

Using Receiver Operating Characteristic Curve to Define the Cutoff Points of Voice Handicap Index Applied to Young Adult Male Smokers

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Summary: Voice performance is an inextricable key factor of everyday life. Obviously, the deterioration of voice quality can cause various problems to human communication and can therefore reduce the performance of social skills (relevant to voice). The deterioration could be originated from changes inside the system of the vocal tract and larynx. Various prognostic methods exist, and among them is the Voice Handicap Index (VHI). This tool includes self-reported questionnaires, used for determining the cutoff points of total score and of its three domains relevant to young male Greek smokers. The interpretation of the calculated cutoff points can serve as a strong indicator of imminent or future evaluation by a clinician. Consistent with previous calculation, the VHI can also act as a feedback for smokers' voice condition and as monitoring procedure toward smoking cessation. Specifically, the sample consisted of 130 male nondysphonic smokers (aged 18–33 years) who all participated in the VHI test procedure. The test results (through receiver operating characteristic analysis) concluded to a total cutoff point score of 19.50 (sensitivity: 0.838, 1-specificity: 0). Also, in terms of constructs, the Functional domain was equal to 7.50 (sensitivity: 0.676, 1-specificity: 0.032), the Physical domain was equal to 7.50 (sensitivity: 0.706, 1-specificity: 0.032), and the Emotional domain was equal to 6.50 (sensitivity: 0.809, 1-specificity: 0.048).

Key Words: Voice Handicap Index–Males–Cutoff scores–Smoking cessation–Screening.

INTRODUCTION

Cigarette smoking continues to be the leading preventable cause of death of about six million people worldwide. Many of these deaths occur prematurely.¹ Particularly, smoking among young adults in Greece was estimated at 48.10% (aged 25–29 years) and 45.20% (aged 15–24 years) in 2010 and specific for young men at 45%.¹ According to Lipari et al,² the number of young adult smokers has doubled, whereas onset of smoking in young adults occurs between the ages of 18 and 25 years.³ Probably, these adults will develop health issues in the future.

These health issues will also include changes in the laryngeal area^{4–6} and alterations of the voice mechanism with imminent clinical conditions of voice disorders.^{7–9} The changes include chronic inflammation or irritation of the laryngeal mucosa,^{10–12} Reinke edema,¹³ or even benign and malignant tumors.^{4,6,10,14} The aforementioned structural changes of the larynx because of smoking will probably lead to voice deviations and complaints.^{15–18} As a consequence of these symptoms, smokers seek for a laryngeal evaluation or imaging,^{19–23} followed by a referral to the appropriate speech pathologist for acoustic-perceptual^{24–27} and aerodynamic assessments^{28–30} of their voice. Additionally, the clinician will determine the level of patients' perception of voice

status using self-reported questionnaires,³¹ such as the Voice Handicap Index (VHI).³²

The VHI has been translated in many languages,^{33–41} including Greek.⁴² The utility has three domains, which are named as Functional (VHI-F), Physical (VHI-P), and Emotional (VHI-E). Each domain includes 10 questions. Every question responds to a 0–4 Likert-type scale, resulting to a total maximum score (VHI-T) of 120. The VHI has been used in many studies for populations with voice and laryngeal disorders^{43–48} and for voice professionals^{49–52} and smokers.^{53,54} Furthermore, VHI cutoff points are intended for the voice-disordered population⁵⁵ and also for young female smokers.⁵⁶ Moreover, receiver operating characteristic (ROC) curve was used for finding the cutoff values of VHI-T and its three domains to conclude to a typical score, which should lead the participant to a voice specialist for clinical assessment.

ROC curve and the methodology of its operation has its roots back to the era of radar evolution (1950s). The mentioned procedure of the accurate detection of a signal is based on producing positive and negative results. The type of the result is relevant to the presence or the absence of a signal or disease accordingly. The accuracy is defined by “sensitivity” (probability of positive result—presence of the disease) and “specificity” (probability of negative result—absence of the disease). The ROC curve connects sensitivity with specificity, whereas their paired information (sensitivity, 1-specificity) produces a well-estimated prediction.⁵⁷ The applications of ROC curve range from medical decision-making to machine learning processes.⁵⁸ Specifically, whereas a possible presence of upper corner of the curve represents perfect accuracy, the diagonal line deteriorates prediction to a random guessing operation. Also, another important factor of the curve is the area under curve (AUC) with a maximum value of 1.⁵⁸ The AUC can be split into four categories ranging from “No predictive” (AUC < 0.5) to “Outstanding” (AUC ≥ 0.9).^{56,59} Moreover,

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TABLE 1.
Comparison of Medians Between Male Smokers and Nonsmokers for VHI Total Score and VHI Domains

	Smokers (N = 68)	Nonsmokers (N = 62)	Mann-Whitney <i>U</i>	<i>P</i> Level
	Median (IQR)	Median (IQR)		
Total	29.00 (24.25–32.00)	15.00 (13.00–16.00)	290.00	<0.001*
Functional	9.00 (6.25–11.00)	5.00 (4.00–6.00)	514.00	<0.001*
Physical	10.00 (7.00–11.00)	5.00 (4.00–6.00)	563.00	<0.001*
Emotional	10.00 (8.00–11.00)	5.00 (4.75–5.25)	442.50	<0.001*

* *P* level at <0.05.

Abbreviations: IQR, interquartile range; VHI, Voice Handicap Index.

AUC is equivalent to Wilcoxon tests of ranks having almost the same value as Gini coefficient.^{60,61}

The current study had the purpose of calculating the cutoff points of VHI total score along with those of its three domains. In parallel, for the case of young male smokers, the probability of developing voice symptoms was estimated.

MATERIALS AND METHODS

Participants

In this study, 130 young males (68 smokers and 62 nonsmokers) were enrolled in the testing procedure. The collection of data was conducted in the School of Health and Welfare at the Technological Educational Institute of Epirus. The participants consented (via signing a consensus letter) to fill in the two questionnaires after being informed of the research purposes. All male participants who experienced any laryngeal or respiratory disorders for a period of 2 weeks were excluded from this study. Furthermore, other male groups were excluded as well.

Exclusionary criteria included subtle symptoms of gastroesophageal reflux or laryngopharyngeal reflux, history of alcohol or drug addiction, working or living under environmental conditions that may influence voice (noise, exposure to chemicals etc), or any history of voice abuse.

Data collection

All participants filled out the translated version of the Voice Evaluation Form (VEF)⁶² and the standardized Hellenic version of the VHI.⁴² The VEF was developed by the American Speech-Language-Hearing Association as a consensus template for voice disorders. The VEF was also used to exclude subjects with history of voice disorders. The VHI is a 30-item questionnaire summarizing a VHI-T from 0 to 120 points. This score is split into three equal domains (0–40 points): VHI-E, VHI-P, and VHI-F. As already mentioned, each domain included 10 questions.

Statistical analysis

All skewed variables (VHI scores) are expressed through a median calculation (interquartile range), and all normal distributed variables are expressed in mean and standard deviations (SD). The Mann-Whitney *U* test was used for the comparison of continuous variables between the two study groups of smokers and nonsmokers. Also, the ROC curve was used for assessing the cutoff values of VHI-T and its three domains (VHI-F, VHI-P, VHI-E). All reported *P* values were two-tailed, and the statistical

significance was set to *P* < 0.05. The analysis was conducted using *SPSS Statistics 19* (IBM, Armonk, NY).

RESULTS

The sample consisted of 130 male participants (68 smokers and 62 nonsmokers). Total mean age was 22.32 years (standard deviation [SD] = ±2.28). Mean age of smokers was 22.01 years (SD = ±2.35) and of nonsmokers was 22.66 years (SD = ±2.18). The average calculated years of smoking was equal to 2.65 (SD = ±1.21), with a number of cigarettes per day of a mean value equal to 14.27 (SD = ±7.06).

Smokers had a significantly higher overall VHI total score than did nonsmokers (*U* = 358.00, *P* < 0.001). Similar statistically significant differences of medians were computed for the VHI-F (*U* = 469.00, *P* < 0.001), VHI-P (*U* = 943.00, *P* < 0.001), and VHI-E domains (*U* = 426.00, *P* < 0.001). In all comparisons, the smokers subgroup exhibited higher scores (Table 1).

A ROC analysis was conducted to determine the cutoff points of VHI-T and its three domains (Functional, Physical, and Emotional). A statistically significant positive discrimination between smokers and nonsmokers was revealed. Particularly, an excellent value of VHI-T (AUC 0.930, *P* < 0.001) was noted, whereas very high effects were noted for the VHI-F (AUC 0.878, *P* < 0.001), VHI-P (AUC 0.866, *P* < 0.001), and VHI-E domains (AUC 0.895, *P* < 0.001) (Table 2). The cutoff point of VHI-T score was equal to 19.50, with a sensitivity of 0.838 and 1-specificity of 0.000 (Figure 1); VHI-F cutoff point was equal to 7.50, with sensitivity of 0.676 and 1-specificity of 0.032 (Figure 2). Also, the VHI-P cutoff point was equal to 7.50, with sensitivity of 0.706 and 1-specificity of 0.032 (Figure 3), and

TABLE 2.
Coordinates for Smokers and Nonsmokers Curve for VHI Total Score and VHI Domains

	AUC	SE	<i>P</i> Level	95% CI
Total	0.930	0.025	<0.001*	0.882–0.978
Functional	0.878	0.030	<0.001*	0.801–0.934
Physical	0.866	0.033	<0.001*	0.645–0.823
Emotional	0.895	0.030	<0.001*	0.817–0.943

* *P* level at <0.05.

Abbreviations: AUC, area under curve; CI, confidence interval; SE, standard error; VHI, Voice Handicap Index.

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