Voice Characteristics and Functional Laryngeal Findings in Swimming Coaches: A Multidimensional Cross-Sectional Study

[*]Kaisa Pollisinski, [†,‡]Linda Sõber, and [*,§]Lagle Lehes, *†‡§*Tartu, Estonia*

SUMMARY: Objectives. Swimming coaches are occupational voice users exposed to elevated background noise, high humidity and temperature, and chlorination by-products such as nitrogen trichloride (NCl_3). This study aimed to describe the voice quality of Estonian swimming coaches and examine occupational factors associated with dysphonia.

Study design. This was an observational, analytical cross-sectional study combining subjective self-report measures with objective acoustic and laryngeal assessment.

Methods. Fifty-nine certified swimming coaches (8 males, 51 females) completed a background questionnaire and the Voice Handicap Index in Estonian (VHI-30_EST). Coaches reporting voice-related complaints (n = 34; 58%) were invited for clinical assessment; 21 participants participated. Evaluation included transnasal endoscopic videostroboscopy and acoustic analysis using *Praat* (acoustic voice quality index [AVQI], smoothed cepstral peak prominence [CPPS], harmonics-to-noise ratio [HNR], and maximum phonation time).

Results. According to the background questionnaire, voice problems were common (58%), and 42.4% of participants had elevated VHI-30 scores (≥16). Occupational variables, including work experience and weekly training hours, were not significantly associated with dysphonia ($P > 0.05$). Coaches with complaints demonstrated significantly higher VHI scores ($P < 0.001$). Acoustic measures indicated predominantly mild to moderate voice deviations (mean AVQI = 2.94; mean HNR = 17.32 dB), while CPPS values were largely within normal limits. Laryngoscopic findings were mainly characterized by supraglottic hyperfunction with preserved mucosal waves and without predominant structural pathology.

Conclusions. Estonian swimming coaches demonstrate a high prevalence of voice problems primarily associated with laryngeal hyperfunction. Preventive occupational voice care may be warranted in this professional group.

Keywords: Occupational voice users– Swimmingcoaches– Voiceuse.

INTRODUCTION

Occupational voice disorders are common among professional voice users, particularly in occupations requiring sustained and high-intensity phonation. While teachers have been extensively investigated, other professional groups with comparable vocal demands remain less studied.[1,2] Sports coaches represent one such group, as their work typically involves prolonged voice use in acoustically challenging environments.

Previous research has demonstrated a noticeable prevalence of voice problems among coaches in various disciplines. Approximately 28% of football coaches have reported multiple dysphonia-related symptoms,[1] and more than 70% of fitness instructors have experienced acute or chronic voice complaints.[3] Aerobic instructors have also been shown to report more voice problems than participants in their classes.[4] These findings suggest that occupational vocal load may place coaches at increased risk of voice disorders.

Swimming coaches may face additional environmental challenges related to indoor aquatic facilities. Such environments are characterized by elevated background noise, high humidity and temperature, and exposure to chlorination by-products, including nitrogen trichloride (NCl_3).[5,6] Noise levels in indoor pools may reach up to 99 dB during peak activity.[7] Increased environmental noise has been shown to correlate with increased speaking effort, potentially leading to elevated vocal intensity and increased vocal fold collision forces.[7] Repeated exposure to such loading conditions may contribute to the development of functional voice disorders, including supraglottic hyperfunction.[8]

In addition, chlorine-derived air contaminants have been associated with airway irritation and inflammatory responses.[5] Although primarily studied in relation to respiratory symptoms, chronic mucosal irritation may also influence laryngeal function and phonatory behavior.

Despite these plausible occupational risk factors, empirical data on swimming coaches remain limited, and multidimensional instrumental assessment of voice function in this population has not been systematically reported.

The present study aimed to describe the voice quality of Estonian swimming coaches, examine associations between occupational factors and dysphonia, and explore laryngeal and acoustic characteristics underlying voice complaints in this professional group.

Based on previous findings in occupational voice users and the specific environmental characteristics of indoor aquatic facilities, we formulated the following hypotheses:

Accepted for publication April 20, 2026.
From the *University of Tartu, Department of Special Education and Speech Therapy, Jakobi 5, Tartu, Estonia; †University of Tartu, Department of Otorhinolaryngology, L. Puusepa 8, Tartu, Estonia; ‡Tartu University Hospital, ENT Clinic, L. Puusepa 8, Tartu, Estonia; and the §Tartu University Hospital, Head of Speech and Swallowing Center, Riia 167, Tartu, Estonia.
Address correspondence and reprint requests to Kaisa Pollisinski. E-mail: kaisa.pollisinski@ut.ee
Journal of Voice, Vol xx, No xx, pp. xxx–xxx
0892-1997

https://doi.org/10.1016/j.jvoice.2026.04.029

1. The prevalence of self-reported voice problems among swimming coaches is high and comparable to those reported in other coaching professions.
2. Higher occupational voice load (eg, greater weekly training hours and longer work experience) is associated with increased self-reported voice handicap.
3. Coaches reporting voice complaints demonstrate measurable differences in acoustic parameters and a higher prevalence of functional laryngeal findings compared to those without complaints.

METHODS

Ethical considerations

The study was approved by the Research Ethics Committee of the University of Tartu (Approval No. 404/T-4). All participants received written and verbal information regarding the purpose and procedures of the study. Participation was voluntary, and written informed consent was obtained prior to data collection. Confidentiality and anonymity were ensured in accordance with institutional and national research ethics guidelines.

Participants

Certified swimming coaches across Estonia were invited to participate through professional networks, conferences, and direct contact. Participants completed a background questionnaire and the Estonian version of the Voice Handicap Index (VHI-30_EST) either on paper (n = 50) or electronically (n = 11). A total of 61 coaches responded. Two participants were excluded due to incomplete data (n = 1) or prior vocal fold surgery (n = 1), resulting in a final sample of 59 actively working swimming coaches. Inclusion criteria were: (1) age ≥18 years, (2) current employment as a swimming coach, and (3) certification by the Estonian Olympic Committee.

Instrumentation

A multidimensional voice assessment protocol was employed, combining self-reported voice handicap, acoustic analysis, and laryngeal videostroboscopy.

Self-perceived voice handicap was evaluated using the VHI-30_EST, a validated 30-item instrument assessing functional, physical, and emotional dimensions of voice disorders.[9]

Acoustic recordings were analyzed using *Praat* software (version 6.4.23). The primary acoustic outcome measure was the acoustic voice quality index (AVQI), calculated using the validated Praat script developed by Maryn et al.[10] The AVQI is a multiparametric composite index derived from a weighted linear combination of shimmer (local and dB), harmonics-to-noise ratio (HNR), spectral slope, spectral tilt, and smoothed cepstral peak prominence (CPPS), providing an overall estimate of dysphonia severity from sustained vowel and connected speech samples.

Additional acoustic parameters included CPPS, HNR, and maximum phonation time (MPT), enabling complementary characterization of voice quality and phonatory efficiency.

Laryngeal structures and vocal fold vibratory function were assessed using flexible transnasal endoscopic videostroboscopy (Olympus CS-170 system with ENF-V4 video rhinolaryngoscope equipped with a stroboscopic light source). Videostroboscopic examination enables evaluation of glottal closure configuration, mucosal wave characteristics, amplitude and symmetry of vocal fold vibration, supraglottic activity, and the presence of inflammatory or structural abnormalities.

All instrumental assessments were conducted by a multidisciplinary voice team consisting of an experienced otorhinolaryngologist and a speech-language pathologist.

Statistical analysis

Statistical analyses were performed using appropriate parametric and non-parametric methods based on data distribution. Between-group comparisons for non-normally distributed variables were conducted using Mann–Whitney U tests, while independent samples *t* tests were applied for normally distributed continuous variables. Associations between categorical variables were evaluated using chi-square tests where appropriate. One-way ANOVA was used to examine age-group differences in laryngeal findings.

In addition, regression analyses were conducted to examine associations between occupational and demographic factors and voice-related outcomes. Logistic regression models were used to identify predictors of voice complaints (yes/no), including work experience, weekly training hours, coaching level, group size, pool size, age, and sex as predictors.

Linear regression analyses were performed for continuous outcome variables, including VHI scores and acoustic parameters (AVQI, HNR, CPPS, and MPT). For VHI, predictors included occupational and demographic variables as well as the presence of voice complaints. Separate models were also conducted to examine the association between laryngeal findings and VHI scores.

Receiver operating characteristic (ROC) analysis was used to evaluate the discriminatory ability of selected VHI items in identifying moderate to severe voice handicap (VHI ≥ 31).

Statistical significance was set at $P < 0.05$.

Procedure

Phase 1: questionnaire assessment

Recruited participants completed a structured background questionnaire followed by the VHI-30_EST. The background questionnaire included 14 items covering demographic characteristics, professional qualification level, work experience, weekly workload in the pool and in other settings, training group size, pool characteristics, and history of voice-related complaints.

The VHI-30_EST consists of 30 items evaluating functional, physical, and emotional aspects of voice disorders. Each item is rated on a 5-point Likert scale (0 = never to 4 = always), with higher scores indicating greater perceived voice handicap.

At the end of the questionnaire, participants indicating willingness to undergo further assessment provided contact information for the second phase of the study.

Clinically relevant voice impairment was defined a priori using Estonian validated cut-off scores: VHI-30_EST ≥ 16 and AVQI_EST ≥ 2.8.[9] These population-specific thresholds were applied to determine the prevalence of subjective and acoustic voice deviation in the present sample. Participants were classified into the voice disorder group if they met at least one of the following criteria: VHI-30_EST ≥ 16, AVQI_EST ≥ 2.8, or self-reported presence of a current voice disorder in the background questionnaire.

Phase 2: instrumental voice assessment

Coaches reporting voice-related complaints (n = 34; 58%) were invited for instrumental evaluation; of these, 21 participated.

All acoustic recordings were conducted in a quiet clinical environment under standardized conditions. A Shure SM48 microphone was positioned at a fixed distance of 10 cm from the participant's mouth at a 45° angle. The microphone was calibrated prior to data collection and connected to a laptop computer running *Praat* software (version 6.4.23).

Participants were instructed to produce three sustained phonations of the vowel /a/ at a comfortable pitch and loudness. The following prompt was used: "Hold the vowel /a/ as long as you can at a comfortable pitch and loudness". The most stable phonation without voice breaks was selected, and a 5-second segment representing the most stable portion of the signal was used for analysis.

In addition, participants read three phonetically balanced sentences in Estonian to analyze AVQI. The following prompt was used: "Read these sentences silently to yourself. Now, if you are ready, read them out loud at a comfortable pitch and loudness." The sentences were not analyzed separately; instead, they were combined with the sustained vowel phonation to compute the AVQI as a composite measure. The entire production was used for the analysis.

Acoustic measures, including the AVQI, CPPS, HNR, and MPT, were extracted using Praat.

Laryngeal videostroboscopy was performed using a flexible transnasal endoscope. Participants were instructed to sustain vowels /i/ and /e/, perform an ascending glissando on /i/, and repeat a standardized sentence (*"Juulikuus suur tuul."*), and count numbers from 1 to 10. Laryngeal videostroboscopic recordings were independently evaluated by two experienced clinicians (an otolaryngologist and a speech-language pathologist). Both evaluators were blinded to participants' VHI scores and prior clinical classifications at the time of assessment. In cases of disagreement, findings were reviewed jointly, and consensus was reached. The use of dual independent blinded evaluators was intended to reduce observer bias in videostroboscopic interpretation. Laryngeal parameters assessed included glottal closure configuration, mucosal wave characteristics, vibratory symmetry, supraglottic activity, and signs of inflammatory or structural abnormalities. Although formal inter-rater reliability statistics (eg, kappa coefficients) were not calculated, all videostroboscopic recordings were archived and are available for retrospective, blinded re-evaluation if needed.

RESULTS

The final group consisted of 8 males and 51 females. Participants represented a wide age distribution (18–60+ years), with the largest proportion in the 40–59 age group (n = 25). Professional qualification levels, according to the Estonian Qualifications Framework (EQF), ranged from EQF3 to EQF7/8, with the majority holding EQF5 certification (n = 35). According to the EQF, levels 3 to 8 represent respectively assistant coach, junior coach, coach, senior coach, master coach, and elite coach.

Work environment characteristics varied across participants. Most coaches worked in pools with eight or more lanes (n = 33). The vast majority (n = 54) conducted swimming sessions simultaneously with other user groups (eg, swimming or aerobics classes), whereas only five reported working alone in the pool. The typical training group size was 10–20 participants (n = 40).

Weekly coaching hours in the pool showed considerable variability. The largest subgroup reported 16–20 hours per week (n = 11), while six coaches reported more than 31 hours per week. Additionally, 28 coaches reported employment in other settings involving up to 40 hours per week of additional voice use (Table 1).

Based on the inclusive classification criteria (VHI ≥ 16 OR AVQI ≥ 2.8 OR self-reported disorder), 58% (n = 34) met criteria for voice disorder. All of them were invited to participate in the instrumental study; 21 participated.

Prevalence of voice problems

Among the 59 swimming coaches, 34 (58%) reported voice problems within the previous six months. Twenty-five participants (42.4%) demonstrated elevated VHI-30_EST scores (≥16). The mean VHI-30 score was 16.2 (standard deviation [SD] = 15.9; range 0–79). The most frequently endorsed VHI items were:

"People have difficulty understanding me in a noisy room" (n = 45),

"The sound of my voice varies throughout the day" (n = 43),

"My voice is worse in the evening" (n = 42).

Occupational factors and voice outcomes

Work experience and weekly training hours were not significantly associated with the occurrence of voice problems

TABLE 1.
Participant Characteristics

Characteristic	n	%
Age (years)		
18–24	8	13.6
25–39	20	33.9
40–59	24	40.7
60+	7	11.9
Sex		
Women	50	84.7
Men	9	15.3
EQF level*		
3	10	16.9
4	7	11.9
5	35	59.3
6	5	8.5
7 or 8	2	3.4
Workload (hours/week)		
≤5	10	16.9
6–10	10	16.9
11–15	8	13.6
16–20	11	18.6
21–25	9	15.3
26–30	5	8.5
≥31	6	10.2
Group size		
< 10	11	18.6
10–20	39	66.1
> 20	9	15.3
Pool size (lanes)		
≤4	14	23.7
6	12	20.3
≥8	33	55.9

* EQF - Estonian Qualification Framework, prevalence (%).

(P > 0.05). Although coaches with complaints reported slightly higher weekly training hours, this difference was not statistically significant (U = 484.5, P = 0.526). Coaching qualification level and training group size were also not significantly associated with dysphonia or specific symptoms (P > 0.05). The only significant factor was pool size, which was associated with voice complaints (P = 0.021). Larger pools (≥8 lanes) were more frequently observed in the affected group compared to smaller pools (≤4 lanes).

A logistic regression analysis was conducted to examine whether coaching-related and demographic factors predict the presence of voice complaints. The model included work experience, weekly training hours, coaching level, group size, pool size, age, and sex as predictors. The model shown in Table 2 demonstrated moderate explanatory power (Nagelkerke R^2 = 0.303), and it was statistically significant (P = 0.035), although just one individual predictor reached statistical significance. The strongest predictor was pool size.

A linear regression analysis was performed with VHI scores as the dependent variable. The model included work experience, weekly training hours, coaching level, group size, pool size, age, sex, and the presence of voice complaints as predictors. The model explained 39.6% of the variance (R^2 = 0.396) and was statistically significant (P < 0.001). Although only self-reported voice complaints were significantly associated with higher VHI scores, the other variables were retained in the model as relevant covariates Table 3.

TABLE 2.
Logistic Regression Analysis of Occupational Factors Associated with Voice Complaints

Variable	OR	95% CI Lower	95% CI Upper	z	P
Sex	0.154	0.023	1.031	-1.928	0.054
Work experience	2.070	0.711	6.025	1.335	0.182
Pool size	2.850	1.223	6.637	2.428	0.015
Age	0.582	0.214	1.581	-1.062	0.288
Coaching level	1.165	0.561	2.418	0.409	0.683
Workload	1.044	0.748	1.458	0.254	0.799
Group size	1.741	0.550	5.508	0.943	0.346

Abbreviations: CI, confidence interval; OR, odds ratio.

TABLE 3.
Occupation Factors Predicting VHI

Variable	β	t	P
Age	0.242	1.530	0.132
Coaching level	-0.249	-1.868	0.068
Work experience	-0.069	-0.375	0.709
Pool size	-0.047	-0.369	0.714
Workload	0.105	0.943	0.350
Group size	0.022	0.199	0.843
Voice complaints	0.628	5.017	< 0.001
Sex	0.041	0.356	0.724

Note. β = standardized regression coefficient; p = significance level.
Abbreviation: VHI, voice handicap index.

According to the background questionnaire, coaches reporting voice complaints demonstrated significantly higher scores across all VHI subscales and in total VHI compared to those without complaints (all P < 0.001) Effect sizes were large across all domains (r = 0.54–0.68), indicating substantial group differences Table 4.

ROC analysis

ROC analysis demonstrated that the single VHI item "My voice is worse in the evening" predicted moderate to severe voice handicap (VHI ≥ 31) with good accuracy (area under the curve = 0.85). A two-item combination ("People have difficulty understanding me in a noisy room" and "I use a great deal of effort to speak") showed excellent discriminatory ability (area under the curve = 0.99) (Figure 1).

Instrumental assessment

Twenty-one coaches (20 females, 1 male) underwent instrumental assessment.

TABLE 4.
Comparison of VHI Scores between Coaches with and without Voice Complaints (n = 59)

Scale	No Complaints (n = 25)	Voice Complaints (n = 34)	*U*	*P**	*r*
Functional subscale	1.0 (0.0–3.0)	5.0 (3.0–10.0)	148.5	< 0.001	0.55
Physical subscale	3.0 (1.0–7.0)	12.0 (7.2–16.0)	93.5	< 0.001	0.66
Emotional subscale	0.0 (0.0–0.0)	2.5 (1.0–5.0)	165.5	< 0.001	0.54
Total VHI	4.0 (2.0–9.0)	19.5 (11.2–30.5)	83.5	< 0.001	0.68

Abbreviation: VHI, voice handicap index.
* Significant at $P < 0.05$, Spearman rank correlation coefficient (r).

Laryngeal findings

Videostroboscopic examination revealed findings predominantly consistent with functional voice disorder (Table 5). Supraglottic hyperfunction was frequently observed, most commonly in the form of anteroposterior compression, whereas mediolateral compression was less common.

Glottal closure was complete in approximately half of the participants, and the mucosal wave was generally regular and preserved. Structural lesions were not predominant. Mild inflammatory changes and arytenoid hyperemia were observed in a subset of participants, whereas findings suggestive of laryngopharyngeal reflux were rare.

No statistically significant associations were found between occupational exposure variables and laryngeal findings.

A linear regression model was conducted to examine the association between laryngeal findings and VHI scores. The model explained 34.7% of the variance ($R^2 = 0.347$) but was not statistically significant ($P = 0.737$).

No statistically significant associations were identified between VHI scores and laryngeal findings, including supraglottic hyperfunction, laryngopharyngeal reflux, vibratory regularity, mucosal wave characteristics, inflammatory changes, and arytenoid hyperemia (all $P > 0.05$) Table 6.

Acoustic analysis

In Table 7. acoustic findings are presented. Overall, acoustic measures indicated mild deviations in voice quality.

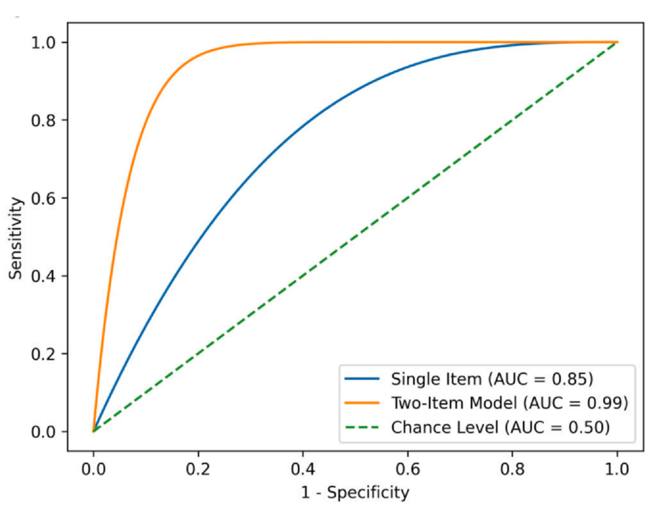

FIGURE 1. ROC curves for the prediction of moderate to severe voice handicap. ROC, receiver operating characteristic.

TABLE 5.
Laryngeal Examination Findings (n = 21)

Variable	Level	n	%
Supraglottic hyperfunction	None	6	28.6
	Mild	5	23.8
	Moderate	8	38.1
	Severe	2	9.5
Supraglottic hyperfunction (direction)	Anteroposterior	13	61.9
	Mediolateral	7	33.3
Glottal closure	Complete	11	52.4
	Hourglass	4	19.1
	Physiological gap	3	14.3
	Partial	3	14.3
Laryngopharyngeal reflux	Present	2	9.5
Mucosal wave	Regular	20	95.2
	Irregular	1	4.8
Inflammatory changes	Present	9	42.9
Arytenoid hyperemia	Present	4	19.1

Note. Percentages are calculated within the examined subgroup (n = 21).

TABLE 6.
Associations between Laryngeal Findings and VHI Scores (n = 21)

Variable	β	t	*P*
Supraglottic hyperfunction (severity)	0.036	0.070	0.946
Anteroposterior hyperfunction	-0.535	-1.018	0.331
Mediolateral hyperfunction	-0.286	-0.766	0.460
Inflammatory changes	0.688	1.247	0.238
Glottal closure	-0.085	-0.166	0.871
Laryngopharyngeal reflux	0.348	0.937	0.369
Vibratory regularity	-0.052	-0.171	0.867
Mucosal wave	-0.040	-0.136	0.894
Arytenoid hyperemia	0.059	0.147	0.886

Note. β = standardized regression coefficient; *P* = significance level.
Abbreviation: VHI, voice handicap index.

The mean AVQI was 2.94 (SD = 1.15; 95% confidence interval [CI]: 2.42–3.46), with values ranging from 1.16 to 5.35. Based on the validated Estonian cut-off (AVQI ≥ 2.8), 57.1% of participants (12/21) demonstrated clinically relevant acoustic voice deviation (95% CI: 36.5–75.5%).

TABLE 7.
Acoustic Parameters in Swimming Coaches Undergoing Instrumental Assessment

Parameter	Mean	SD	Minimum	Maximum
AVQI	2.94	1.15	1.16	5.35
HNR, dB	17.32	2.45	12.48	23.64
MPT, s	15.55	7.63	7.13	44.1
CPPS	11.97	1.58	8.75	14.42

Note. Values are presented as mean and standard deviation (SD).
Abbreviations: AVQI, acoustic voice quality index; CPPS, smoothed cepstral peak prominence; HNR, harmonics-to-noise ratio; MPT, maximum phonation time.

Overall, acoustic findings indicate considerable variability within the sample, with more than half of the participants exceeding the clinical AVQI threshold despite moderate average values.

Linear regression analyses examining associations between occupational factors and acoustic parameters are presented in Table 8.

Coaching level was statistically associated with shimmer, meaning that higher-level coaches had higher shimmer values. No statistically significant associations were observed between occupational factors and other acoustic parameters (all $P > 0.05$).

Although MPT appeared to be significantly associated with sex, with men demonstrating longer phonation time, this finding should be taken with caution, as only one male participant was included in the clinical phase.

DISCUSSION

This study provides a multidimensional evaluation of voice function in Estonian swimming coaches and demonstrates a substantial burden of self-reported voice problems accompanied predominantly by functional laryngeal alterations. The findings extend previous research on sports coaches and contribute novel instrumental data from an occupational group exposed to unique environmental conditions.

Prevalence of voice problems in coaching professions

The prevalence of self-reported voice problems (58%) observed in this study is consistent with previous findings in coaching populations. Fellman and Simberg[1] reported dysphonia-related symptoms in nearly one-third of football coaches, while Rumbach[3] found that over 70% of fitness instructors experienced acute or chronic voice complaints. The present results align with this body of literature and support the notion that sustained occupational vocal loading places coaches at increased risk for voice disorders.

The most frequently endorsed symptoms – difficulty being understood in noisy environments and worsening of voice toward the evening – mirror patterns described in teachers and other occupational voice users.[11] These symptoms are characteristic of vocal fatigue and may reflect cumulative phonatory loading across the workday. The high discriminatory accuracy of selected VHI items in ROC analysis suggests that brief screening approaches may be feasible in occupational settings, although external validation is warranted.

Occupational load and environmental exposure

Contrary to expectations, measured workload variables such as weekly training hours and years of work experience were not significantly associated with voice complaints. Similar findings have been reported among teachers, where subjective vocal complaints were not consistently predicted by objective workload measures.[11] This suggests that quantitative workload alone may not adequately capture vocal risk and that environmental and behavioral factors may play a more prominent role.

In contrast, logistic regression analysis demonstrated that pool size was the only significant predictor of voice complaints when occupational and demographic factors were considered simultaneously, suggesting an independent effect of environmental factors. Larger pool environments may therefore impose greater vocal demands, likely reflecting increased background noise and communication distance.

Voice disorders in occupational contexts are increasingly understood as multifactorial phenomena involving vocal intensity, speaking technique, recovery time, and environmental acoustics rather than duration of phonation alone.

TABLE 8.
Acoustic Parameters and Associations between Occupational Factors

	AVQI β (*P*)	HNR β (*P*)	Shimmer β (*P*)	CPPS β (*P*)	MPT β (*P*)
Coaching level	0.251 (0.364)	-0.292 (0.287)	0.506 (0.050)	-0.237 (0.387)	0.233 (0.066)
Work experience	-0.112 (0.772)	-0.136 (0.721)	0.280 (0.413)	0.238 (0.536)	-0.006 (0.973)
Pool size	0.094 (0.732)	0.343 (0.216)	-0.149 (0.538)	-0.185 (0.500)	-0.026 (0.825)
Workload	-0.083 (0.752)	0.070 (0.788)	0.006 (0.978)	0.091 (0.729)	-0.152 (0.199)
Group size	-0.225 (0.420)	0.240 (0.384)	-0.137 (0.572)	0.249 (0.370)	0.222 (0.082)
Age	0.386 (0.299)	0.072 (0.842)	-0.058 (0.856)	-0.427 (0.207)	-0.121 (0.451)
Sex	-0.776 (0.451)	-0.924 (0.372)	0.132 (0.897)	0.913 (0.378)	0.222 (< 0.001)

Note. β = standardized regression coefficient; *P* = significance level.
Abbreviations: AVQI, acoustic voice quality index; CPPS, smoothed cepstral peak prominence; HNR, harmonics-to-noise ratio; MPT, maximum phonation time.

Indoor swimming facilities present acoustically challenging conditions, with reported noise levels approaching 99 dB.[7] Exposure to high noise levels may trigger a Lombard response, increasing vocal intensity and, consequently, vocal fold collision forces. Repeated exposure to elevated phonatory effort may promote hyperfunctional compensatory patterns even in the absence of structural pathology.

In addition, exposure to chlorination by-products such as nitrogen trichloride (NCl_3) has been associated with airway irritation and inflammatory responses.[5] Although the present study did not directly measure environmental exposure levels, the combination of acoustic strain and potential mucosal irritation provides a plausible occupational framework for functional dysphonia in swimming coaches.

From a theoretical standpoint, these findings can be further contextualized within vocal loading theory, which conceptualizes voice use as a cumulative biomechanical demand placed on laryngeal tissues. Within this framework, vocal dose in occupational settings is determined not solely by duration of phonation, but by the interaction between intensity, frequency, recovery time, and environmental constraints. The absence of significant associations between quantitative workload measures and dysphonia in the present study may therefore reflect limitations of simplified exposure metrics rather than the absence of an underlying dose–response relationship. Future studies incorporating objective vocal dose monitoring and environmental exposure modeling may provide a more precise understanding of potential dose–response dynamics in aquatic coaching environments.

Subjective voice handicap and predictors of VHI

Linear regression analysis revealed that self-reported voice complaints were the strongest predictor of VHI scores, while occupational and demographic variables did not show significant independent associations. This finding suggests that subjective perception of voice problems is closely aligned with self-reported handicap but may not be directly explained by measurable occupational exposure factors.

The model explained a moderate proportion of variance in VHI scores ($R^2 = 0.396$), indicating that additional factors not captured in the present study – such as vocal technique, individual susceptibility, or psychosocial influences – may contribute to perceived voice handicap.

Laryngeal patterns: functional rather than structural

Videostroboscopic findings were characterized predominantly by supraglottic hyperfunction with largely preserved mucosal waves and minimal structural pathology. This pattern aligns with descriptions of functional dysphonia, in which compensatory supraglottic activity may develop in response to increased phonatory demand.[12]

The absence of prevalent structural lesions distinguishes swimming coaches from populations with established phonotraumatic pathology and suggests that maladaptive phonatory behavior, rather than irreversible tissue damage, may underlie many complaints. This is clinically relevant, as functional patterns are potentially modifiable through behavioral intervention.

Importantly, regression analysis did not demonstrate a statistically significant association between laryngeal findings and VHI scores, despite a moderate proportion of explained variance. The lack of statistical significance despite this moderate explanatory power may be related to the small sample size and heterogeneity of laryngeal findings. This suggests that observable laryngeal characteristics may not directly correspond to the subjective experience of voice handicap in this population, potentially reflecting differences between structural, functional, and perceptual dimensions of voice disorders.

Acoustic–perceptual discrepancy

Acoustic analysis demonstrated predominantly mild deviations, and no significant associations were found between VHI scores and acoustic parameters. The pattern of mildly elevated AVQI combined with reduced HNR and largely preserved CPPS may reflect early functional alterations characterized by increased noise components without marked cepstral degradation. Such discrepancies between subjective handicap and objective acoustic measures have been documented in other occupational voice users and highlight the multidimensional nature of voice disorders. Early functional alterations may manifest perceptually before measurable acoustic deterioration occurs. Moreover, composite indices such as AVQI, while sensitive to dysphonia severity, may not fully capture transient fatigue-related changes.

Linear regression analyses further indicated that occupational factors were not significantly associated with most acoustic parameters. A borderline association was observed between coaching level and shimmer, suggesting a potential trend toward increased perturbation measures in higher-level coaches, although this finding requires cautious interpretation.

Previous research has demonstrated that AVQI is sensitive to overall dysphonia severity across sustained and connected speech samples, whereas cepstral measures such as CPPS are particularly robust in detecting periodicity disturbances and breathiness.[10,13] In occupational voice users, cepstral parameters may remain within normal limits during early functional loading, while noise-related measures such as HNR may reflect increased turbulent components associated with vocal effort. Thus, the present constellation of mildly elevated AVQI, reduced HNR, and largely preserved CPPS appears more consistent with early-stage functional voice alterations than with advanced structural dysphonia.

These findings reinforce the importance of integrating self-report measures with instrumental assessment in occupational voice research, as early functional voice alterations may not yet be fully captured by acoustic measures.

Clinical implications

The combination of high self-reported burden and predominantly functional laryngeal patterns suggests that preventive and early-intervention strategies are particularly relevant for swimming coaches. Voice education, training in efficient phonation techniques, and strategies to reduce vocal intensity in noisy environments may mitigate long-term risk. In addition, occupational health programs in aquatic facilities could incorporate routine voice screening using brief, validated questions.

Strengths

This study integrates subjective assessment, acoustic analysis, and videostroboscopic evaluation within a single occupational cohort. To our knowledge, this is the first study to combine VHI-based screening, acoustic multiparametric analysis, and blinded dual-evaluator videostroboscopy in a cohort of swimming coaches.

Limitations

Several limitations should be acknowledged. The cross-sectional design precludes causal inference. The instrumental assessment subgroup was relatively small, limiting statistical power and generalizability. The study was not powered a priori to detect small to moderate effect sizes, and the absence of significant associations should therefore be interpreted cautiously. Formal inter-rater reliability statistics were not calculated, which may limit the reproducibility of videostroboscopic interpretations. Furthermore, environmental exposure variables, including objective noise measurements and airborne chlorination by-product concentrations, were not directly quantified.

Future studies should incorporate longitudinal designs, larger multicenter samples, and objective environmental monitoring to clarify dose–response relationships between occupational exposure and vocal outcomes.

Future directions

Future research should explore:

- Longitudinal progression of functional laryngeal patterns in swimming coaches.
- Objective measurement of noise levels and chemical exposure in aquatic facilities.
- The effectiveness of targeted voice training interventions in this population.
- Development and validation of brief occupational voice screening tools derived from high-performing VHI items.

CONCLUSION

Swimming coaches demonstrate a high prevalence of voice problems primarily characterized by laryngeal hyperfunction rather than structural pathology. Although quantitative workload measures were not significantly associated with dysphonia, the occupational demands of indoor aquatic environments likely contribute to compensatory phonatory behavior. Environmental factors such as pool size appear to influence the likelihood of voice complaints, while subjective voice handicap is primarily driven by self-perceived voice problems rather than measurable occupational variables. Multidimensional assessment and targeted preventive strategies are warranted to support vocal health in this professional group.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI, GPT-4/5) in order to assist with language editing and formatting. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Acknowledgments

The authors would like to thank the coaches who participated in the study.

References

1. Fellman D, Simberg S. Prevalence and risk factors for voice problems among soccer coaches. *J Voice.* 2017;31:121.e9–121.e15. https://doi.org/10.1016/j.jvoice.2016.02.003.
2. Morawska J, Niebudek-Bogusz E. Risk factors and prevalence of voice disorders in different occupational groups - a review of literature. *Otorynolaryngologia.* 2017;16:94–102.
3. Rumbach AF. Vocal problems of group fitness instructors: prevalence of self-reported sensory and auditory-perceptual voice symptoms and the need for preventative education and training. *J Voice.* 2013;27:524.e11–524.e21. https://doi.org/10.1016/j.jvoice.2013.01.016.
4. Heidel SE, Torgerson JK. Vocal problems among aerobic instructors and aerobic participants. *J Commun Disord.* 1993;26:179–191. https://doi.org/10.1016/0021-9924(93)90007-W.
5. Yazdi Z, Zohal M, Abkenar S. Comparing respiratory symptoms and spirometry disorders among healthy people and workers of indoor swimming pools: a case–control study. *Eurasian J Pulmonol.* 2021;23:14. https://doi.org/10.4103/ejop.ejop_3_19.
6. Nordberg GF, Lundstrom NG, Forsberg B, et al. Lung function in volunteers before and after exposure to trichloramine in indoor pool environments and asthma in a cohort of pool workers. *BMJ Open.* 2012;2:e000973. https://doi.org/10.1136/bmjopen-2012-000973.
7. Wadle LM, Müller B, Nolte A. Noise in indoor swimming pools: Insights from a survey and acoustic measurements. In: 2021.
8. Merati G, Bonato M, Agnello L, et al. Occupational disorders, daily workload, and fitness levels among fitness and swimming instructors. *Front Public Health.* 2021;9:666019. https://doi.org/10.3389/fpubh.2021.666019.

9. Ello A, Sõber L, Viigand M, Lehes L. Cross-cultural adaptation and validation of the voice handicap index into Estonian. (Published online). *J Voice.* 2025. https://doi.org/10.1016/j.jvoice.2025.01.017. S0892199725000177.
10. Maryn Y, De Bodt M, Roy N. The acoustic voice quality index: toward improved treatment outcomes assessment in voice disorders. *J Commun Disord.* 2010;43:161–174. https://doi.org/10.1016/j.jcomdis.2009.12.004.
11. Kompus M. *Õpetajate Hinnangud Hääleprobleemidele.* Tartu Ülikool: Teadusmagistritöö; 2010.
12. Rubin AD, Praneetvatakul V, Gherson S, et al. Laryngeal hyperfunction during whispering: reality or myth? *J Voice.* 2006;20:121–127. https://doi.org/10.1016/j.jvoice.2004.10.007.
13. Awan SN, Roy N. Outcomes measurement in voice disorders: application of an acoustic index of dysphonia severity. *J Speech Lang Hear Res.* 2009;52:482–499. https://doi.org/10.1044/1092-4388(2008/08-0034).