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Relationship between Laryngeal Disorders and Respiratory Function in Professional Road Cyclists

Samaneh Ebrahimi[1,2], Khadijeh Irandoust[3*], Samira Sadat Ghalishourani[4], Mandana Gholami[5*], Mohsen Avatef Rostami[2,6], John W. Dickinson[7], Aslan Ahmadi[8]

[1] Department of Sports Sciences, Faculty of Social Sciences, Imam Khomeini International University, Qazvin, Iran
[2] Department of Speech Therapy, School of Rehabilitation, Tehran University of Medical Sciences Tehran, Iran
[3] Associate Professor, Department of Sports Sciences, Faculty of Social Sciences, Imam Khomeini International University, Qazvin, Iran
[4] Department of Physical Education and Sport Sciences, Faculty of Literature, Humanities and Social Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran
[5] Associate Professor, Department of Physical Education and Sport Sciences, Faculty of Literature, Humanities and Social Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran
[6] Department of Biomechanics, Faculty of Medical science and Technologies, South Tehran Branch, Islamic Azad University, Tehran, Iran
[7] Professor in School of Sport & Exercise Sciences, University of Kent, Canterbury CT2 7NB, UK
[8] ENT and Head and Neck Research Center and Department, the Five Senses Institute, Hazrat Rasoul Hospital, Iran University of Medical Sciences, Tehran, Iran

*** Corresponding authors email address**: irandoust@ikiu.ac.ir, gholami_man@yahoo.com

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A B S T R A C T

Objective: Engaging in outdoor cycling, particularly within cold and arid environments, frequently precipitates dryness in the laryngeal mucosa and induces various supraglottic disorders. Such conditions hold the potential to detrimentally impact respiratory system efficiency. This study principally sought to elucidate the influence of supraglottic and upper airway disorders on the the results of spirometry flow-volume measurements of road cyclist.
Methods and Materials: This investigation encompassed seventy-two professional and elite road cyclists, comprising 22 females and 50 males, with an average age of 22 years and a Body Mass Index (BMI) of 21.95(±0.02) kg/m². Utilizing stroboscopic examinations, supraglottic conditions including Sicca, Tension, Edema, and Gastroesophageal Reflux Disease were assessed. Concurrently, respiratory capacity was evaluated through spirometric tests, encompassing Forced Vital Capacity [FVC], Forced Expiratory Volume in the first second [FEV1], Tidal Volume [VT], Maximum Vital Capacity [VC MAX], Mean Mid-Expiratory Flow [MMEF (FEF25-75)], Peak Expiratory Flow [PEF], and Controlled Mechanical Volume Ventilation [cMVV]. Analysis of Variance (ANOVA) was employed to analyze the relationship between stroboscopic and spirometric findings, additionally exploring correlations between the two. A backward method in regression analysis was used, with Edema (ED), Gastroesophageal Reflux Disease (GERD), Dry Laryngeal Mucosa (Sicca), and Tension (TE) serving as predictor variables against spirometric outcomes.
Results: Predominantly, participants exhibited low levels of ED, GERD, Sicca, and TE. No substantial correlation emerged between ED, GERD, TE, and any spirometric indices (p-value > 0.05). However, a notable relationship was observed between Sicca and the MMEF index (p-value < 0.05). Regression

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analysis revealed significant outcomes for independent variables impacting VT and MEF25, with GERD negatively influencing VT in a statistically significant manner. Likewise, GERD's effect on the MEF25 variable was both negative and significant.
Conclusion: Based on the findings, it seems that supraglottic disorders negatively affect the efficiency of the respiratory system in cyclists. Therefore, it is recommended that cyclists consider the necessary evaluations to check the supraglottis in order to improve their performance during training and competitions.
Keywords: *Laryngeal Disorders, Road Cyclists, Outdoor Exercise, Respiratory Function.*

1. Introduction

Laryngeal Disorders (LD) encompass a diverse array of conditions, frequently observed in athletes (1). Manifesting in various forms, these include Dry Laryngeal Mucosa (Sicca) (2), Tension Laryngitis (TE), Laryngeal Edema (ED) (3) and Gastroesophageal Reflux Disease (GERD) (4). Several factors contribute to the onset and aggravation of LD: inhalation of cold, dry air during outdoor sports (5); stress and muscle tension in the laryngeal area (6); Different posture during cycling leads to an increase of ventricle content pressure on the lower esophageal sphincter that are important mechanisms underlying GERD (7); and poor dietary habits (7-9). Road cyclists are particularly susceptible to LD due to their exposure to cold, dry air (10), the forward-bent posture while cycling (11), and sustained contraction of head and neck muscles (12). However, the evaluation, diagnosis, and treatment of these disorders are often overlooked.

Maintaining adequate airflow is crucial for most physical activities (13), yet LD can impair the function of the upper airway and supraglottic area (14). Respiratory Indices (RI), vital for assessing the health of the Upper Respiratory System (URS), are directly influenced by its condition (15). Any dysfunction in the URS adversely affects pulmonary function (16). Key RIs include Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV1), the percentage of vital capacity expired in the first second (FEV1% F), Tidal Volume (VT), Maximum Vital Capacity (VC MAX), Mean Mid-Expiratory Flow (MMEF (FEF25-75)), Peak Expiratory Flow (PEF), and Controlled Mechanical Volume Ventilation (cMVV). Athlete need to at least achieve near predicted values (>90% predicted) for maximal spirometry to ensure performance is not compromised (17). Aerobic exercises, such as cycling, heavily rely on RI. Cyclists, engaged in outdoor aerobic activities, are at an elevated risk of developing LD. LD appears to be more commonly associated with exercise that involves high bursts of ventilation rather than steadystate ventilation such as cycling. Breathing with bursts of high-minute ventilation requires ventilation through the mouth, which may result in less vocal cord abduction and more penetration of cooler and drier air into the lungs, which can irritate the vocal cords. Although transient laryngeal closure is a normal physiological reaction to exposure to irritants, it has been proposed that acute or recurrent irritant exposure (eg, repeated extreme cold air exposure) may lead to laryngeal hypersensitivity, resulting in laryngeal sensory and motor nerve stimulation, as well as abnormal paradoxical adduction of the true and/or false vocal cords during respiration (18).

Airway obstruction from LD during physical exertion elevates respiratory pressure and leads to exercise-induced respiratory symptoms. Increased ventilation during exercise generates negative pressures in the narrower sections of the airway, including the larynx (19). Intensified exercise promotes oral respiration, consequently leading to dehydration of the airway cell layer. This dryness of the laryngeal mucosa, often signified by a persistent cough (20), is a common complaint among athletes, significantly affecting their health and training efficacy (21). Obstructions in the larynx from these disturbances may present as respiratory distress symptoms, such as dyspnea, wheezing, coughing, and occurring during or after exercise (19). In athletes, dyspnea and wheezing might emanate from transient airflow blockage due to laryngeal disorders, especially during high-intensity exercises, and are particularly linked to movement-related exercise, ED, and Sicca. Studies suggest that specific abnormal lung volume and capacity ratios are indicative of supraglottic dysfunction (22, 23). Walstad et al. (24) discovered that swimmers frequently report laryngeal discomfort symptoms, including sore throat, viscous secretions, and coughing. Colbey et al. (25) noted that upper respiratory symptoms could adversely affect athletic performance, diminishing aerobic capacity, muscle strength and coordination, contraction speed, alertness, and cognitive processing. Dickinson et al. (26) emphasized the value of respiratory screening in discussing illness prevention, especially concerning upper respiratory tract infections. They advocate for annual respiratory health surveillance in athletes, typically aligned with pre-season or end-of-season screening/training camps. Sandnes et al. (27) found that treating laryngeal disorders can influence inspiratory muscle function. Furthermore, Clemm et al. (28)

identified exercise-induced laryngeal obstruction as a significant cause of upper airway dysfunction in young individuals and athletes, potentially impairing exercise performance and mimicking lower airway conditions like asthma or exercise-induced bronchoconstriction. Considering the prevalence of outdoor sports activities, athletes are often exposed to cold, dry air. This environmental factor can induce dryness in the laryngeal mucosa, particularly affecting the supraglottic area and potentially leading to disorders. This study sought to investigate the effect of larynx and upper airway disorders on the respiratory capacity of road cyclists, to describe the relationship between stroboscopy and spirometric findings, and to examine the relationship between these diagnostic methods.

2. Materials and Methods

This cross-sectional investigation sought to delineate the relationship between stroboscopic and spirometric findings, probing the correlation between these diagnostic methods. Initially, participants underwent stroboscopic examinations targeting the upper airway region above the epiglottis to identify potential disorders (29). This was followed by maximal flow-volume measures assessments, aimed at quantifying pulmonary capacities. The interrelation between these two sets of data was subsequently analyzed (30, 31). The study's protocols garnered approval from the Sports Science Research Institute (SSRI) and registration with the Iranian Clinical Trials Registry (IR.SSRC.REC.1400.018). The cohort comprised both male and female professional and elite cyclists, hailing from Iran's national team. The exclusion criteria included acute respiratory symptoms, a history of various diseases and cardiovascular complications, hypertension, and specific medical conditions. None of the participants reported seasonal allergies. Their training regimen entailed cycling sessions spanning 3 to 6 days per week, each lasting a minimum of 2 hours. Evaluations were conducted in winter, subjecting participants to cold (~7°C) and dry (~28%) air during their training and competitive endeavors, thereby incorporating the influence of severe weather conditions. All participants were non-smokers.

2.1 Instruments

For the supraglottic evaluation in this study, a proMIS stroboscopic device, model FHD ECS777, manufactured in Germany, was utilized (Figure 1). The assessment of the results of spirometry flow-volume measurements and indices employed a Ganshorn Medizin Electronic GmbH spirometer, also of German origin (Figure 2).

Figure 1. proMIS stroboscopic device, FHD ECS777 model made in Germany to examine the Supraglottic evaluation

Figure 2. Ganshorn Medizin Electronic GmbH spirometer made in Germany to examine the results of spirometry flow-volume measurements and indices

2.2 Procedures

Participant recruitment was conducted through invitations from the Tehran Province Cycling Board. Appointments were scheduled at specific clinics on predetermined dates and times. Upon arrival, participants provided initial information and signed informed consent forms after agreeing to partake in the study. The research comprised a single-phase approach, involving supraglottic examination using a stroboscopic device and spirometric assessment of the results of spirometry flow-volume measurements and indices. These evaluations were sequentially conducted at the pulmonary and ENT clinics of Milad Superspeciality Hospital, under the guidance of specialized physicians. Demographic data, including birth, sex, ethnicity, age, height, and weight, were documented in the spirometer's software. During spirometry, participants were positioned with their feet flat on the ground, ensuring a neutral head and neck posture. They were instructed to inhale deeply and then exhale forcefully and completely. The procedure began with several normal breaths, followed by a full inhalation and a forceful, continuous exhalation to maximal capacity. Spirometry data analysis included evaluations of FVC, FEV1, FEV1% F, VT, VC MAX, MMEF (FEF25-75), PEF, and cMVV (30, 31).

For the supraglottic evaluation, a speech and language pathologist assessed the participants' vocal cords using the stroboscopic device. The examination aimed to identify conditions such as Sicca, TE, ED, and GERD (32). During the procedure, participants were seated, asked to extend their tongue and consistently vocalize the /e/ sound. The pathologist then inserted a rigid endoscope into the mouth to image the upper portion of the vocal cords. Stroboscopic examination is generally safe, with infrequent post-procedure complications. Nevertheless, possible side effects include oral, lingual, or pharyngeal discomfort, bleeding, fatigue, nausea, and infection risk. Participants experiencing such symptoms were offered consultation with an ENT specialist (33).

2.3 Statistical Analysis

The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Pearson's correlation test was applied to parametric variables (spirometry results), and Spearman's correlation coefficient to non-parametric variables (stroboscopy results). Results were presented as means ± standard deviation. The Analysis of Variance (ANOVA) was utilized to examine the relationship between the outcomes of the stroboscopic evaluations and spirometric indices. Additionally, the correlation between these two sets of results was investigated. A backward elimination method was employed in the regression model for significance analysis. Variables including ED, GERD, Sicca, and TE were considered as predictors. Initially, all potential predictors were included in the regression model, with subsequent removal of non-significant variables to select the most suitable model based on the best fit criteria. A p-value of less than 0.05 was deemed statistically significant. Data analysis was conducted using SPSS software, version 21.

3. Results

The research encompassed an evaluation of 72 professional and elite road cyclists, both male and female, with a composition of 50 men (69.4%) and 22 women (30.6%). The participants' average age, height, weight, and Body Mass Index (BMI) were 22.48 (6.17) years, 173.12 (8.09) cm, 65.32 (2.84) kg, and 21.95 (0.02) kg/m², respectively. The frequency distribution of the stroboscopic findings, alongside a comprehensive analysis of the spirometry results among the participants, are delineated in Figure 3 and Table 1, respectively.

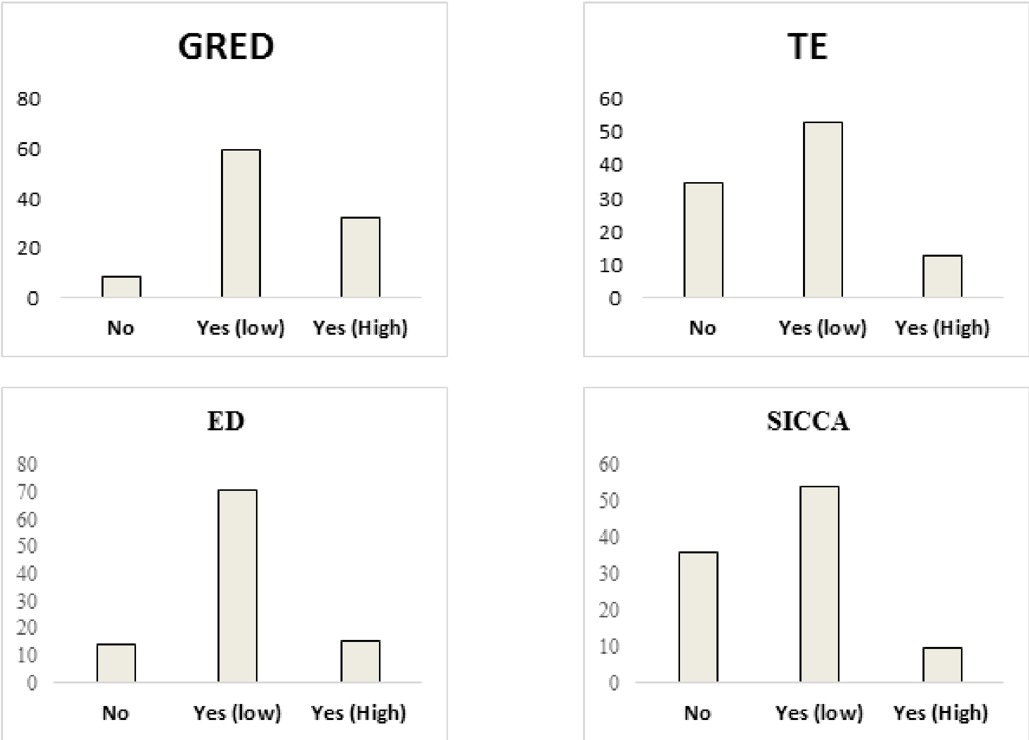

Figure 3. Frequency distribution of stroboscopy results in road cyclists

Table 1. Description of spirometry results in road cyclists

Variable (Quantitative)	Mean (±SD)	(Max and Min)
FVC	5.28(0.84)	(7.28,3.51)
FEV1	3.54(0.80)	(5.86,1.68)
FEV1%f	67.57(13.82)	(93.87,35.92)
VT	1.12(0.60)	(3.04,0.00)
VC max	5.26(0.82)	(7.28,3.51)
MMEF	2.89(1.19)	(6.31,0.51)
MEF25	1.54(0.96)	(4.59,0.06)
MEF50	3.65(1.36)	(8.11,0.79)
MEF75	4.62(20.4)	(9.38,1.27)
PEF	5.18(1.98)	(10.22,1.94)
cMVV	106.08(24.42)	(175.72,50.35)

Laryngeal disorders, encompassing conditions such as Sicca, TE, ED, and GERD, were stratified into three categories: 1) absence of disorder, 2) low-level disorder, and 3) high-level disorder. A predominant proportion of the participants demonstrated low levels of Edema (70.8%), GERD (59.8%), Sicca (54.2%), and Tension (52.8%) (Figure 3). An analysis was conducted to explore the correlation between stroboscopic findings and spirometric indices, with the results comprehensively presented in Table 2 to Table 5. Table 2 elucidates the absence of a significant correlation between ED and any spirometric indices (p-value > 0.05). Correspondingly, Table 3 indicates a lack of significant association between GERD and spirometric indices (p-value > 0.05). Conversely, Table 4 discloses a significant correlation between Sicca and the MMEF spirometric index (p-value < 0.05). The average (±SD) MMEF in participants without Sicca was 2.79 (1.11), in those with low Sicca it was 3.14 (1.23), and in those with high Sicca it was 1.88 (0.74). As per Table 5, there was no significant association found between Tension and any spirometric indices (p-value > 0.05).

Table 2. Relationship between ED and spirometric indices (Mean (±SD))

Index	Test statistics	ED			p-value
		Yes (High)	Yes (Low)	No	
FVC	0.617	5.31(0.87)	5.22(0.86)	5.55(0.71)	0.543
FEV	0.311	3.43(0.95)	3.53(0.74)	3.71(0.98)	10.734
FEV1%f	0.308	65.0(16.17)	68.37(13.26)	66.21(15.06)	0.736
VT	0.479	1.24(0.57)	1.15(0.69)	0.98(0.36)	0.621
VC max	0.671	5.28(0.82)	5.02(0.84)	5.53(0.72)	0.514
MMEF	0.002	3.43(0.95)	3.53(0.74)	3.71(0.98)	0.998
MEF25	0.722	1.23(0.47)	1.58(0.97)	1.69(1.30)	0.489
MEF50	0.072	3.79(1.66)	3.62(1.29)	3.66(1.46)	0.931
MEF75	0.366	4.80(2.30)	4.68(2.02)	4.11(21.00)	0.695
PEF	0.081	5.36(2.47)	5.17(1.91)	5.01(1.97)	0.922
$_C$MVV	0.294	103.09(28.59)	105.74(22.87)	111.12(29.20)	0.764

Table 3. Relationship between GERD and spirometric indices (Mean (±SD))

Index	Test statistics	GERD			p-value
		Yes (High)	Yes (Low)	No	
FVC	1.570	4.82(0.62)	5.36(0.88)	5.32(0.82)	0.215
FEV	1.542	3.28(0.68)	3.46(0.90)	3.75(0.63)	0.221
FEV1%f	1.735	68.39(13.78)	64.86(14.33)	71.39(12.57)	0.184
VT	0.521	1.15(0.48)	1.05(0.62)	1.21(0.63)	0.596
VC max	1.464	4.82(0.62)	5.33(0.85)	5.30(0.82)	0.238
MMEF	1.073	2.72(0.92)	2.75(1.34)	3.18(1.02)	0.348
MEF25	2.411	1.29(0.59)	1.38(0.93)	1.87(1.05)	0.097
MEF50	0.491	3.39(1.24)	3.58(1.53)	3.85(1.12)	0.614
MEF75	0.083	4.87(2.31)	4.56(2.17)	4.61(1.80)	0.920
PEF	0.132	5.42(2.42)	5.07(2.14)	5.24(1.59)	0.877
$_C$MVV	1.487	98.41(20.60)	103.72(27.69)	112.43(19.19)	0.233

Table 4. Relationship between Dry Laryngeal Mucosa (Sicca) and Spirometric Indices (Mean ± Standard Deviation)

Index	Test statistics	Sicca			p-value
		Yes (High)	Yes (Low)	No	
FVC	0.342	5.47(0.59)	5.31(0.87)	5.19(0.86)	0.712
FEV	2.605	3.00(0.57)	3.70(0.73)	3.45(0.89)	0.081
FEV1%f	3.731	55.58(13.05)	70.32(12.31)	66.66(14.77)	0.029
VT	0.920	1.23(0.57)	1.19(0.70)	0.99(0.44)	0.404
VC max	0.246	5.42(0.53)	5.28(0.85)	5.18(0.86)	0.783
MMEF	3.739	1.88(0.74)	3.14(1.23)	2.79(1.11)	0.029
MEF25	1.582	0.94(0.69)	1.63(0.97)	1.56(0.98)	0.213
MEF50	3.085	2.73(0.95)	3.96(1.41)	3.43(1.26)	0.052
MEF75	2.755	3.93(2.20)	5.12(2.02)	4.04(1.90)	0.071
PEF	2.751	4.32(1.93)	5.66(2.01)	4.68(1.82)	0.071
$_C$MVV	2.463	90.15(17.23)	110.76(22.79)	103.36(26.83)	0.093

Table 5. Relationship between Tension Laryngitis (TE) and Spirometric Indices (Mean ± Standard Deviation)

Index	Test statistics	TE			p-value
		Yes (High)	Yes (Low)	No	
FVC	1.570	4.82(0.62)	5.36(0.88)	5.32(0.82)	0.251
FEV	1.542	3.28(0.68)	3.46(0.90)	3.75(0.63)	0.221
FEV1%f	1.735	68.38(13.78)	64.86(14.33)	71.39(12.57)	0.184

VT	0.521	1.15(0.48)	1.05(0.62)	1.21(0.63)	0.596
VC max	1.464	4.82(0.62)	5.33(0.85)	5.30(0.82)	0.238
MMEF	1.073	2.72(0.92)	2.75(1.34)	3.18(1.02)	0.348
MEF25	2.411	1.29(0.59)	1.38(0.93)	1.87(1.05)	0.097
MEF50	0.491	3.39(1.24)	3.58(1.53)	3.85(1.12)	0.614
MEF75	0.083	4.87(2.31)	4.56(2.17)	4.16(1.80)	0.920
PEF	0.132	5.42(2.42)	5.07(2.14)	5.24(1.59)	0.877
$_{C}$MVV	1.487	98.41(20.60)	103.72(27.69)	112.43(19.19)	0.233

In this regression analysis, a backward method was employed, utilizing variables such as ED, GERD, Sicca, and TE as predictors. The process began by incorporating all predictive variables into the regression model. Subsequently, those failing to meet predefined criteria were methodically excluded, thus determining the most fitting model based on established fit criteria. Table 6 delineates the significant outcomes of the regression model. The analysis revealed notable correlations when aligning the independent variables with Tidal Volume (VT) and Mean Expiratory Flow at 25% of Forced Vital Capacity (MEF25), evidenced by p-values < 0.05. The coefficient of determination suggested that a relatively modest 11.3% of the variations in VT and 5.8% of the variations in MEF25 could be ascribed to the independent variables. The regression coefficients pertaining to these significant findings were subsequently subjected to a more detailed examination.

Table 6. Significance of the Regression Model with Predictor Variables (ED, GERD, Sicca, and TE) Using the Backward Method

Dependent Variable	Effect	SS	F	p	S.E	R^2	R^2_{adjt}
FVC	Total	3.15	1.22	0.354	0.838	0.063	0.007
	residual	47.08					
	regression	50.23					
FEV1	Total	3.30	1.295	0.281	0.798	0.072	0.016
	residual	42.73					
	regression	46.03					
FEV1%f	Total	493.36	0.632	0.641	13.96	0.036	0.021
	residual	13072.33					
	regression	13565.70					
VT	Total	2.92	2.846	0.044	0.584	0.113	0.073
	residual	22.96					
	regression	25.88					
VC max	Total	2.65	0.973	0.428	0.826	0.055	0.001
	residual	45.76					
	regression	48.42					
MMEF	Total	7.05	1.243	0.301	1.190	0.069	0.013
	residual	95.03					
	regression	102.08					
MEF25	Total	3.85	4.335	0.041	0.942	0.058	0.045
	residual	62.19					
	regression	66.04					
MEF50	Total	9.15	1.252	0.298	1.351	0.070	0.014
	residual	122.42					
	regression	131.57					
MEF75	Total	6.42	0.829	0.371	2.081	0.022	-0.037
	residual	290.24					
	regression	296.67					
PEF	Total	3.355	0.203	0.936	2.031	0.012	-0.047
	residual	276.38					
	regression	279.74					
$_{C}$MVV	Total	3084.12	1.315	0.273	24.213	0.073	0.017
	residual	39282.04					
	regression	42366.17					

Table 7 presents the significant outcomes of the regression analysis on the dependent variable. The regression model, developed by applying independent variables to Tidal Volume (VT), is as follows:

$$VT = 1/188 + 0/232ED - 0/411GERD + 0/278$$

The results indicate that Gastroesophageal Reflux Disease (GERD) significantly and negatively impacts Tidal Volume (VT).

The regression model, developed by applying independent variables to the Mean Expiratory Flow at 25% of Forced Vital Capacity (MEF25), is outlined as follows:

$$MEF25 = 2/031 - 0/393\ GERD$$

The analysis reveals that the Gastroesophageal Reflux Disease (GERD) variable significantly and negatively affects the Mean Expiratory Flow at 25% of Forced Vital Capacity (MEF25).

Table 7. Significance of Regression Coefficients

Dependent variable	Predictive variable	Regression coefficient	T test statistics	P -Value
VT	TE	1.188	6.915	<0.0001
	ED	0.232	1.467	0.147
	GERD	-0.411	-2.565	0.013
	SICCA	0.278	1.989	0.051
MEF25	TE	2.031	7.864	<0.0001
	GERD	-0.393	-2.082	0.041

4. Discussion

The participants of the study, which included male and female professional and elite cyclists of the Iranian national team, showed different degrees of ED, GERD, Sicca and TE by stroboscopy evaluation. While no significant correlations were found between ED, GERD, TE, and spirometric indices, a notable relationship existed between Sicca and the MMEF index. Moreover, the regression analysis highlighted a significant negative impact of GERD on VT and MEF25. Ebrahimi et al. (29) underscored the influence of GERD on the respiratory quality in Kabaddi athletes, highlighting its potential detrimental effects.

Factors like prolonged exposure to cold and dry air (34), breathing in fine particle dust (36), stress, muscle contractions (6), specific postures, and poor eating habits (7-9) common in endurance athletes like road cyclists (35, 36) can lead to vocal cord and laryngeal dysfunction. Symptoms include throat pain and tightness, coughing, aspiration, foreign body sensation, and sore throat (37, 38). which can impair breathing, affect respiratory indices, and reduce athletic performance during training and competition (39). Superficial dehydration due to inadequately conditioned inspired air and mouth breathing can cause laryngeal dryness. The hydration of airway epithelia, including that over the vocal folds, is facilitated by a thin layer of surface water known as the sol layer. Although this layer in the upper airway is less than 10 µm deep, it's vital for vocal fold oscillation, as shown in ex vivo animal tissue studies. Oral breathing, common in activities like singing, teaching, exercising, and loud speaking, reduces the depth of this sol layer, leading to superficial dehydration of tracheal and bronchial airway epithelia. This dehydration increases phonation threshold and perceived vocal effort, as the sol layer plays a role in mucosal rheology (39). Dickinson et al. (26) highlighted that screening concepts are as applicable to athlete health as to any medical condition. Implementing a respiratory screening policy for athletes could enhance the detection and management of both upper and lower airway issues, provided the key screening characteristics are met for the target population.

Forrest et al. (40) stated in a research that The largest percentile of patients with Paradoxical vocal cord motion had a conversion disorder with an associated comorbid medical condition such as laryngeal edema/chronic laryngitis, reflux, laryngeal sicca, or asthma. The laryngeal mistiming leads to breathing difficulty and is often misdiagnosed as refractory asthma. Fairfax et al. (41) studied 17 patients with pulmonary disease, eight of whom had sicca syndrome alone, and various pulmonary disorders were found in them. Pirogowicz et al. (42) conclude that cough accompanying GERD suggests a mild airway inflammation developing as a sequel of GERD. GERD is also considered by Theodoropoulos et al. (43) as a factor contributing to airway inflammation. Due to its unique location, the larynx is susceptible to infectious and gastroesophageal reflux-related insults. Couple this with key roles in regulation of airflow and mediation of airway protective reflexes, it is not surprising that neuropathic abnormalities and muscle dysfunction can develop frequently. The expression of laryngeal dysfunction as hypersensitivity to mechanical, thermal, chemical and other stimuli leads to exaggerated airway protective reflexes manifesting as upper airway insufficiency (44).

5. Conclusion

This study, focusing on professional and national team road cyclists, revealed a limited significant relationships between LD and RI through regression models. We advocate for the assessment and diagnosis of LD because of its association with RI. Addressing these disorders could lead to practical and advantageous improvements in athletes' performance during training and competitions, thereby enhancing their overall performance.

6. Limitations

This study is constrained by certain limitations. In research involving correlation and regression analysis, a larger sample size typically produces more definitive results (45). However, the sample size is adequate because the majority of the population was assessed and due to the restricted availability of professional and elite athletes meeting the study's criteria, the sample size was limited to 72 participants. Although the assessments were conduvcted in the winter time they were conducted outside in the cold and dry environment. Moreover, other outdoor sports such as skiing, swimming, and running, often performed in cold environments, might also expose athletes to laryngeal disorders impacting their respiratory indices. Therefore, in future researches, athletes of the mentioned sports can be used as a statistical population. There has been no assessment of exercise performance, therefore, it is difficult to indicate the relevance of our findings for the athletes. There is a continued need for comprehensive investigations into the URS.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Study concept and design: S. E., and M. A.; analysis and interpretation of data: S. Gh., and M. Gh.; drafting of the manuscript: S. E.; critical revision of the manuscript for important intellectual content: Kh. I., J.D., and A. A.; statistical analysis: S. Gh.

Data Availability Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Ethical Considerations

The authors have adhered to ethical standards in conducting their research and preparing this review, ensuring transparency, objectivity, and integrity in the dissemination of knowledge related to the topic. The study's protocols garnered approval from the Sports Science Research Institute (SSRI) and registration with the Iranian Clinical Trials Registry (IR.SSRC.REC.1400.018).

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References

1. Hamdan AL, Sataloff RT, Hawkshaw M. Voice Disorders in Athletes, Coaches and Other Sports Professionals: Springer; 2021. [DOI]
2. Xu W. Atlas of Strobolaryngoscopy: Springer; 2019. [DOI]
3. Peroš-Golubičić T, Tekavec-Trkanjec J. Upper respiratory tract infections. Textbook of Respiratory and Critical Care Infections. 2015;1:16. [DOI]
4. Rouev P, Chakarski I, Doskov D, Dimov G, Staykova E. Laryngopharyngeal symptoms and gastroesophageal reflux disease. Journal of Voice. 2005;19(3):476-80. [PMID: 15936924] [DOI]
5. Boulet L-P, Turmel J. Cough in exercise and athletes. Pulmonary pharmacology & therapeutics. 2019;55:67-74. [PMID: 22487846] [PMCID: PMC3580050] [DOI]
6. Kolnes L-J, Vollsæter M, Røksund OD, Stensrud T. Physiotherapy improves symptoms of exercise-induced laryngeal obstruction in young elite athletes: a case series. BMJ open sport & exercise medicine. 2019;5(1):e000487. [PMID: 30740235] [PMCID: PMC6347884] [DOI]
7. Jozkow P, Wasko-Czopnik D, Medras M, Paradowski L. Gastroesophageal reflux disease and physical activity. Sports medicine. 2006;36(5):385-91. [PMID: 16646627] [DOI]
8. de Oliveira EP, Burini RC, Jeukendrup A. Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. Sports Medicine. 2014;44(1):79-85. [PMID: 24791919] [PMCID: PMC4008808] [DOI]
9. Parmelee-Peters K, Moeller JL. Gastroesophageal reflux in athletes. Current sports medicine reports. 2004;3(2):107-11. [PMID: 14980140] [DOI]
10. Ostapiak Z, Vypasniak I, Lisovskyi B, Mytskan T. Respiratory Tract Dysfunction in Sportsmen. Physical education, sport and health culture in modern society. 2017(2 (38)):169-77. [DOI]
11. Sodhi JS, Zargar SA, Javid G, Khan MA, Khan BA, Yattoo G, et al. Effect of bending exercise on gastroesophageal

reflux in symptomatic patients. Indian J Gastroenterol. 2008;27(6):227-31.
12. Hamdan A-L, Sataloff RT, Hawkshaw MJ. Exercise-Induced Laryngeal Obstruction (EILO) in Athletes. Voice Disorders in Athletes, Coaches and other Sports Professionals: Springer; 2021. p. 155-82. [DOI]
13. Kolnes L-J, Stensrud T. Exercise-induced laryngeal obstruction in athletes: contributory factors and treatment implications. Physiotherapy theory and practice. 2019;35(12):1170-81. [PMID: 29757061] [DOI]
14. Fan E, Olin JT. Exercise-induced laryngeal obstruction. American journal of respiratory and critical care medicine. 2019;199(12):P23-P4. [PMID: 31199188] [DOI]
15. Prontenko K, Griban G, Prontenko V, Bezpaliy S, Bykova G, Dvoretsky V. Level and dynamics of functional preparedness indexes of kettlebell sportsmen. Journal of Physical Education and Sport. 2017(17):712-6.
16. Castro M, Dedivitis RA, Macedo AG. Evaluation of a method for assessing pulmonary function in laryngectomees. Acta Otorhinolaryngologica Italica. 2011;31(4):243.
17. Koyunlu A, Dağlioğlu Ö, Özdal M. Comparison of Physical Fitness and Respiratory Parameters of Elite Wrestlers and Judokas. Turkish Journal of Sport and Exercise. 2020;22(3):360-5.
18. Al-Alwan A, Kaminsky D. Vocal cord dysfunction in athletes: clinical presentation and review of the literature. The Physician and sportsmedicine. 2012 May 1;40(2):22-7. [PMID: 22759602] [DOI]
19. Baz M, Haji G, Menzies-Gow A, Tanner R, Hopkinson N, Polkey M, Hull J. Dynamic laryngeal narrowing during exercise: a mechanism for generating intrinsic PEEP in COPD? Thorax. 2015;70(3):251-7. [PMID: 25586938] [PMCID: PMC4345987] [DOI]
20. Sivasankar M, Fisher KV. Oral breathing increases Pth and vocal effort by superficial drying of vocal fold mucosa. Journal of Voice. 2002;16(2):172-81. [PMID: 12150370] [DOI]
21. Nielsen EW, Hull JH, Backer V. High prevalence of exercise-induced laryngeal obstruction in athletes. Medicine and science in sports and exercise. 2013;45(11):2030-5. [PMID: 23657163] [DOI]
22. Sandnes A, Hilland M, Clemm HH, Heimdal J-H, Halvorsen T, Røksund OD. Laryngoscopy but not resting spirometry is diagnostic for exercise induced laryngeal obstruction. Eur Respiratory Soc; 2013.
23. Fretzayas A, Moustaki M, Loukou I, Douros K. Differentiating vocal cord dysfunction from asthma. Journal of asthma and allergy. 2017;10:277. [PMID: 29066919] [PMCID: PMC5644529] [DOI]
24. Walsted ES, Swanton LL, van van Someren K, Morris TE, Furber M, Backer V, Hull JH. Laryngoscopy during swimming: a novel diagnostic technique to characterize swimming-induced laryngeal obstruction. The Laryngoscope. 2017;127(10):2298-301. [PMID: 28236311] [DOI]
25. Colbey C, Cox AJ, Pyne DB, Zhang P, Cripps AW, West NP. Upper respiratory symptoms, gut health and mucosal immunity in athletes. Sports Medicine. 2018;48(1):65-77. [PMID: 29363055] [PMCID: PMC5790851] [DOI]
26. Dickinson JW, Greenwell J, Hull JH. Epilogue: Bringing it all together to optimise athlete respiratory care. Complete Guide to Respiratory Care in Athletes: Routledge; 2020. p. 182-96. [DOI]
27. Sandnes A, Andersen T, Clemm HH, Hilland M, Heimdal J-H, Halvorsen T, et al. Clinical responses following inspiratory muscle training in exercise-induced laryngeal obstruction. European Archives of Oto-Rhino-Laryngology. 2022;279(5):2511-22. [PMID: 34954812] [PMCID: PMC8986676] [DOI]
28. Clemm HH, Olin JT, McIntosh C, Schwellnus M, Sewry N, Hull JH, Halvorsen T. Exercise-induced laryngeal obstruction (EILO) in athletes: a narrative review by a subgroup of the IOC Consensus on 'acute respiratory illness in the athlete'. British Journal of Sports Medicine. 2022;56(11):622-9. [PMID: 35193856] [PMCID: PMC9120388] [DOI]
29. Ebrahimi S, Gholami MJJoV. Comparison of Maximum Oxygen Uptake and Rating Perceived Exertion in Woman's Kabaddi Athletes (Without Breathy Voice to Severe Breathy Voice). 2018.
30. Hankinson JL, Odencrantz JR, Fedan KBJAjor, medicine cc. Spirometric reference values from a sample of the general US population. 1999;159(1):179-87. [PMID: 9872837] [DOI]
31. Alemayehu HK, Salvadego D, Tringali G, De Micheli R, Caccavale M, Sartorio A, Grassi BJSR. Acute respiratory muscle unloading improves time-to-exhaustion during moderate-and heavy-intensity cycling in obese adolescent males. 2020;10(1):1-9. [PMID: 33046823] [PMCID: PMC7550339] [DOI]
32. Casper JK, Leonard R. Understanding voice problems: A physiological perspective for diagnosis and treatment: Lippincott Williams & Wilkins; 2006.
33. Won H-K, Kang S-Y, Kang Y, An J, Lee J-H, Lee SM, et al. Cough-related laryngeal sensations and triggers in adults with chronic cough: symptom profile and impact. 2019;11(5):622. [PMID: 31332974] [PMCID: PMC6658400] [DOI]
34. Dou ZJE. Effects of Atmospheric Particulate Matter Pollution on Physical Function of Elderly Sports Population. 2019;28(108):2057-62.
35. Sue-Chu M, Kippelen PJCLF. Effects of Cold and Heat on the Lung. 2020:653-9. [DOI]
36. Fretzayas A, Moustaki M, Loukou I, Douros KJJoa, allergy. Differentiating vocal cord dysfunction from asthma. 2017;10:277. [PMID: 29066919] [PMCID: PMC5644529] [DOI]
37. Dickinson JW, Boniface A. Breathing pattern disorders in athletes. Complete Guide to Respiratory Care in Athletes: Routledge; 2020. p. 147-69. [DOI]
38. Marcinow AM, Thompson J, Chiang T, Forrest LA, deSilva BWJTL. Paradoxical vocal fold motion disorder in the elite athlete: experience at a large division I university. 2014;124(6):1425-30. [PMID: 24166723] [DOI]
39. Sivasankar M, Fisher KVJJoV. Oral breathing increases Pth and vocal effort by superficial drying of vocal fold mucosa. 2002;16(2):172-81. [PMID: 12150370] [DOI]
40. Forrest LA, Husein T, Husein O. Paradoxical vocal cord motion: classification and treatment. The Laryngoscope. 2012;122(4):844-53. [PMID: 22434681] [DOI]
41. Fairfax A, Haslam P, Pavir D, Sheahan N, Bateman J, Agnew J, et al. Pulmonary disorders associated with Sjögren's syndrome. QJM: An International Journal of Medicine. 1981;50(3):279-95.
42. Pirogowicz I, Patyk M, Popecki P, Rudnicki J, Gojny L, Pokorski M. Lung function in patients with gastro-esophageal reflux disease and respiratory symptoms. Neurobiology of Respiration. 2013:161-6. [PMID: 23835974] [DOI]
43. Theodoropoulos DS, Pecoraro DL, Efstratiadis SE. The association of gastroesophageal reflux disease with asthma and chronic cough in the adult. American Journal of Respiratory Medicine. 2002;1:133-46. [PMID: 14720067] [DOI]
44. Sundar KM, Stark A, Morris MJ. Laryngeal Dysfunction Manifesting as Chronic Refractory Cough and Dyspnea Laryngeal Physiology in Respiratory Health and Disease. Chest. 2024. [PMID: 38508333] [DOI]
45. Green SB. How many subjects does it take to do a regression analysis. Multivariate behavioral research. 1991;26(3):499-510. [PMID: 26776715] [DOI]