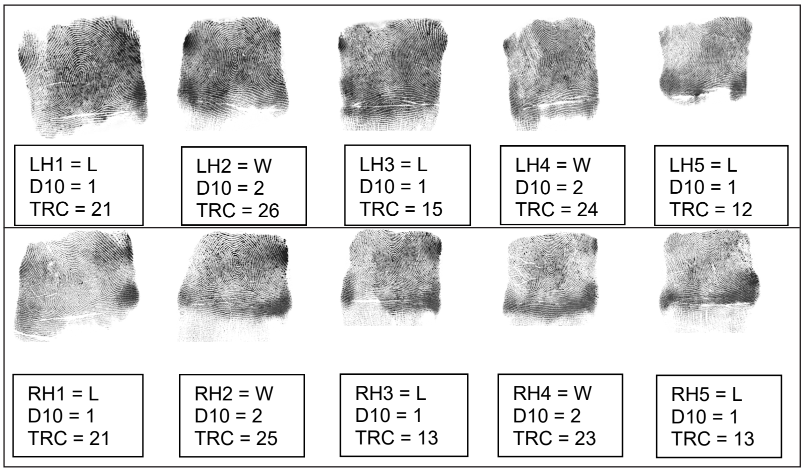
Dermatoglyphic information of singers 1 to 4 is shown in Table 1.

Table 1. Dermatoglyphic profile (numbers of arches, loops and whorls, TRC, D10, muscle profile and muscle potential) as a result of the interpretation of fingerprints of the lyrical and pop singers

-Singer	Style	Arch	Loop	Whorl	TRC	D10	PROFILE	Physical Skills			
		A	L	W				Speed	Endurance	Coordination	Strength
1	Lyrical	0	7	3	162	13	Anaerobic	Absolute predominance	Secondary predominance	Secondary predominance	Absent
2	Lyrical	0	2	8	199	18	Aerobic	Absent	Absolute predominance	Absolute predominance	Absent
3	Pop	0	3	7	165	17	Aerobic	Absent	Absolute predominance	Absolute predominance	Absent
4	Pop	0	10	0	153	10	Anaerobic	Absolute predominance	Secondary predominance	Secondary predominance	Absent

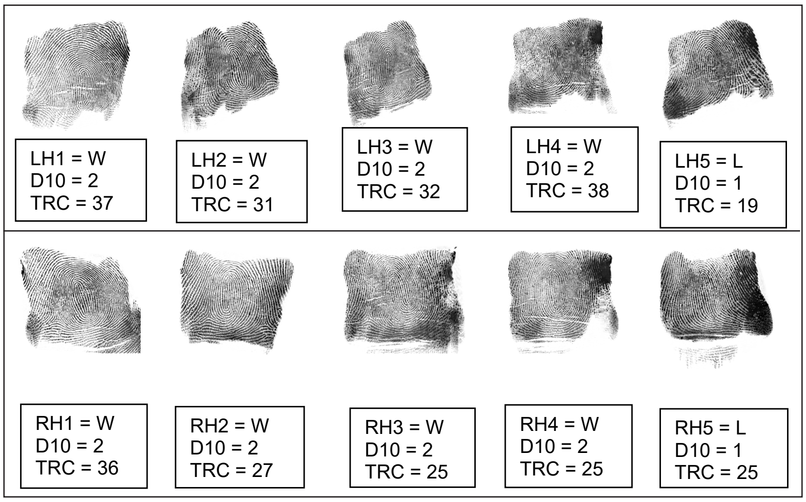
* Result of the dermatoglyphic profile of lyrical and pop singers through fingerprint analysis.

Figures 3 to 6 display the collection of fingerprints for singers 1 to 4.



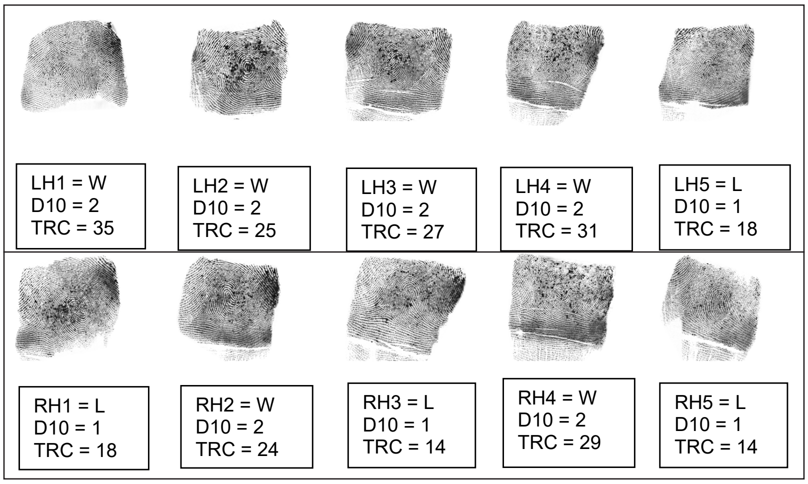
Captions: LH = Left hand, fingers from 1 to 5; RH = Right Hand, fingers from 1 to 5. A = Arch; L = Loop; W = Whorl; D10 = number of deltas; TRC = Total Ridge Count

Figure 3. Result of fingerprint analysis (left and right hands) of singer 1.



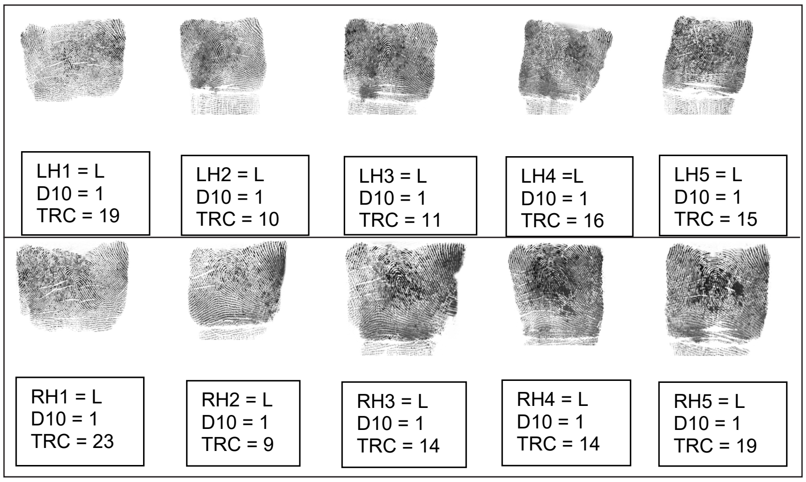
Captions: LH = Left hand, fingers from 1 to 5; RH = Right Hand, fingers from 1 to 5. A = Arch; L = Loop; W = Whorl; D10 = number of deltas; TRC = Total Ridge Count

Figure 4. Result of fingerprint analysis (left and right hands) of singer 2.



Captions: LH = Left hand, fingers from 1 to 5; RH = Right Hand, fingers from 1 to 5. A = Arch; L = Loop; W = Whorl; D10 = number of deltas; TRC = Total Ridge Count

Figure 5. Result of fingerprint analysis (left and right hands) of singer 3.



Captions: LH = Left hand, fingers from 1 to 5; RH = Right Hand, fingers from 1 to 5. A = Arch; L = Loop; W = Whorl; D10 = number of deltas; TRC = Total Ridge Count

Figure 6. Result of fingerprint analysis (left and right hands) of singer 4.

(3) Acoustic Analysis

Acoustic measures (f0-median, intensity-asymmetry, spectral slope mean and LTAS-SD) are presented in Table 2 for tasks 1 to 3.

Table 2. Acoustic profile (F0-median, intensity-asymmetry, mean-spectral slope E SD-LTAS) of lyrical and pop singers' utterances

SINGER 1 – LYRICAL				
TASK	f0-median (Hz)	Intensity-Asymmetry	Spectral Slope Mean (dB)	LTAS-SD (dB)
1	147.02	1.30	5.70	18.40
2	130.78	2.30	6.10	18.70
3	201.54	2.60	3.00	14.10
SINGER 2 – LYRICAL				
TASK	f0-median (Hz)	Intensity-Asymmetry	Spectral Slope Mean (dB)	LTAS-SD (dB)
1	162.10	-0.80	6.10	35.60
2	162.68	-0.30	6.10	34.60
3	160.94	3.30	2.80	20.70
SINGER 3 - POP				
TASK	f0-median (Hz)	Intensity-Asymmetry	Spectral Slope Mean (dB)	LTAS-SD (dB)
1	127.88	-0.20	4.80	23.70
2	120.34	1.50	5.10	29.30
3	142.38	0.30	3.00	28.00
SINGER 4 – POP				
TASK	f0-median (Hz)	Intensity-Asymmetry	Spectral Slope Mean (dB)	LTAS-SD (dB)
1	162.10	0.20	2.90	19.50
2	162.68	1.16	3.50	11.70
3	200.38	0.70	2.80	12.50

(4) Integrated Approach: Statistical analysis of the "Self-Perception of Vocal Characteristics" questionnaire, the dermatoglyphic profile and the acoustic data of lyrical and pop singers

The results of the statistical analysis are summarized in Tables 3 and 4, with the Pearson Correlation Test.

Table 3. Similarity matrix of the Pearson's test result, regarding the relationship between dermatoglyphic (D10 E TRC), acoustic vocal variables (F0- MEDIAN, intensity-asymmetry, spectral slope-mean and LTAS-SD) and the "self-perception of vocal characteristics (training, professional practice of singing voice, vocal habits and phenotypic characteristics)" questionnaire of the lyrical singers group

INDICATORS		Professional Qualification (years)	Professional Action (years)	D10	TRC	f0-median (Hz)	Intensity Asymmetry	Spectral Slope Mean (dB)	LTAS SD
Professional Qualification (years)	r d Pearson	1	-1.00	1.00	1.00	0.05	-0.44	0.02	0.80
	P		0.000	0.000	0.000	0.466	0.190	0.483	0.029
	N	6	6	6	6	6	6	6	6
Professional Action (years)	r d Pearson		1	-1.00	-1.00	-0.05	0.44	-0.02	-0.80
	P			0.000	0.000	0.466	0.190	0.483	0.029
	N		6	6	6	6	6	6	6
D10	r d Pearson			1	1.00	0.05	-0.44	0.02	0.80
	P				0.000	0.466	0.190	0.483	0.029
	N			6	6	6	6	6	6
TRC	r d Pearson				1	0.05	-0.44	0.02	0.80
	P					0.466	0.190	0.483	0.029
	N				6	6	6	6	6
f0-median (Hz)	r d Pearson					1	0.10	-0.64	-0.13
	P						0.429	0.084	0.403
	N					6	6	6	6
Intensity Asymmetry	r d Pearson						1	-0.75	-0.88
	P							0.043	0.011
	N						6	6	6
Spectral Slope mean(dB)	r d Pearson							1	0.57
	P								0.120
	N							6	6
LTAS -SD	r d Pearson								1
	P								
	N								6

* Statistical Test used: Pearson's Correlation. Statistically significant values highlighted in bold.

Table 4. Similarity matrix of the Pearson's test result, regarding the relationship between dermatoglyphic (D10 E TRC), acoustic vocal variables (F0-median, intensity-asymmetry, spectral slope-mean and LTAS-SD) and the "self-perception of vocal characteristics (training, professional practice of singing voice, vocal habits and phenotypic characteristics)" questionnaire of the pop singers group

INDICATORS		Professional Qualification (years)	Professional Action (years)	D10	TRC	f0-median (Hz)	Intensity Asymmetry	Spectral Slope-mean (dB)	LTAS-SD
Professional Qualification (years)	r d Pearson	1	-1.00	-1.00	-1.00	0.84	0.12	-0.67	-0.90
	P		0.000	0.000	0.000	0.017	0.413	0.074	0.007
	N	6	6	6	6	6	6	6	6
Professional Action (years)	r d Pearson		1.00	1.00	1.00	-0.84	-0.12	0.67	0.90
	P			0.000	0.000	0.017	0.413	0.074	0.007
	N		6	6	6	6	6	6	6
D10	r d Pearson			1.00	1.00	-0.84	-0.12	0.67	0.90
	P				0.000	0.017	0.413	0.074	0.007
	N			6	6	6	6	6	6
TRC	r d Pearson				1.00	-0.84	-0.12	0.67	0.90
	P					0.017	0.413	0.074	0.007
	N				6	6	6	6	6
f0-median (Hz)	r d Pearson					1.00	0.00	-0.80	-0.84
	P						0.499	0.028	0.019
	N					6	6	6	6
Intensity Asymmetry	r d Pearson						1.00	0.23	-0.07
	P							0.333	0.447
	N						6	6	6
Spectral Slope-mean (dB)	r d Pearson							1.00	0.53
	P								0.139
	N							6	6
LTAS-SD	r d Pearson								1
	P								
	N								6

* Statistical Test used: Pearson's Correlation. Statistically significant values highlighted in bold.

Statistical analysis of Dermatoglyphic and acoustic data of lyrical and pop singers

The data resulting from the Agglomerative Hierarchical Cluster Analysis are shown in Figure 7.

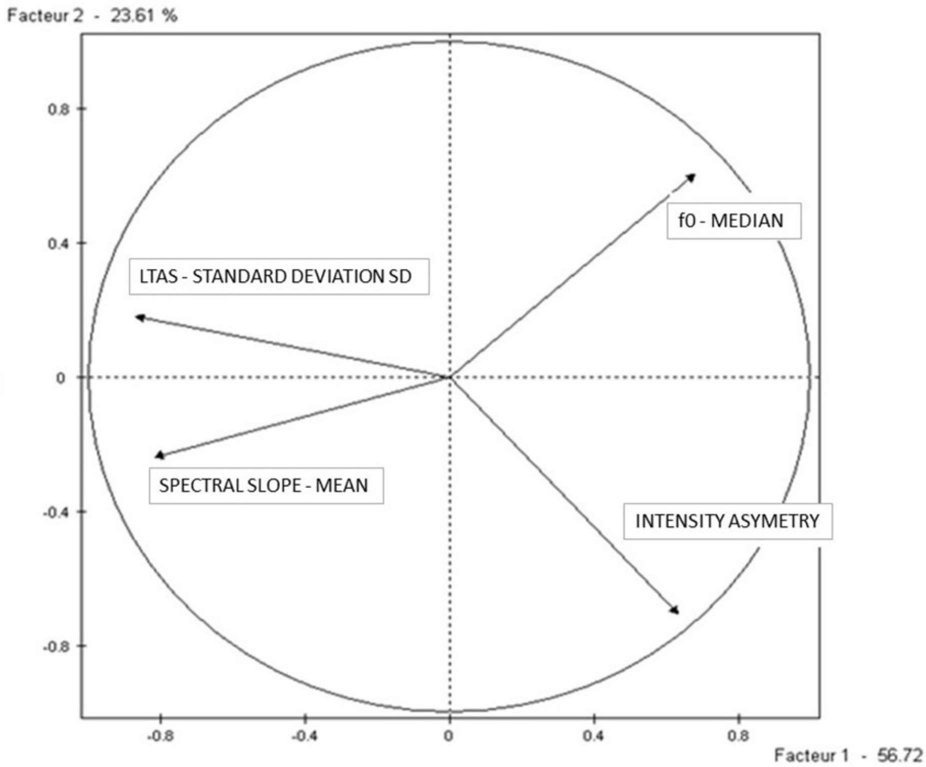


Figure 7. Diagram of agglomerative hierarchical cluster analysis for acoustic measures of the voices of lyrical and pop singers

DISCUSSION

The discussion is presented in terms of multiple case reports, containing Self-Perception of Vocal Characteristics in Singers, dermatoglyphic and acoustic data, followed by an integrated (statistical) analysis.

Multiple Case Report

Singer 1

In terms of self-perception of vocal characteristics, singer 1 is a professor at a music school at the Federal University of Rio de Janeiro, 49 years old, baritone, who took singing lessons for approximately 15 years; he is currently a lyrical singer (for over 20 years). He believes that the singing voice needs gift and technique. He rates his voice as very good. He says he has no difficulty singing. He realizes that he has more skill in vocal endurance, as he sings for hours without fatigue.

As for the dermatoglyphic analysis, singer 1 (Figure 3, Table 1), lyrical style, presented seven patterns of his fingers as Loop (L), followed by three Whorl (W) and no Arch (A). The absence of Arch helped to add up the number of lines (TRC = 162) and also the number of Deltas (D10 = 13). The digital formula that best represents his dermatoglyphic profile is L > W (greater number of fingers presenting the pattern Loop than Whorl and no Arch). Although the formula indicates an anaerobic profile (an individual with muscle contraction speed potential), the increase in D10 and TRC values also suggests motor coordination and endurance. Such findings fit the self-report of vocal endurance[18-21].

Taking into account that, ideally, the speaking habitual fundamental frequency is around the 3rd and 5th notes above the lowest tone in the male vocal classification[22], it can be considered that the usual tone range for male singers is from 110 Hz to 174 Hz. These results are in accordance with self-reported data suggesting no difficulties in reaching his tessitura. The range of his vocal rating is approximately from G2 (98Hz) to G4 (396 Hz). From the laryngeal physiology perspective, singer 1 satisfactorily recruits intrinsic thyroarytenoid (TA) and cricothyroid (CT) muscles, due to his genetic predisposition to the speed of muscle contraction. In singing, baritones have most notes of their vocal range in chest register. His genetic predisposition for motor coordination (high value of D10) may justify the ability to recruit TA and CT with agility without much difficulty, of course, associated with the training time throughout his career [6-11,13, 23,24].

Singer 2

In terms of self-perception of vocal characteristics, singer 2 is 36 years old, baritone and is from Petrópolis, Rio de Janeiro. He studied classical singing for over 15 years. He has been a professional for over 7 years. In his opinion, the singing voice represents the sum of gift and technique. He rates his voice as excellent, having no difficulty singing. He believes he has more skill in vocal intensity, since when he sings with more "volume" for a long time, he perceives greater comfort.

As for the dermatoglyphic analysis, singer 2 (Figure 4, Table 1), lyrical style, presented eight patterns of his fingers as Whorl (W), two Loops (L) and no fingers with Arch (A). The sum of the number of lines (TRC) was 199 and D10 was 18. The singer's dermatoglyphic profile is represented by the formula W > L, that is, a greater number of fingers presenting the digital pattern Whorl than Loop and no Arch; indicating an aerobic profile, due to the high number of fingers with the digital design Whorl, added to the high indexes of D10 and TRC. Thus, singer 2 revealed predominance of endurance and motor coordination[7,18-21], in agreement with the self-report of singing with "volume" for a long time.

As for the acoustic analysis, the measures of f0 of singer 2 (Table 2), baritone, lyrical style, are consistent with the f0 values of spoken voice for males[22]. These results are in accordance with self-reported data suggesting no difficulties in singing. From the laryngeal perspective, singer 2 satisfactorily recruits intrinsic TA and CT muscles, similarly to singer 1. This is in accordance to his predisposition to motor coordination compared to singer 1[7].

Singer 3

In terms of self-perception of vocal characteristics, singer 3 is 53 years old, baritone, contemporary commercial music singer (CCM) and TV actor, born in Rio de Janeiro. He underwent singing lessons for approximately 7 years. He has been singing professionally for over 20 years. He believes that the singing voice is the result of gift and technique. He rates his voice as very good. He claims that when he sings for a long time, he does not feel vocal fatigue, showing greater skill in endurance.

As for the dermatoglyphics analysis, singer 3 (Figure 5, Table 1), did not present the pattern Arch (A), but in turn there were seven Whorls (W), and three Loops (L). The sum of the total number of lines (TRC) was 165, and D10 was 17. Similar to singer 2 (W> L), singer 3 revealed tendencies to endurance and motor coordination, fitting the aerobic profile[7,18-21]. Dermatoglyphic findings seemed to confirm the singer's self-report of his muscular endurance capability, due to the fact that he does not present vocal fatigue, although he mentioned some difficulties in singing throughout his career.

As for the acoustic analysis, f0 measures for singer 3 (Table 2), baritone, musical style, are consistent with the f0 values of spoken voice for males[22]. The usual tone region for the expected baritone starts at 98 Hz, demonstrating that the participant also recruits intrinsic muscles satisfactorily[23,24]. His dermatoglyphic profile identifies that the participant presents predisposition to endurance and maybe that is why he does not fatigue easily. These results are in accordance with the self-reported endurance data.

From the physiological perspective, singers 1, 2 (lyrical) and 3 (musical) seem to recruit predominantly TA muscle activity, with a higher proportion of highly fatigable white muscle fibers as a physiological characteristic. The spectral slope values demonstrate an important decrease along the frequency bands in task 3 (singing section). This fact seems to demonstrate decrease in laryngeal tension level due to the decrease in the adduction force of the vocal folds. However, based on the singers' genetic potential, such participants are considered resistant to muscle fatigue with respect to higher levels of TRC (in case of singer 1), as well as by the predominance of Whorl (W) (in case of singers 2 and 3)[1,2,6,7], according to Table 1 and 2.

Singer 4

In terms of self-perception of vocal characteristics, singer 4 is 31 years old, born in Rio de Janeiro, contemporary commercial music singer, tenor, and studied music for approximately 13 years. He has been working professionally for almost 10 years. He claims that the singing voice is the result of gift and technique. He believes that his singing voice is very good, not presenting any difficulties in his performance. He mentions that his best skill is muscular speed, despite not mentioning having muscle fatigue.

The dermatoglyphic analysis of singer 4 (Figure 6, Table 1) revealed ten patterns of fingers as Loop (L), no Whorl (W) and no Arch (A). He showed ten deltas (D10 = 10) and TRC was 153. An increase in digital pattern Loop (greater than six), combined with a decrease in digital pattern Whorl (less than four) and the presence or increase of digital pattern Arch together with a reduction in TRC characterize an anaerobic profile: potential for muscle contraction speed, with digital formula 10L[7,18-21]. These dermatoglyphic findings match self-reported muscular speed ability.

Taking into account the underlying muscular skill, a strategy of singing pedagogy could reinforce the non-potentiated skill, with the aim of offering the singer both speed and muscular endurance abilities.

As for the acoustic analysis, f0 measures for singer 4 (Table 2) tenor, musical style, are consistent with the f0 values of spoken voice for males[23]. These results match the self-reported data suggesting no difficulties in singing. Similar to singer 1, singer 4 also demonstrates a genetic predisposition to muscle contraction speed and this fact makes him navigate well between TA and CT muscles[6-11,13].

Voice samples from singers 3 and 4, representing the musical style, revealed decreased values of intensity asymmetry in task 3 when compared to task 2. This fact can be supported by some practices related to instructions for nonclassical music, reinforcing the resonator system, air flow and refined muscular action of TA and CT[22].

Spectral slope values from singers 3 and 4 were softly reduced in task 3 in relation to tasks 1 and 2 and in relation to singers 1 and 2, which indicated a tendency towards a decrease in laryngeal hyperfunction[24-26]. This finding is probably associated with increased levels of laryngeal adduction in singing voice (task 3), due to the higher position of the larynx[2].

Lyrical and pop singers seem to strongly enhance vocal fold adduction, but prevent voice loading, thanks to respiratory, laryngeal positioning, and, especially, resonance adjustments[27-29].

Integrated analysis of "Self-Perception of Vocal Characteristics (training, professional practice of singing voice, vocal habits and phenotypic characteristics)", dermatoglyphic profile and acoustic data

Some findings on various levels of correlation are discussed, taking into account that these findings were preliminary and stimulated the discussion of particular acoustic-to-physiological correspondences, mediated by dermatoglyphic findings. The results in Table 3 (lyrical singers) reinforce the relationship between professional training and professional performance indexes; training and professional performance indexes with dermatoglyphics (D10 and TRC) and acoustic measure (LTAS-SD); dermatoglyphics (D10 with TRC); dermatoglyphics (D10 and TRC) with acoustic measure (LTAS-SD); and among acoustic measures (intensity-asymmetry; spectral slope-mean and LTAS-SD). A strong correlation preliminarily detected between professional training and professional performance indexes can indicate that the stimulus environment (phenotype) might be efficient in the search for the development of skills necessary to achieve high performance.

The results in Table 4 (pop singers) favor for some instance of correspondence between professional training and professional performance indexes; training and professional performance with dermatoglyphics (D10 and TRC); dermatoglyphic (TRC) with acoustic measures (f0-median and LTAS-SD) and acoustic measures (f0-median and LTAS-SD); dermatoglyphics (D10 with TRC); and acoustic measures (f0-median with spectral slope-mean and LTAS-SD).

Another preliminary correlation was detected between dermatoglyphic indicators D10 and TRC and singing style (lyrical and musical) (Tables 3 and 4, respectively). Increased levels of D10 and TRC are related to motor coordination and muscle endurance, found in high performance athletes, as well as not presenting Arch digital design, considered a simple design, compared to Loop and Whorl. Singers with this profile would be more resistant to muscle fatigue. On the other hand, decreased levels of D10 and TRC signal greater potential for muscle contraction speed, representing singers who are agile in muscular demands, yet more susceptible to vocal fatigue[6,7].

Correspondences were also found between dermatoglyphic indicator D10 and LTAS-SD for lyrical singers (Table 3) and pop singers (Table 4). LTAS measures were associated with dermatoglyphic indicator D10, reinforcing the hypothesis of laryngeal musculature and vocal tract adjustments in line with motor skills of speed and motor coordination. Singers 1 and 4 seem to be genetically predisposed to speed. Singer 1, in addition, presents potential for speed of muscle contraction, due to the high index of D10 and TRC, and some motor coordination and muscular endurance.

Correlation was identified between dermatoglyphic indicator TRC and acoustic measurement of LTAS standard deviation in the group of lyric singers (Table 3) and in pop singers (Table 4). The higher the number of lines in the digital patterns are, the higher the ability in endurance (singers 2 and 3). The lower these values are, the higher the ability for muscle speed (singers 1 and 4). These findings reinforce some levels of correspondences between dermatoglyphic indicators D10 and TRC[6,7].

Lyrical singers (Table 3) showed a correspondence between acoustic measures (intensity-asymmetry and spectral slope-mean) and for intensity-asymmetry and LTAS-SD. These acoustic measures were associated with laryngeal adduction, which is required to be balanced in singing voices[1,2,4].

In the lyrical style, the phonatory type is more fluid, with moderate subglottic pressure and values of glottic compliance and relative intensity of the fundamental frequency component being higher compared to tense phonation. The singer's formant, a phenomenon that occurs in lyrical singing, allows the singer to be heard in front of an orchestra without vocal effort, thanks to the clustering of F3, F4 and F5. The more formants are clustered, the greater the amplitude of the singer's formant. The two lyrical singers have in common, in dermatoglyphic terms, physical skills of endurance and motor coordination (although singer 1 represents the anaerobic profile, high levels of D10 and TRC are responsible for endurance and motor coordination skills). These findings seem to indicate that these singers present greater latency in muscle fatigue[1,2,4-6].

In pop singers (Table 4), correspondences were found between: acoustic f0-median and dermatoglyphic D10 and TRC indicators; acoustic indexes f0-median and LTAS-SD; acoustic measures of f0-median and spectral slope-mean.

Singers 3 and 4 showed increased levels of laryngeal tension, probably caused by the increase in adductor force, which can be achieved by enhancing the activity of the TA muscle's external part. Muscle adjustments at the respiratory level, usually found in singers, are responsible for the lower impact of tension at the laryngeal level[28,30,31].

Singer 3, who presents the aerobic profile, will probably experience decreased vocal impact over time, as opposed to singer 4, who presents an anaerobic profile – predisposition for the speed of muscle contraction.

In the cluster analysis (Figure 7), associated factors 1 and 2 represented 80.33% of the degree of influence, in which the acoustic measures of f0-median (83.3%) and LTAS-SD (16.6%) were highlighted. Pop singers showed the highest correlation of f0-median acoustic measure with spectral slope-mean and LTAS-SD.

Such findings have shown that the dermatoglyphic method was correlated with acoustic vocal data of lyrical and pop singers in this study, deepening the understanding of relationships between genotypic, phenotypic and acoustic vocal aspects. It is believed that results found here can provide relevant contributions to various areas of knowledge gathered in the vocal sciences.

A tendency for a positive relationship between the dermatoglyphic profile and acoustic vocal quality parameters was identified, favoring a potential application of studies on dermatoglyphic profiles and vocal quality, both for spoken and singing voices. Future studies encompassing the casuistic ampliation and perceptual analyses incorporation seem to be useful to foster future investigation in this field.

CONCLUSION

There was a preliminary correlation between dermatoglyphic variables (Arch, Loop, Whorl, D10, TRC) and acoustic vocal parameters fundamental frequency (median), intensity (asymmetry), spectral slope (mean) and long-term average spectrum – LTAS (SD), thus, showing a relationship between dermatoglyphic profile and acoustic parameters in singing voices. The dermatoglyphic profile did not segregate singing styles.

Given the sample universe of the present research, generalizations are not possible. The results point to ways that suggest a relationship between the dermatoglyphic method and acoustic vocal measurements and, therefore, indicate the need for further studies.

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APPENDIX

Self-Perception of Vocal Characteristics in Singers

A) Personal Data

Name: ________________________________ Date: ___/____/_____

Birth date: ____/____/____

Place and Year of Singing Training: ___________________________________

Sing Style: ( ) Lyrical ( ) Popular

Vocal rating ____

B) Professional Training

Singing lessons:

( ) there was no class

( ) from 5 to 10 years ( ) from 16 to 20 years

( ) from 11 to 15 years ( ) more than 20 years

C) Professional Performance

Singing professionally:

( ) from 1 to 5 years ( ) from 16 to 20 years

( ) from 6 to 10 years ( ) more than 21 years

( ) from 11 to 15 years

D) Self-Assessment of singing voice

You rate your voice as:

( ) Excellent ( ) Reasonable

( ) Very good ( ) Bad

( ) Good

In your opinion, singing voice is:

( ) Gift ( ) Technique ( ) Both

Have you had difficulty singing? ( ) Yes ( ) No

When you sing with intensity, do you feel vocal fatigue? ( ) Yes ( ) No

When singing longer, do you feel vocal fatigue? ( ) Yes ( ) No

Do you think you have more skill in intensity or endurance? Why?

( ) Intensity, because ____

( ) Endurance, because ____