Relating ambulatory voice measures with self-ratings of vocal fatigue in individuals with phonotraumatic vocal hyperfunction

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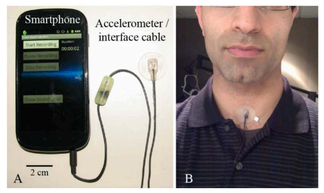
Motivation

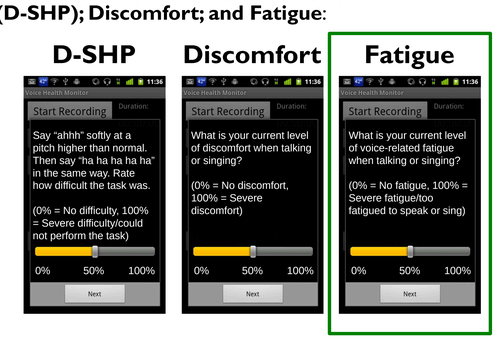
Advancements in mobile and wearable technologies continue to enhance ambulatory voice monitoring for the improved assessment and treatment of behaviorally based voice disorders. Phonotraumatic vocal hyperfunction is one common behaviorally based voice disorder associated with **faulty patterns of chronic vocal behavior** that result in vocal fold tissue trauma, such as nodules or polyps. As a result, **individuals often exhibit dysphonia and elevated levels of vocal fatigue**.

Study Design

This study investigated the relationships between **self-ratings of vocal fatigue and ambulatory voice measures in adult patients with vocal fold nodules or polyps.** Using a smartphone-based ambulatory voice monitor, self-ratings were provided on a visual analog scale at five-hour intervals during the day, and data were continuously recorded from a subglottal neck-surface accelerometer:



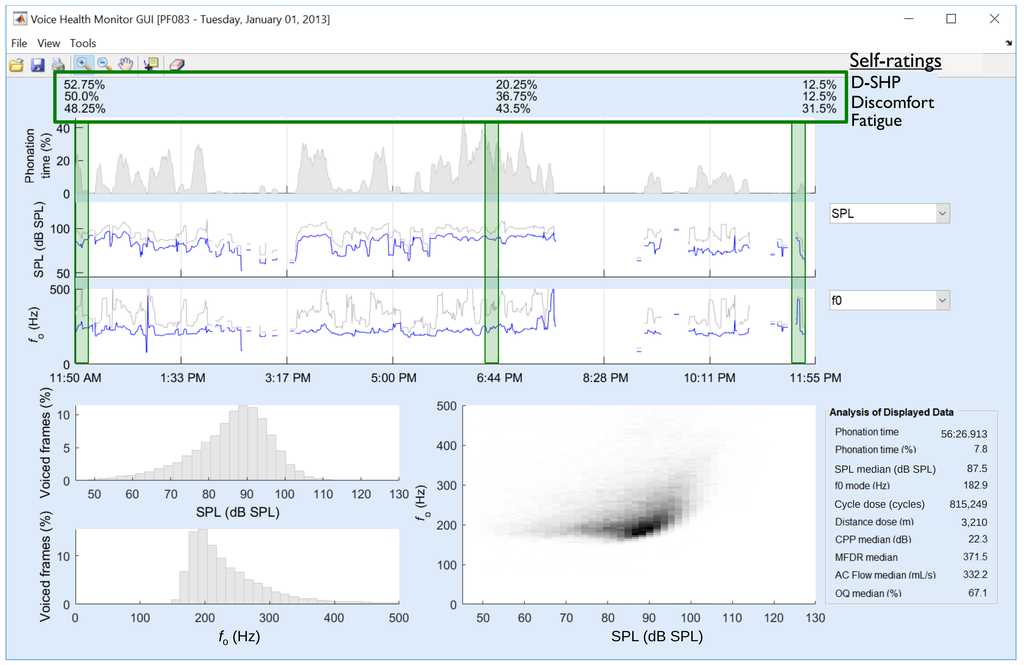
Three vocal status prompts on visual analog scales from 0–100: **Difficulty producing soft, high-pitched phonation (D-SHP); Discomfort; and Fatigue**:



Voice dosimetry metrics and summary statistics of ambulatory voice measures were computed from voiced phrases preceding the self-rating prompts, often including the standardized Rainbow Passage**:**

Phonation time	%	Percentage of voiced frames
Cycle dose	cycles	Integer number of glottal cycles
Distance dose	m	Theoretical distance the vocal folds travel
Low-to-high spectral ratio	dB	Difference between spectral power below and above 2000 Hz
Fundamental frequency	Hz	Reciprocal of first non-zero peak location in the normalized autocorrelation function
Cepstral peak prominence	dB	Magnitude of the highest peak in the power cepstrum
Sound pressure level	dB SPL	Acceleration amplitude mapped to acoustic sound pressure level
Harmonic spectral tilt	dB/oct	Linear regression slope over the first 8 spectral harmonics
Subharmonic peak	0–1	Relative amplitude of a secondary peak, if it exists, located around half way to the autocorrelation peak
Autocorrelation peak amplitude	0–1	Amplitude of first non-zero peak in the normalized autocorrelation

Results: Example Daily Voice Use Profile



Results: Significant Changes in Self-Ratings of Vocal Fatigue

Given the variance inherent in perceptual judgments, the analysis focused on comparisons between time periods that exhibited **clinically significant differences in self-ratings (>19.7 points on a 100-point scale)**, approximately one standard deviation in patients:

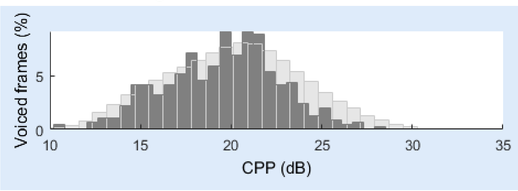
Vocal status question	Patients with nodules or polyps	Matched-control subjects with typical voices
D-SHP	43.2 (20.6)	5.8 (7.5)
Discomfort	36.9 (20.0)	5.0 (6.6)
Fatigue	42.5 (20.3)	6.4 (8.1)

Standard Deviation ≈ Minimal Detectable Change (95% Confidence Interval)

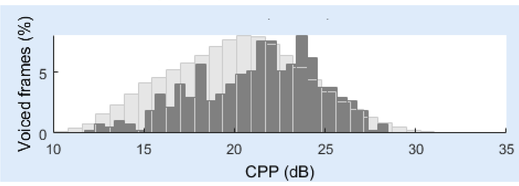
Subject	Vocal Fatigue Rating 1	Vocal Fatigue Rating 2	Change in Vocal Fatigue	Change in Measure
Male	29.50	73.75	44.25	ΔTilt = -2.0
	63.75	87.50	23.75	ΔTilt = -0.79
Male	34.25	68.00	33.75	N/A
	23.25	65.50	42.25	N/A
Male	27.00	50.00	23.00	ΔCPP = -5.9
	12.25	37.50	25.25	ΔCPP = -7.3
Female	66.00	91.75	25.75	ΔCPP = +5.3
	13.25	50.00	36.75	ΔCPP = +3.2
Female	15.75	68.75	53.00	ΔAper = -2.2
	28.00	61.25	33.25	ΔAper = +1.4
Female	32.25	65.75	33.50	ΔTilt = -0.71
	30.75	64.75	34.00	ΔTilt = -1.5
Female	26.50	67.50	41.00	ΔCPP = -2.6
	72.25	34.00	-38.25	ΔCPP = -3.7
Female	2.50	50.00	47.50	ΔTilt = -0.66
	27.50	78.25	50.75	ΔTilt = -0.39
Female	28.00	0.00	-28.00	ΔCPP = -6.2
	9.75	32.00	22.25	ΔCPP = +7.2
Female	100.00	60.75	-39.25	ΔTilt = +1.4
	61.75	100.00	38.25	ΔTilt = -0.58

Example Increase in Cepstral Peak Prominence (CPP) with Increase in Vocal Fatigue

Vocal Fatigue = 27.50, CPP mode = 19.6 dB



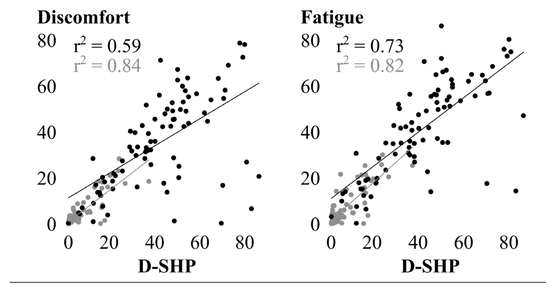
Vocal Fatigue = 78.25, CPP mode = 24.0 dB

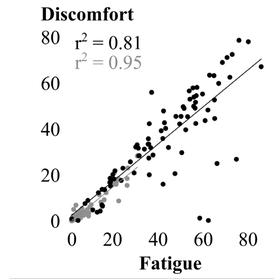


Whole day (light gray)
Pre-rating segment (dark gray)

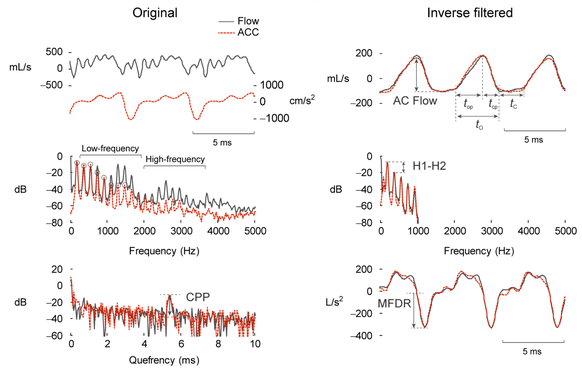
Discussion

Pairwise correlation of self-ratings: The three scales exhibit a level of redundancy, especially for healthy speakers (gray circles). However, since pairwise correlations are lower in patient group (black circles), the degree of redundancy may be a predictor of the presence or absence of a voice disorder.





Accelerometer-based measures of glottal airflow, such as maximum flow declination rate (MFDR) and peak-to-peak airflow, may correlate better with self-ratings of vocal fatigue.



Conclusion

An initial look at **relationships among self-ratings of vocal fatigue and objective, ambulatory voice measures** was undertaken. Further study is needed to investigate subject-specific relationships and treatment-related effects due to laryngeal surgery and/or voice therapy. **Ambulatory measures of glottal airflow are hypothesized to yield clinically salient measures** of the voice source that relate strongly to self-ratings of vocal status.

Acknowledgments

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