J Occup Med Toxicol
https://doi.org/10.1186/s12995-026-00516-6
Article in Press

Voice characteristics of iron and steel workers: an acoustic and self-reported cross-sectional study

Received: 2 March 2026
Accepted: 9 June 2026
Published online: 15 June 2026

Cite this article as: Yesilli-Puzella G. & Coşkun-Karaveli İ. Voice characteristics of iron and steel workers: an acoustic and self-reported cross-sectional study. *J Occup Med Toxicol* (2026). https://doi.org/10.1186/s12995-026-00516-6

Gamze Yesilli-Puzella & İlknur Coşkun-Karaveli

Voice characteristics of iron and steel workers: an acoustic and self-reported cross-sectional study

Authors

Gamze Yesilli-Puzella[1]*, İlknur Coşkun-Karaveli[2]

Affiliations

[1] Department of Speech and Language Therapy, Cappadocia University, Nevşehir, Turkiye

[2] Private Speech and Language Therapy Clinic, Karabük, Turkiye

***Correspondence**

Gamze Yesilli-Puzella

Department of Speech and Language Therapy, Cappadocia University, Mustafapaşa, Ürgüp, Nevşehir, Turkiye, 50400

Email: gamze.puzella@kapadokya.edu.tr

Abstract

Background

Occupational environments with dust, noise, and high vocal demands can adversely impact voice production. Iron and steel workers encounter several environmental risk factors that may impair vocal function, nevertheless, objective acoustic and self-reported voice outcomes in this population have not been thoroughly investigated. This study aimed to evaluate the acoustic and self-reported voice characteristics of iron and steel manufacturing workers and compare these findings with those of a normophonic control group.

Methods

This cross-sectional comparative research comprised 128 male participants: 64 steel and iron factory workers and 64 normophonic controls. Voice evaluation consisted of F0, jitter, shimmer, noise-to-harmonics ratio, smoothed cepstral peak prominence, Acoustic Voice Quality Index, maximum phonation time, Voice Handicap Index-10 and Voice-Related Quality of Life. Mann-Whitney U tests or Welch’s t-tests were used for between-group comparisons, as appropriate.

Results

Iron and steel workers had significantly lower F0 and smoothed cepstral peak prominence values and higher jitter, shimmer, noise-to-harmonics ratio, and Acoustic Voice Quality Index scores than controls (all $p < 0.01$). The maximum phonation time was significantly shorter in workers ($p < 0.001$). The mean Voice Handicap Index-10 score among workers exceeded the Turkish threshold, and the Voice-Related Quality of Life scores were significantly lower than those of controls ($p < 0.001$).

Conclusions

Iron and steel industry workers had lower acoustic and self-reported markers of voice quality than normophonic individuals. These findings indicate that exposure to industrial noise and airborne irritants may be associated with subclinical changes in voice characteristics. In occupational health, a comprehensive voice assessment can serve as a time-saving, non-

invasive screening tool to support early diagnosis and prevention of work-related voice problems.

Keywords: Occupational voice health, iron and steel workers, acoustic voice analysis, industrial exposure, smoothed cepstral peak prominence, Acoustic Voice Quality Index, voice handicap

Background

Voice is a fundamental component of human communication and has an impact on professional performance and quality of life. Occupational voice health is an interdisciplinary field that examines the effects of workplace factors on voice function, which is a part of general occupational health [1]. The primary objective of occupational health is to avoid illnesses and health consequences brought on by exposures at work, such as non-communicable diseases caused by inhaled chemicals, particulates, and ergonomic risk factors.

The larynx is a physiologically and functionally vulnerable target organ for work-related adverse health effects, as it is the major organ exposed during inhalation and is necessary for occupational voice use [2]. Therefore, variables associated with the workplace may negatively impact the structure and function of the vocal folds, potentially leading to occupational voice disorders [3]. Due to their detrimental effects on psychological well-being, social involvement, communication effectiveness, and job productivity, these conditions represent a public health problem [4]. Contributors to vocal dysfunction include prolonged vocal use, insufficient vocal rest, poor acoustics, ambient noise, psychological stress, dehydration, and exposure to airborne toxins or allergens [5–7]. Occupational noise exposure stands out among these factors because people who work in noisy environments often raise their vocal volume and fundamental frequency to preserve speech intelligibility, a phenomenon known as the Lombard effect [8]. This adaptive vocal response raises vocal stress and might eventually lead to the rise of voice problems [9].

Iron and steel factories and other heavy industrial settings pose several occupational risks, including constant exposure to high noise levels, airborne chemicals and dust, demanding physical work, and limited opportunities for voice rest. Although the effects of such conditions on diverse health aspects of iron and steel workers have been extensively studied [10–13], to our knowledge, no research has been conducted on the laryngeal function and voice aspects of these workers. The use of objective acoustic measurements, and self-reported voice-related quality of life in a comprehensive voice assessment may provide a sensitive, non-invasive method for detecting early functional changes in voice production that reflect stress on the larynx and related respiratory systems triggered by occupational irritants and work environment conditions. Acoustic voice analysis provides objective, non-invasive measures of voice quality that can detect subtle changes in vocal function [14]. Key acoustic parameters include fundamental frequency (F0), jitter, shimmer, noise-to-harmonics ratio (NHR), and smoothed cepstral peak prominence (CPPS). The Acoustic

Voice Quality Index (AVQI) is a multiparametric measure that combines several acoustic parameters to provide overall assessment of voice quality [15]. Self-reported measures capture the patient's perception of voice problems and their impact on daily life [16]. Therefore, this study aimed to evaluate the acoustic and the self-reported voice characteristics of iron and steel manufacturing workers in Turkiye and compare these findings with those of a normophonic group. It was hypothesized that iron and steel workers would exhibit poorer acoustic voice quality and report higher self-perceived impact of voice problems on daily life.

Methods

Study design and participants

This cross-sectional comparative study was conducted between February 2024 and November 2024. The study comprised 128 male participants: 64 workers employed in production activities at a single iron and steel factory in Turkiye, and 64 normophonic controls recruited from the local community.

Inclusion criteria for the worker group were male sex, at least 1 year of employment in the iron and steel industry, and willingness to participate in the study. For both groups exclusion criteria were a history of laryngeal surgery, current upper respiratory tract infection, cognitive impairment, speech or language disorders, self-reported or diagnosed hearing problems, neurodegenerative, progressive neurological, laryngeal, or respiratory system disorders, professional voice use outside work, poor general health, and smoking. Workers were under routine audiological monitoring at the factory, and the included participants had no reported abnormal results on hearing screening.

Control participants met the same sex and adult age-range criteria and had no history of voice problems, occupational voice use, or smoking. To ensure normophonic voice characteristics, additional criteria were applied to the control group, including normal perceptual voice quality (GRBAS (Grade, Roughness, Breathiness, Asthenia, and Strain) scale scores of 0 across all dimensions) [17], and no voice-related complaints, as evidenced by a Voice Handicap Index-10 score of 0. Written informed consent was obtained from all participants prior to enrollment.

Data collection procedures

Data collection included self-reported voice surveys, objective acoustic analyses, and maximum phonation time measurements, all conducted under standardized conditions.

Voice recording and acoustic analysis

All voice assessments were conducted by the second author, who is a certified speech and language therapist. Voice recordings were made at the iron and steel factory’s audiology cabin, which is regularly used for occupational audiological exams. The recordings were performed in accordance with the recommendations of Deliyski et al. [18, 19], maintaining a signal-to-noise ratio (SNR) of more than 30 dB. Recordings were made using a SAMSON Go Mic condenser microphone in cardioid mode at a sampling rate of 44,100 Hz. The microphone was positioned around 10 cm from the participant's mouth, and the same distance and settings were used throughout all recordings. Participants completed three voice tasks: (1) sustained vowel /a/ phonation at a comfortable pitch and loudness, from which a 3-second mid-portion segment was chosen for analysis; (2) reading of the standardized phrase "Serüvenin resimde gördüğünüz şu dağ köyünde başladı." taken from the Turkish "Pinokyo" passage [20]; and (3) maximum phonation time (MPT), which was calculated as the longest duration of sustained /a/ across three trials following deep inhalation. Praat, version 5.2.26, was used to record voices and perform acoustic analyses [21]. Mean fundamental frequency (F0), jitter (%), shimmer (%), noise-to-harmonics ratio (NHR), and smoothed cepstral peak prominence (CPPS) values were extracted using a 3-second mid-portion segment of /a/ phonation. CPPS was additionally analyzed using the standardized reading phrase to evaluate continuous speech. Acoustic Voice Quality Index version 2 (AVQIv2) was evaluated according to the standard guidelines [22, 23].

Self-reported voice assessment

Participants were asked to complete the Turkish version of the Voice Handicap Index-10 (VHI-10) [24] to assess the perceived impact of voice problems on daily life. The Voice-Related Quality of Life (V-RQOL) questionnaire [25] was also administered to all participants to evaluate voice-related quality of life. The V-RQOL raw scores were converted to a standardized 0-100 scale, with higher scores reflecting greater voice-related quality of life.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 22 (SPSS Inc., Chicago, IL). Shapiro-Wilk tests, skewness and kurtosis values, and visual inspection of histograms and Q-Q plots were used to assess normality. Categorical variables are shown as percentages and frequencies, while continuous variables are shown as mean ± standard deviation, median, and minimum-maximum values.

Comparisons between groups were tested by Mann-Whitney U tests or Welch's t-tests, when appropriate. VHI-10 scores were analyzed descriptively only in the worker group and were excluded from between-group comparisons, as VHI-10 scores of 0 were preset inclusion criteria for the normophonic control group. Cohen's d was calculated as an effect size measure. Holm-Bonferroni-adjusted p-values were calculated for the acoustic parameters and MPT. All statistical tests were two-tailed, and statistical significance was set at $p < 0.05$. P values were reported to three decimal places, and values below 0.001 were reported as $p < 0.001$.

Results

Table 1 displays descriptive data for participant age, maximum phonation time, and acoustic voice characteristics. The mean age of the control group was 32.98 ± 11.17 years, and the mean age of the iron and steel workers was 38.16 ± 9.94 years.

In the iron and steel factory worker group, the mean F0 was 120.58 ± 18.83 Hz. Mean jitter and shimmer values were 0.71 ± 1.46% and 10.48 ± 5.29%, respectively. The mean NHR was 0.13 ± 0.18. The CPPS value for sustained vowel (CPPS-SV) was 12.49 ± 2.88 and 6.50 ± 0.94 for connected speech (CPPS-CS). The mean Acoustic Voice Quality Index Version 2 (AVQIv2) was 5.84 ± 1.24, and the mean MPT was 11.89 ± 3.88 seconds.

In the control group, the mean F0 was 133.56 ± 21.94 Hz. Mean jitter and shimmer values were 0.33 ± 0.42% and 3.21 ± 1.79%, respectively. The mean NHR was 0.02 ± 0.02. The mean CPPS-SV was 16.95 ± 2.09, and CPPS-CS was 8.27 ± 1.25. The mean AVQIv2 score was 2.92 ± 0.85, and the mean MPT was 19.07 ± 3.19 seconds.

Table 2 shows between-group comparisons of acoustic voice parameters and maximum phonation time. Iron and steel factory workers had significantly lower F0 compared to the control group, with a medium effect size ($U = 1247$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = -0.63$). The factory worker group had significantly higher jitter values than the control group, with a small effect size ($U = 2640$, $p = 0.005$, Holm-adjusted $p = 0.005$, Cohen's $d = 0.35$).

Shimmer and NHR values were significantly higher in the worker group than in the control group, with large effect sizes (shimmer: $U = 3768$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = 1.84$; NHR: $U = 3506$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = 0.87$). The worker group revealed significantly lower CPPS values for both sustained vowel phonation and connected speech than the control group, with large effect sizes (CPPS-SV: $t(114.9) = -10.02$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = -1.77$; CPPS-CS: $t(116.9) = -9.03$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = -1.60$).

AVQIv2 values were significantly higher in the worker group compared with the control group, with a large effect size ($U = 3978$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = 2.76$). Maximum phonation time was significantly shorter in the worker group than in the control group, also with a large effect size ($t(121.4) = -11.43$, $p < 0.001$, Holm-adjusted $p < 0.001$, Cohen's $d = -2.02$).

Descriptive statistics and between-group comparison of self-reported voice assessment are presented in Table 3. The mean VHI-10 score of iron and steel factory workers was 10.42 ± 7.85. In the control group, VHI-10 scores were not reported because a score of 0 was required for inclusion. V-RQOL raw scores were converted to the standard 0-100 scale. The mean V-RQOL score of the worker group was 82.58 ± 12.70, and the mean V-RQOL score of the control group was 100.00 ± 0.00. The worker group had significantly lower V-RQOL scores than the control group, with a large effect size ($U = 352$, $p < 0.001$, Cohen's $d = -1.94$).

Discussion

This study is among the first to evaluate the voice characteristics of iron and steel factory workers using both acoustic analysis and self-report questionnaires. Overall, the findings revealed that workers had poorer acoustic and self-reported voice outcomes compared to the normophonic control group. The main acoustic findings were lower CPPS values and higher AVQIv2 scores in the worker group. Therefore, lower voice quality in the worker group appears to be better reflected in cepstral and composite acoustic measurements, with perturbation measures providing supporting results.

Lower F0 values were identified in the worker group. Although the F0 value remained within the normative range [26], the group difference may reflect subtle vocal fold vibratory characteristics. Increased vocal fold mass due to edema or inflammatory changes has been shown to reduce vibratory frequency, resulting in decreased fundamental frequency [27]. This outcome in the current study may be associated with several interacting occupational factors. There might be a potential laryngeal irritation from airborne exposures and increased vocal demands caused by workplace noise. However, since the workplace noise levels, airborne irritant concentrations, and individual exposure data were not objectively assessed, this interpretation should be considered premature.

The worker group showed higher jitter and shimmer values, indicating elevated cycle-to-cycle variability in both the frequency and amplitude of vocal fold vibration. Higher levels of these characteristics are usually linked to less stable phonation and irregular glottal closure [28]. These findings may be due to workplace variables such as increased vocal effort associated with noise and airborne irritants, which can result in irregular vibratory patterns that are acoustically reflected as higher jitter and shimmer values. However, jitter and shimmer outcomes should be interpreted cautiously. Perturbation evaluations have historical importance in the acoustic analysis of voice, but their reliability decreases with increased aperiodicity or unstable phonation.

Iron and steel workers had higher NHR values, although it remained within commonly reported reference ranges [26]. Elevated NHR levels indicate decreased harmonic energy and increased noise components in voice, which is frequently related to inadequate glottal closure or irregular mucosal wave activity [30]. In industrial environments, workers generally raise their voices to drown out background noise (the Lombard effect). Similar results were documented in industrial workers exposed to low-frequency noise, where lower HNR values were observed compared with the control group [6], indicating increased noise components in the voice signal.

Lower CPPS values in the worker group may indicate less harmonic structure and more aperiodicity in the acoustic signal [31]. For assessing voice quality in this group, CPPS measurements were considered more informative than perturbation measures due to their less reliance on cycle-by-cycle periodicity. The control group's CPPS levels for both tasks were above the normative values stated in the literature (Praat: ≈16-17 dB for SV, ≈7-8 dB for CS) [32]. By contrast, the worker group's CPPS-SV values were below the normative range, and their CPPS-CS values were closer to the lower limit of the normative range. This conclusion should be interpreted with caution, as CPPS norms may vary depending on language, speech content, and software. In particular, there are presently no defined normative CPPS values for the Turkish language obtained through Praat, so the normative values compared here are based on other languages. Cepstral parameters are increasingly used in the evaluation of voice quality and reflect the strength of harmonic structure [33]. Studies have shown that low cepstral values are correlated with increased dysphonia severity and low voice quality [14, 32]. The lower CPPS values observed in the worker group may be attributed to chronic vocal loading in a noisy work environment and exposure to occupational irritants.

The elevated AVQIv2 scores among iron and steel workers may suggest reduced overall voice quality. AVQIv2 is a composite measure that combines multiple acoustic parameters and demonstrates high sensitivity and specificity in discriminating between normophonic and dysphonic voices [22]. The cutoff value for AVQIv2 in Turkish has been reported as 2.98 [23]. The mean AVQIv2 score among the workers (5.84±1.24) is above this threshold, exceeding the dysphonic cutoff. In contrast, the mean value of the control group (2.92±0.85) is below the cutoff value and remains within the normophonic limits.

Lower MPT values among iron and steel industry workers may reflect reduced phonatory capacity, since MPT is related to expiratory (phonatory) volume, airflow rate, and glottal closure. The typical MPT for young and middle-aged people is about 22.9 seconds [34]. While the control group’s results reached normative limits, the worker group showed significantly shorter phonatory time. Shorter MPT in this context may be associated with higher airflow due to reduced glottal closure, potential inflammatory alterations of the vocal folds, or increased laryngeal strain, which may reduce phonatory efficiency and inhibit sustained vocal fold vibration. In line with this interpretation, previous research has demonstrated that individuals with degenerative or inflammatory laryngeal disorders had shorter MPT than healthy controls [35]. However, the underlying mechanism cannot be confirmed without laryngeal visualization and aerodynamic voice assessment.

The higher VHI-10 scores among the worker group might suggest a clinically relevant self-perceived impact on voice. Given the Turkish cutoff value of 7 points [36], the mean score of 10.42 indicates that workers have significant functional or physical voice-related impairments.

The mean V-RQOL scores of both groups remained above the Turkish cutoff value of 75 [36]. The worker group had significantly lower scores than controls, suggesting poorer voice-related quality of life. Previous occupational voice studies have also revealed similar results, with participants experiencing greater vocal demand and environmental factors associated with higher self-reported voice complaints [37–39].

This study has several limitations. First, the study's cross-sectional design limits causal inferences about the association between occupational exposure and voice changes. The duration of employment at the factory was not examined as a predictor of voice characteristics. Future research with a larger sample size may explore whether years of occupational exposure are associated with voice outcomes. Second, all participants were recruited from a single iron and steel factory, which may limit the generalizability of the findings to other industrial contexts. Third, only male workers were included, limiting the applicability of the results to female employees. Finally, objective laryngeal examination (e.g., videolaryngostroboscopy) was not conducted, so structural vocal fold alterations could not be properly assessed. Workplace noise levels, individual noise dosimetry, airborne irritant concentrations, and chemical exposure were not analyzed. Therefore, the current study cannot assess the potential laryngeal effects of airborne irritants or the effects of increased vocal demand or noise. This research did not analyze comprehensive audiometric threshold data. In future research, audiometric evaluation is recommended to better understand the role of auditory feedback in occupational voice outcomes. Vocal fatigue was not specifically evaluated in the current study. Future studies should include validated measures, such as the Vocal Fatigue Index, to better identify fatigue-related symptoms in industrial workers.

Conclusion

Iron and steel industry workers had significantly poorer acoustic and self-reported voice outcomes compared to normophonic controls, with lower CPPS, V-RQOL scores, shorter maximum phonation time, and higher jitter, shimmer, NHR, AVQIv2, and VHI-10 scores. These findings may point to the presence of phonatory instability, lower voice quality, and self-perceived voice impairment. Given that the larynx is one of the first respiratory structures directly exposed to inhaled irritants, comprehensive voice assessment could be a useful, non-invasive screening tool in occupational health settings. Future research should use longitudinal designs to monitor voice changes over time, measure specific exposure levels, include female workers, and conduct laryngoscopic examinations to clarify the mechanisms underlying occupational voice changes in this group. Preventive strategies such as reducing exposure, providing vocal hygiene education, and ensuring access to voice therapy are recommended to protect the voice health of iron and steel workers.

List of abbreviations

AVQI: Acoustic Voice Quality Index

CPPS: Smoothed Cepstral Peak Prominence

F0: Fundamental frequency

MPT: Maximum phonation time

NHR: Noise-to-harmonics ratio

VHI-10: Voice Handicap Index-10

V-RQOL: Voice-Related Quality of Life

Declarations

Ethics approval and consent to participate

The study has been approved by the Ethics Committee of Cappadocia University (Date: 18.01.2024, Decision No: 24.01). All participants were informed about the purpose, procedures, and potential risks of the study, and written informed consent was obtained. The study was conducted in accordance with the ethical principles of the Helsinki Declaration.

Consent for publication

Not applicable.

Availability of data and materials

Data supporting the study's findings are available from the corresponding author upon reasonable request. Due to institutional and ethical constraints, the data is not available to the public.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

GYP conceptualized and designed the study, supervised data collection, and drafted the manuscript. ICK performed data collection, interpretation, analysis and manuscript review and editing. All authors read and approved the final manuscript.

Acknowledgments

The authors express gratitude to the administrative staff and all participants at the iron and steel factory for their cooperation and for providing necessary facilities for voice recordings and data collection.

Tables

Table 1. Descriptive statistics of participant age, acoustic voice parameters, and maximum phonation time

Group	Variable	Mean ± SD	Median	Min	Max
Iron and steel factory workers (n=64)	Age (years)	38.16 ± 9.94	39	18	64
	F0 (Hz)	120.58 ± 18.83	118.70	85.60	176.30
	Jitter (%)	0.71 ± 1.46	0.33	0.09	10.70
	Shimmer (%)	10.48 ± 5.29	9.31	0.10	22.00
	NHR	0.13 ± 0.18	0.05	0.00	0.80
	CPPS-SV	12.49 ± 2.88	12.79	4.85	17.95
	CPPS-CS	6.50 ± 0.94	6.54	4.50	8.30
	AVQIv2	5.84 ± 1.24	5.90	3.45	8.63
	MPT (s)	11.89 ± 3.88	11.70	3.60	21.50
Control group (n=64)	Age (years)	32.98 ± 11.17	32	18	60
	F0 (Hz)	133.56 ± 21.94	130.75	85.59	196.70

	Jitter (%)	0.33 ± 0.42	0.27	0.08	3.50
	Shimmer (%)	3.21 ± 1.79	3.03	0.08	9.15
	NHR	0.02 ± 0.02	0.01	0.00	0.14
	CPPS-SV	16.95 ± 2.09	16.75	12.35	21.57
	CPPS-CS	8.27 ± 1.25	8.30	5.26	10.73
	AVQIv2	2.92 ± 0.85	2.81	1.17	5.50
	MPT (s)	19.07 ± 3.19	19.20	10.00	28.70

Abbreviations: AVQIv2, Acoustic Voice Quality Index version 2; CPPS-CS, smoothed cepstral peak prominence in connected speech; CPPS-SV, smoothed cepstral peak prominence in sustained vowel; F0, fundamental frequency; MPT, maximum phonation time; NHR, noise-to-harmonics ratio.

Table 2. Between-group comparison of acoustic parameters and maximum phonation time

Variable	**Workers Mean ± SD**	**Controls Mean ± SD**	**Test**	**Test statistic**	**p value**	**Holm-adjusted p value**	**Cohen's d**
F0	120.58 ± 18.83	133.56 ± 21.94	Mann-Whitney U	U = 1247	<0.001	<0.001	-0.63

Jitter	0.71 ± 1.46	0.33 ± 0.42	Mann-Whitney U	U = 2640	0.005	0.005	0.35
Shimmer	10.48 ± 5.29	3.21 ± 1.79	Mann-Whitney U	U = 3768	<0.001	<0.001	1.84
NHR	0.13 ± 0.18	0.02 ± 0.02	Mann-Whitney U	U = 3506	<0.001	<0.001	0.87
CPPS-SV	12.49 ± 2.88	16.95 ± 2.09	Welch t-test	t(114.9) = -10.02	<0.001	<0.001	-1.77
CPPS-CS	6.50 ± 0.94	8.27 ± 1.25	Welch t-test	t(116.9) = -9.03	<0.001	<0.001	-1.60
AVQIv2	5.84 ± 1.24	2.92 ± 0.85	Mann-Whitney U	U = 3978	<0.001	<0.001	2.76
MPT	11.89 ± 3.88	19.07 ± 3.19	Welch t-test	t(121.4) = -11.43	<0.001	<0.001	-2.02

Abbreviations: AVQIv2, Acoustic Voice Quality Index version 2; CPPS-CS, smoothed cepstral peak prominence in connected speech; CPPS-SV, smoothed cepstral peak prominence in sustained vowel; F0, fundamental frequency; MPT, maximum phonation time; NHR, noise-to-harmonics ratio. Note. Mann–Whitney U tests were used for F0, jitter, shimmer, NHR, and AVQIv2, while Welch’s t-tests were used for CPPS-SV, CPPS-CS, and MPT. P values were adjusted for multiple comparisons using the Holm–Bonferroni method. Cohen’s d is reported as a measure of effect size. Negative values indicate lower scores in the worker group compared with controls.

Table 3. Descriptive statistics and between-group comparison of self-reported voice measures

Measure	**Group**	**Mean ± SD**	**Median**	**Min**	**Max**	**Test statistic**	**p value**	**Cohen’s d**
VHI-10	Iron and steel factory workers (n = 64)	10.42 ± 7.85	–	0	28	–	–	–
	Control group	–	–	–	–	–	–	–
V-RQOL converted score	Iron and steel factory workers (n = 64)	82.58 ± 12.70	83.75	47.50	100.00	U = 352	<0.001	-1.94

Control group (n = 64)	100.00 ± 0.00	100.00	100.00	100.00

Abbreviations: VHI-10, Voice Handicap Index-10; V-RQOL, Voice-Related Quality of Life.

Note. VHI-10 scores were not compared between groups because a score of 0 was required for inclusion in the normophonic control group. V-RQOL raw item scores were converted to the standard 0–100 scale, where higher scores indicate better voice-related quality of life. Mann–Whitney U test was used for the between-group comparison of V-RQOL converted scores. Cohen’s d is reported as a measure of effect size; negative values indicate lower scores in the worker group compared with controls.

References

1. Phyland D, Miles A (2019) Occupational voice is a work in progress: active risk management, habilitation and rehabilitation. Curr Opin Otolaryngol Head Neck Surg 27:439–447

2. (2021) World Health Organization; International Labour Organization. WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury, 2000–2016: Global Monitoring Report. Geneva, Switzerland: World Health Organization. In: World Health Organization. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_dialogue/@lab_admin/documents/publication/wcms_819788.pdf. Accessed 2 Oct 2025

3. Williams NR (2003) Occupational groups at risk of voice disorders: a review of the literature. Occup Med (Lond) 53:456–460

4. Niebudek-Bogusz E, Śliwińska-Kowalska M (2013) An overview of occupational voice disorders in Poland. Int J Occup Med Environ Health 26:659–669

5. da Silva BJB, Andrade CADS, Gonçalves IZS, Fernandes GJM, Pirana S, Bittencourt F, Saez DM, Beber GMM, Hermes T de A, Soares EA (2024) Screening of voice disorders concerning anatomy teachers who use formaldehyde cadaveric parts in laboratory classes. Morphologie 108:100757

6. Verma H, Shah J, Singh A, Singh S, Sharma B, Shukla B (2023) Audiological, phonatory and cardiac correlates of individuals exposed to Low-frequency noise or at risk of vibroacoustic disease. Int Arch Otorhinolaryngol 27:e478–e486

7. Demir S, Sizer B, Yildiz S (2025) Self-reported voice problems in call center employees during the COVID-19 pandemic: prevalence, risk factors, and occupational conditions. PeerJ 13:e19595

8. Szabo Portela A, Granqvist S, Ternström S, Södersten M (2018) Vocal behavior in environmental noise: Comparisons between work and leisure conditions in women with work-related voice disorders and matched controls. J Voice 32:126.e23-126.e38

9. Kim J-S, Kim S, Moon T-H, Park S, Kim SH, Kim S, Lee D-H, Kim BG, Chang K-H, Park J-O (2023) Effect of occupational noise exposure on the prevalence of benign vocal fold lesions: A nationwide population-based study. Clin Exp Otorhinolaryngol 16:87–94

10. Al-Batanony MA, Abdel - Rasoul GM, Mahrous OAE, Abou Salem ME, Allam HK (2009) Auditory and respiratory health disorders among workers in an iron and steel factory. Zagazig J Occup Health Saf. https://doi.org/10.4314/zjohs.v2i1.45968

11. Mozaffari S, Heibati B, Jaakkola MS, Lajunen TK, Kalteh S, Alimoradi H, Nazari M, Karimi A, Jaakkola JJK (2023) Effects of occupational exposures on respiratory health in steel factory workers. Front Public Health 11:1082874

12. Biswas MJ, Koparkar AR, Joshi MP, Hajare ST, Kasturwar NB (2014) A study of morbidity pattern among iron and steel workers from an industry in central India. Indian J Occup Environ Med 18:122–128

13. Park RM, Ahn Y-S, Stayner LT, Kang S-K, Jang J-K (2005) Mortality of iron and steel workers in Korea. Am J Ind Med 48:194–204

14. Patel RR, Awan SN, Barkmeier-Kraemer J, Courey M, Deliyski D, Eadie T, Paul D, Švec JG, Hillman R (2018) Recommended protocols for instrumental assessment of voice: American Speech-Language-hearing association expert panel to develop a protocol for instrumental assessment of vocal function. Am J Speech Lang Pathol 27:887–905

15. Maryn Y, De Bodt M, Roy N (2010) The Acoustic Voice Quality Index: toward improved treatment outcomes assessment in voice disorders. J Commun Disord 43:161–174

16. Rosen CA, Lee AS, Osborne J, Zullo T, Murry T (2004) Development and validation of the voice handicap index-10. Laryngoscope 114:1549–1556

17. Hirano M (1981) Disorders of Human Communication 5. Clinical Examination of Voice. 81–84

18. Deliyski DD, Shaw HS, Evans MK (2005) Adverse effects of environmental noise on acoustic voice quality measurements. J Voice 19:15–28

19. Deliyski DD, Shaw HS, Evans MK, Vesselinov R (2006) Regression tree approach to studying factors influencing acoustic voice analysis. Folia Phoniatr Logop 58:274–288

20. İncebay Ö, Köse A, Esen Aydinli F, Özcebe E (2020) The effects of age and gender on laryngeal aerodynamics in the children population. J Voice 34:300.e27-300.e46

21. Boersma P (2001) Praat, a system for doing phonetics by computer. Glot International 5:341–345

22. Maryn Y, Corthals P, Van Cauwenberge P, Roy N, De Bodt M (2010) Toward improved ecological validity in the acoustic measurement of overall voice quality: combining continuous speech and sustained vowels. J Voice 24:540–555

23. Yeşilli-Puzella G, Tadıhan-Özkan E, Maryn Y (2022) Validation and test-retest reliability of Acoustic Voice Quality Index version 02.06 in the Turkish language. J Voice 36:736.e25-736.e32

24. Kiliç MA, Okur E, Yildirim I, et al (2008) Reliability and validity of the Turkish version of the Voice Handicap Index. Kulak Burun Bogaz Ihtis Derg 18:139–147

25. Tezcaner ZÇ, Aksoy S (2017) Reliability and validity of the Turkish version of the voice-Related Quality of Life measure. J Voice 31:262.e7-262.e11

26. Kent SAK, Fletcher TL, Morgan A, Morton ME, Hall RJ, Sandage MJ (2025) Updated acoustic normative data through the lifespan: A scoping review. J Voice 39:1130.e1-1130.e18

ARTICLE IN PRESS

27. Zeitels SM, Hillman RE, Bunting GW, Vaughn T (1997) Reinke's edema: phonatory mechanisms and management strategies. Ann Otol Rhinol Laryngol 106:533–543

28. Teixeira JP, Oliveira C, Lopes C (2013) Vocal acoustic analysis – jitter, shimmer and HNR parameters. Procedia Technol 9:1112–1122

29. Spazzapan EA, Fabbron EMG, Toledo WWF, Paula A de S, Marino VC de C (2024) Acoustic measurements through the life span: Jitter, shimmer, and standard deviation of fundamental frequency. J Voice. https://doi.org/10.1016/j.jvoice.2024.11.025

30. Yumoto E, Gould WJ, Baer T (1982) Harmonics-to-noise ratio as an index of the degree of hoarseness. J Acoust Soc Am 71:1544–1549

31. Murton O, Hillman R, Mehta D (2020) Cepstral peak prominence values for clinical voice evaluation. Am J Speech Lang Pathol 29:1596–1607

32. Yanushevskaya I, Kenny C (2025) Cepstral Peak Prominence: Normative values for clinical voice assessment-A systematic review and meta-analysis. J Voice. https://doi.org/10.1016/j.jvoice.2025.11.013

33. İncebay Ö, Köse A, Esen Aydinli F, Awan SN, Gürsoy MD, Yilmaz T (2025) Investigation of the cepstral spectral acoustic analysis for classifying the severity of dysphonia. J Voice 39:844.e19-844.e30

34. Ma E, Yiu E (2006) Multiparametric evaluation of dysphonic severity. Journal of Voice 20:380–390

35. Karlsen T, Sandvik L, Heimdal J-H, Aarstad HJ (2020) Acoustic voice analysis and maximum phonation time in relation to Voice Handicap Index score and larynx disease. J Voice 34:161.e27-161.e35

36. Tahir E, Yaşar ÖC, Erensoy İ, Kemal Ö (2025) Voice handicap index-10 and voice-Related Quality of Life: Determination of cutoff points in Turkish language for screening of voice disorders. J Voice. https://doi.org/10.1016/j.jvoice.2025.03.019

37. Heider CA, Álvarez ML, Fuentes-López E, González CA, León NI, Verástegui DC, Badía PI, Napolitano CA (2021) Prevalence of voice disorders in healthcare workers in the universal masking COVID-19 era. Laryngoscope 131:E1227–E1233

38. Natour YS, Darawsheh WB, Bashiti S, Wari M, Taha J, Odeh T (2018) A study of VHI scores and acoustic features in street vendors as occupational voice users. J Commun Disord 71:11–21

39. Düzenli-Öztürk S, Ünsal EM, Tetik-Hacıtahiroğlu K, Uz-Hasırcı S (2023) Investigation of the relationship between vocal fatigue, quality of life, and compliance with vocal hygiene in professional voice users. J Voice. https://doi.org/10.1016/j.jvoice.2023.10.013