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Laryngeal response to high-intensity exercise in healthy athletes

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ABSTRACT

Introduction Exercise-induced laryngeal obstruction (EILO) is a common cause of exertional breathing problems. The current diagnostic approach rests on evaluation of laryngeal obstruction visualised by laryngoscopy performed continuously throughout a maximal exercise test (continuous laryngoscopy exercise (CLE) test) in patients who present with compatible symptoms. Laryngeal responses to high-intensity exercise in endurance athletes are not well described, potentially leading to inaccurate reference values and increasing the risk of misdiagnosing EILO.

Aim To investigate laryngeal responses to high-intensity exercise in a healthy population of endurance athletes with no self-reported perception of respiratory problems.

Methods A cross-sectional study was conducted at Haukeland University Hospital, Bergen, Norway, inviting amateur and professional athletes with no self-reported breathing problems who performed endurance training minimum four sessions weekly. Thirty-six eligible athletes completed a questionnaire detailing exercise habits and past and current respiratory symptoms. They performed a standardised CLE test from which cardiopulmonary exercise data and corresponding laryngeal responses were recorded. The CLE tests were evaluated in retrospect by two independent raters according to preset criteria providing a CLE score. The CLE score rates the severity of laryngeal obstruction during moderate and maximum exercise on the glottic and supraglottic regions on a scale ranging from 0 (no obstruction) to 3 (maximum obstruction).

Results Twenty-nine (81%) athletes (15 females) aged 15–35 years completed a CLE test. Ten participants (33%) had a supraglottic CLE subscore of 2 or 3. Among these, two also had a glottic CLE subscore of 2 or 3. Notably, none had isolated glottic obstruction.

Conclusion In healthy well-trained endurance athletes with no prior perception of respiratory symptoms, the laryngeal response to high-intensity exercise was diverse. Supraglottic laryngeal obstruction was observed in one-third of the athletes. The findings underline that a diagnosis of EILO should rest on observed laryngeal obstruction supported by compatible symptoms.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prior research recognised exercise-induced laryngeal obstruction (EILO) as a frequent cause of breathing issues in athletes; however, there is a lack of comprehensive data on laryngeal responses to exercise in healthy athletes.

WHAT THIS STUDY ADDS

⇒ This study uncovers a noteworthy finding: one-third of asymptomatic healthy athletes display supraglottic obstruction in their larynx when subjected to high ventilatory demands during peak exercise.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study highlights the limitations of diagnosing EILO based solely on observed laryngeal obstruction, and advocates for a diagnostic approach where symptoms are considered.

⇒ Specifically, it suggests that continuous laryngoscopy exercise testing should only be conducted when there are evident symptoms of EILO.

INTRODUCTION

Exercise-induced laryngeal obstruction (EILO) is a common cause of exertional breathing problems and affects 5%–7% of otherwise healthy adolescents.[1] EILO seems even more prevalent among athletes reported to be 27% or more.[2] Prevalence studies in general adult populations are lacking. Key symptoms of EILO are inspiratory breathing problems during high-intensity exercise, often accompanied by coarse or high-pitched inspiratory breath sounds, feeling of tightness in the throat or neck area and sometimes stridor.[3] These symptoms are associated with a paradoxical obstruction of laryngeal structures that otherwise appear normal, most often predominantly involving the supraglottic folds, but often followed by adduction also of the vocal cords. Symptoms of EILO typically resolve within minutes after exercise has ended but may also be prolonged in some cases.[4] Episodes of EILO can be associated with profound and frightening symptoms. Affected individuals might have difficulties performing in sports, and some refrain from taking part in even modest physical activities. While historically often misdiagnosed as asthma, studies have demonstrated that EILO and asthma can coexist.[2]

The laryngeal obstruction observed in EILO is exclusively linked to exercise as trigger,[5] but several risk factors have been proposed but not proven, including asthma, gastro-oesophagal reflux disease, anatomic factors related to the upper airways and genetic factors.[4] While the pathophysiology is poorly understood, the increased airflow induced by the high-volume ventilation required to perform exercise, somehow triggers the paradoxical adduction we can observe in the laryngoscope.[6] There is currently consensus that we should distinguish between EILO with predominantly glottic and supraglottic obstruction, as these might represent different phenotypes.[57] Some few studies have suggested how the larynx normally should respond to exercise in non-athletes.[1 8] Athletes have increased physical and ventilatory capacity compared with the more sedentary part of the population, implying higher volumes of air passing through the larynx at higher velocities, setting up a condition with increased negative intraluminal laryngeal pressures. Conceivably, this might lead to inward collapse of laryngeal structures in susceptible individuals. Accordingly, several studies have revealed high prevalence of EILO in athletes compared with non-athletes.[2 4]

This raises the question of whether the higher prevalence of EILO observed in athletes is directly attributable to the increased ventilatory demands imposed by their rigorous training and performance regimes. Such a hypothesis underscores the importance of further research into the interplay between heightened ventilatory needs during intense exercise and the risk of EILO, aiming to clarify the underlying mechanisms that predispose athletes to this condition.

Endurance athletes, during years of training, repetitively expose their airways to high-volume ventilation, and we do not know how this influences laryngeal structure and function over time. Thus, we lack the necessary knowledge to confidently decipher what should be considered normal laryngeal movements during high-intensity exercise in these individuals. This has implications for how EILO could be diagnosed in this group. The main purpose of the CLE test is to identify abnormal laryngeal movement during exercise. If the larynx behaves differently in athletes with higher ventilation volumes compared with the general population, it could potentially lead to misdiagnosis of EILO.

We therefore aimed to investigate laryngeal response patterns to high-intensity exercise in a healthy population of athletes with no prior self-reported perception of respiratory problems. We hypothesised that in this population, no objective signs of laryngeal obstruction would be present during the CLE test.

METHODS

Participants and study design

The study is a retrospective analysis of data collected in a previous study assessing the reliability of maximal oxygen uptake measurements when combining a regular cardiopulmonary exercise test with concomitant continuous flexible laryngoscopy.[9]

Healthy athletes 15–35 years of age performing endurance training for a minimum of four sessions weekly (duration not specified), were invited to participate via posters at the University and local sports clubs. The inclusion and exclusion criteria for this study are given in table 1. A criterion for inclusion was that they considered themselves free from breathing problems. Athletes unable to fulfil the required standards for spirometry or with illnesses or conditions affecting their ability to perform a CLE test were excluded. At inclusion, all participants were asked to complete a questionnaire detailing exercise habits and past and current respiratory symptoms. Questions regarding respiratory symptoms and exercise habits were customised and adapted from the International Study On Asthma and Allergies in Childhood[10] and the WHO's Health Behaviour in Schoolchildren survey.[11] Participants who stated breathing problems in the questionnaire were excluded. User representatives have been involved in the design of the study and development of the final questionnaire.

Pulmonary function test

Spirometry was performed according to guidelines before the CLE test using a Vyntus PNEUMO spirometer (Vyaire Medical, Leibnistrasse, Hoechberg, Germany).[12] Forced vital capacity and forced expiratory volume during the first second (FEV_1) were recorded, with z-scores calculated using the Global Lung Function Initiative calculator.[13 14] Breathing reserve was the percentage difference between calculated maximal ventilatory volume ($FEV_1 \times 35$) and measured peak minute ventilation.

Table 1 Criteria for inclusion and exclusion

Inclusion criteria	Exclusion criteria
Age 15–35 years	Not able to perform a treadmill run
Performs endurance training for a minimum of four sessions per week	Not able to perform spirometry
No self-reported breathing problems	Experiencing breathing problems, or failing to disclose this in the questionnaire

CLE test

CLE tests were performed in conjunction with a maximal cardiopulmonary exercise test (CPET), according to routines at the EILO outpatient clinic at the Children and Youth Clinic at Haukeland University Hospital, Bergen, Norway.[9] After application of local anaesthesia (Lidocaine), a flexible fibre optic laryngoscope (Olympus ENF-V2, Tokyo, Japan) with diameter 3.4 mm was advanced via an opening in a modified facemask (Hans Rudolph, Kansas City, Missouri, USA) and through one nostril to the pharyngeal space until a satisfactory overview of the larynx was achieved. A custom-made headgear secured the handle of the laryngoscope. A modified computerised treadmill (Woodway PPS 55 Med, Weil am Rhein, Germany) Bruce protocol was applied, gradually increasing speed and elevation every 60s. from an initial slow walking phase.[15] After baseline variables were established, subjects ran to exhaustion. Respiratory exchange ratio (RER) >1.10 was considered compatible with maximal effort.[16] Parameters of gas exchange and airflow were measured breath-by-breath and averaged over 30 s by a Vyntus CPX unit powered by SentrySuite software (Vyaire Medical). The test was considered successful when subjects indicated exhaustion, preferably supported by a plateau in the oxygen uptake ($V'O_2$) and/or the heart rate (HR) response. Duration of running and completed treadmill distance were recorded. Peak oxygen consumption ($V'O_2$ peak), peak carbon dioxide output ($V'CO_2$), tidal volume (VT), respiratory rate (RR) and HR were measured directly, while minute ventilation (V′E) was calculated from VT and RR. RER was calculated from $V'CO_2$ and $V'O_2$. An exercise ECG was recorded throughout the treadmill test using Custo Cardio 100 (custo med, Maria-Merian-strasse, Ottobrunn, Germany), the Vyntus CPX unit powered by SentrySuite software (Vyaire Medical) and CustoMed Diagnostics software (custo med). Laryngoscopy recordings, CPET data, soundtracks and a video recording of the upper body were stored in one single computer file for later assessment.

CLE score

A categorical rating scale has been proposed to grade severity of laryngeal obstruction, as this can be observed during a CLE test.[5 8 17] Studies have demonstrated a strong correlation between subjective complaints of respiratory distress and CLE score.[8] The score aims to assess the grade of obstruction at two levels: the medialisation of aryepiglottic folds (supraglottic score), as well as the adduction of the vocal cords (glottic score).

A numerical value from 0 to 3 is assigned to supraglottic and glottic structures at moderate-intensity and peak-intensity exercise, based on the observed extent of narrowing relative to the laryngeal anatomy at rest (figure 1).[8] A score ≥2 at either supraglottic or glottic level at any level of exercise intensity is commonly considered a significant laryngeal obstruction, and therefore compatible with a diagnosis of EILO.[18–20] Experienced clinicians (HHC and ODR) evaluated the CLE test video recordings in retrospect according to the classification described by Maat *et al*[8] (figure 1). For the purpose of this study, we regarded any score ≥2 as compatible with EILO.

Statistical methods

Data were reported as means with SD for continuous data and counts with percentages for categorical data. Statistical calculations were performed using the statistical software SPSS V.26 (IBM SPPS Statistics, Armonk, New York, USA). A power calculation was not performed for this study alone. This decision was made because the study is purely descriptive in nature. For the original study, 31 participants were considered an appropriate sample size for achieving the objective of that study.[9] We had 42 eligible CLE tests from the original study. However, after excluding those with self-reported breathing issues, including controlled asthma, we were left with 36 participants.

Equity, diversity and inclusion statement

Diversity in study population

The study aimed for diversity by recruiting athletes aged 15–35 years from various sports clubs, ensuring sex balance (15 females and 14 males). However, it did not explicitly address racial/ethnic diversity, socioeconomic levels or representation from marginalised groups in recruitment.

Diversity in investigator and author team

Our author team includes both senior and junior researchers, offering diverse experiences and perspectives. While the paper does not detail sex composition or inclusion of individuals from marginalised backgrounds, our multidisciplinary team brings expertise in medical and sports sciences.

Inclusivity in data collection methods

Data collection aimed at inclusivity, involving athletes from various disciplines. Standardised questionnaires and exercise tests considered accessibility needs of participants. However, the study did not specify adjustments for regional geographic differences, education or socioeconomic levels.

Equity in analysis and interpretation of results

The equal sex distribution of participants allowed for an unbiased assessment of EILO for males and females. However, the study did not specifically address socioeconomic disadvantage or inequities in marginalised communities in the interpretation of results.

Generalisability and limitations

The study's findings are primarily relevant to healthy athletes and may not be generalisable to non-athlete populations or athletes with existing respiratory conditions. Our discussion acknowledges these limitations, emphasising the need for caution in generalising the findings beyond the study population.

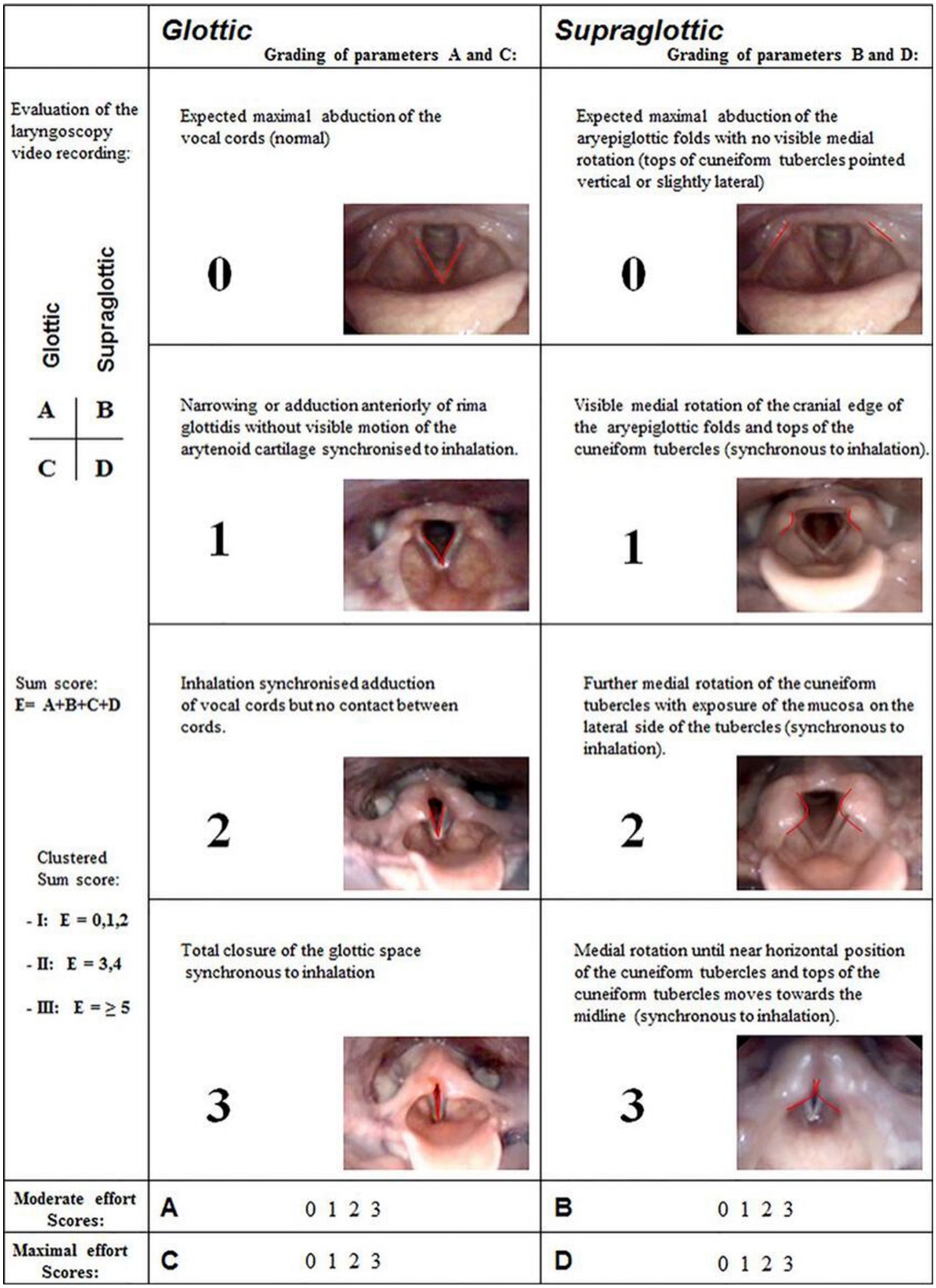

Figure 1 The continuous laryngoscopy exercise (CLE) scoring system. Scores were assigned at glottic (A and C) and supraglottic (B and D) levels, and at moderate (A and B) and maximal effort (C and D). The sum of these four scores constitutes the sum score (E) for each test/subject. For the purpose of this study, we regarded any score ≥2 as compatible with exercise-induced laryngeal obstruction. CLE grading system, reproduced with permission from Maat *et al*.[8]

RESULTS

Thirty-six athletes who reported no exertional breathing problems in the questionnaire were enrolled in this study. See tables 2 and 3 for background characteristics and type of sports. Seven video recordings could not be evaluated due to technical difficulties, leaving 29 participants (14 male, 15 female), aged 15–35 years (mean 25.4) (figure 2).

Cardiopulmonary function test

All athletes ran to exhaustion reaching VO_2 plateau, with a mean RER 1.20 and mean HR of 184 per minute.

Table 2 Background characteristics, lung function and selected peak cardiopulmonary exercise variables

Variables	Males N=14 Mean (SD)	Females N=15 Mean (SD)
Age, years	27.6 (6.4)	22.8 (6.8)
Height, cm	182.2 (6.6)	167.0 (4.5)
Weight, kg	77.7 (9.6)	58.4 (5.5)
BMI	23.4 (2.2)	20.9 (2.0)
FVC, z-score	0.86 (0.81)	0.24 (0.75)
FEV_1, z-score	0.26 (0.88)	−0.16 (0.48)
Peak respiratory rate, breaths/min	56 (9.2)	51 (8.7)
Peak heart rate, beats/min	183 (8.8)	185 (0.5)
Peak RER, units	1.19 (0.06)	1.21 (0.04)
Running distance, m	1258 (179.7)	1058 (114.0)
Running time, min	14.2 (1.2)	12.8 (0.8)
Peak VO_2, mL/kg/min	58.9 (5.9)	52.0 (4.1)
Peak VE, L/min	173.9 (12.2)	107.8 (11.1)
Peak breathing reserve, %	−5 (11.7)	8 (10.0)
Speed at peak VO_2, m/s	2.54 (0.22)	2.30 (0.12)

Breathing reserve is the percentage difference between maximal voluntary ventilation (FEV_1×35) and peak minute ventilation.
BMI, body mass index; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; RER, respiratory exchange ratio; VE, minute ventilation; VO_2, oxygen consumption.

Table 3 Types of sports and competing level among the participants

Type of sports	N (n, males)
Running	6 (3)
Cross-country skiing/biathlon	5 (0)
Triathlon	1 (0)
Swimming	1 (1)[1]
Cycling	1 (1)[1]
Rowing	1 (1)[1]
Orienteering	1 (0)
Randone	1 (0)
Football	1 (0)
Track and field	1 (1)[1]
Speed skating	1 (0)
Missing	8
Competing level	
Exerciser	6 (4)[4]
Local	2 (1)[1]
Regional	5 (3)[3]
National	3 (0)
Missing	13 (6)

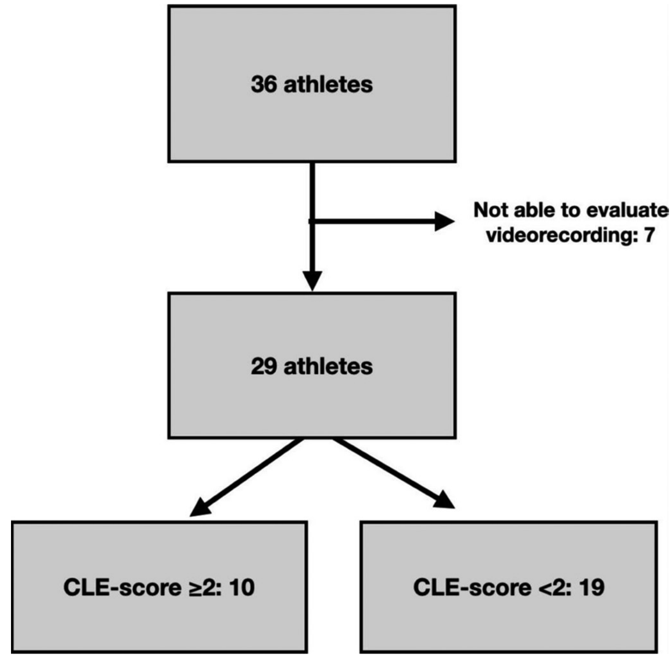

Figure 2 Recruitment of study participants with a continuous laryngoscopy exercise score ≥2 is compatible with exercise-induced laryngeal obstruction.

CPET data measured during the CLE test are presented in table 2.

Laryngeal evaluation—CLE score

CLE scores are presented in table 4. At moderate exercise, no one had CLE scores ≥2, although there was some adduction at the supraglottic level in eight (28%) athletes, rated as CLE score=1. At maximum effort, 19 (66%) athletes had a CLE score <2, 10 (33%) athletes had supraglottic obstruction with CLE score ≥2. Two (7%) athletes had glottic obstruction ≥2, both of whom also had a supraglottic obstruction of ≥2 at maximal effort.

Questionnaire

All participants reported no breathing problems in the questionnaire, as this was an inclusion criterion. None had a diagnosis of asthma; but four participants had previously been using asthma medication. All were non-smokers. Of the 16 participants who replied to the questionnaire, 5 described their own health as 'good', while 10 described their health as 'very good'. 16 participants detailed their exercise habits in the questionnaire. The mean amount of exercise sessions per week was 6.4, and the mean time spent exercising per week was 5.8 hours.

DISCUSSION

In this group of healthy athletes with no self-perception of breathing problems, 10 (33%) participants had supraglottic obstruction compatible with EILO during the CLE test, of whom 2 also had an additional glottic obstruction. None had glottic obstruction only. This finding was unexpected and did not align with our

Table 4 Laryngeal findings during exercise in the 29 participating athletes

	Moderate-intensity exercise		Peak-intensity exercise	
	Glottic	Supraglottic	Glottic	Supraglottic
CLE subscore 0	29 (100%)	21 (72%)	22 (76%)	7 (24%)
CLE subscore 1	0	8 (28%)	5 (17%)	12 (41%)
CLE subscore 2	0	0	1 (3%)	9 (31%)
CLE subscore 3	0	0	1 (3%)	1 (3%)

The percentages (%) refer to the number with this score relative to the total number of participants. Scores ≥2 (below the black line) is compatible with EILO.
CLE, continuous laryngoscopy exercise; EILO, exercise-induced laryngeal obstruction .

initial hypothesis. Contrary to what we anticipated, a substantial number of athletes in our study displayed objective signs of EILO.

Our findings complement those of Irewall *et al*, who screened 89 cross-country skiers with CLE tests and identified supraglottic obstruction compatible with EILO in 27%.[2] Among these, 37% did not report respiratory symptoms. A disjunction between CLE findings and symptoms were also demonstrated in the prevalence study by Christensen *et al*, who invited randomly selected Danish youths to perform a CLE test.[1] Of those with laryngeal findings compatible with EILO, 26% reported no exercise-related symptoms during the previous 12 months.

Contrasting our study, both of these studies also included participants with a physician-diagnosed asthma, which should be kept in mind when comparing the results. Asthma and EILO may coexist or EILO may be misinterpreted as asthma as symptoms may be difficult to distinguish. It is therefore possible that studies investigating EILO and including patients with asthma will be over-represented by patients with EILO compared with a study with no self-reported breathing problems.

These prevalence studies above indicate that supraglottic laryngeal obstruction may be a relatively common phenomenon in healthy individuals, even when there are no subjective perception of breathing problems or other hallmark symptoms of EILO. The findings from Irewall *et al*, as well as our findings, indicate that this applies to athletes as well. However, it is worth mentioning that solely supraglottic obstruction can cause a lot of breathing problems, which may be resolved through training or surgery.[21 22]

In our study, few participants had significant glottic obstruction equaling to CLE subscore 2 or more and none without preceding supraglottic involvement, findings which support what Irewall *et al* found.[2] The pathophysiology of EILO is highly under-researched, and there is no evidence to explain this scenario. However, one may speculate that athletes with more pronounced glottic obstruction tend to experience more breathing problems, as glottic obstruction (at least in our clinical experience) produce more severe respiratory symptoms and abnormal breath sounds, which would be apparent both to the athletes themselves and to others. This is supported by Maat *et al*,[8] who found that subscore C (glottic obstruction) correlates more with subjective symptoms compared with supraglottic obstruction.

Thus, athletes with higher subscores at the glottic level would be more likely to have subjective breathing problems, making them ineligible for inclusion in this study. Furthermore, if glottic obstruction is indeed associated with more pronounced breathing problems, this would more likely be a less common finding among successful endurance athletes.

Implications for the diagnostics of EILO

It has previously been debated if a diagnosis of EILO should rest exclusively on the degree of laryngeal obstruction.[8 18] The European Respiratory Society/European Laryngological Society/American College of Chest Physicians (ERS/ELS/ACCP) consensus nomenclature published in 2015 clearly defines EILO as *'inducible laryngeal obstruction causing breathing problems'*.[5] Our findings suggest that we are at risk of overdiagnosing EILO in athletes if diagnostic decisions are solely based on observed laryngeal obstruction during a CLE test.

In the future, measuring translaryngeal resistance may be of assistance in diagnostic evaluations, as it provides an objective functional measure, contrasting the solely visual impression provided by the CLE test.[6 23]

While the patient's symptom history is undoubtedly important, it should be noted that proposing association between self-reported symptoms and EILO, asthma or other respiratory conditions has proven notoriously difficult.[24 25] Breathing problems or dyspnoea are subjective perceptions that are difficult to define and evaluate, and do not necessarily correspond to test results.[26] Interestingly, several of our participants with laryngeal obstruction, who did not report any breathing problems or respiratory symptoms in the questionnaire filled out before testing, on retrospectively viewing their laryngeal video recordings, questioned whether their laryngeal obstruction could explain some of the performance limitations they experienced. However, they had never related this to breathing problems before this study, which is a phenomenon also described in patients with asthma.[27] This underlines how difficult it can be for both physicians and patients to recognise and interpret perceptions of breathlessness during exercise.

In clinical practice, patients are usually referred and preselected for specific examinations based on the presence of respiratory symptoms. We know that targeting testing to groups of individuals with a high disease prevalence reduces the number of false positives.[28] Examining patients with breathing problems typical of EILO will, therefore, reduce the risk of false-positive EILO diagnosis in a clinical practice. To what extent evaluations have been correct, will gain support by a positive response to treatment (although placebo needs to be kept in mind) and preferably accompanied by objective improvement of the laryngeal findings.[22]

As in all areas of medicine, clinicians who are responsible for interpreting relations between EILO symptoms and laryngeal findings should handle the available information with great caution. The CLE test should be perceived as a tool in this process, supplementing and aiding evaluations in a population with high prevalence of EILO, such as athletes. There should be a low threshold for investigating respiratory symptoms with a CLE test.

Strengths and weaknesses of this study

Our test population was familiar with running on a treadmill, ensuring a highly trained population where all reached their maximum exercise level documented by high peak oxygen consumptions with a plateau (table 2). Thus, we know that we were studying larynxes exposed to very high airflows, both during our specific test situation and presumably also repeatedly and for long periods of time before this study. A limitation of the study was the relatively low number of participants. Furthermore, a study from Campisi *et al* demonstrated that 74% of patients referred for suspected EILO were female, which differs significantly from the sex distribution in our study.[29]

Incorporating athletes from a variety of sports disciplines within such a relatively small sample size may also be considered a limitation due to the increasing heterogeneity of the sample. Furthermore, the minimum duration for the minimum 4 weekly training sessions was not recorded, contributing to the heterogeneity of our population. Regrettably, neither subjective symptom scores (eg, Borg Rating of Perceived Exertion) nor the test personnel's objective evaluations of the participants' breathing problems during the test were recorded.

CONCLUSION

In a group of healthy well-trained endurance athletes with no prior perception of respiratory symptoms, we found that the laryngeal response to high-intensity exercise was diverse. Two-thirds of the participants had little or no signs of laryngeal obstruction, while one-third had supraglottic obstruction in line with a CLE subscore of 2. These findings support the ERS/ELS/ACCP nomenclature report from 2015,[5] emphasising that in addition to laryngeal findings during exercise, a diagnosis of EILO should rely on plausible respiratory symptoms.

Contributors PM and PHC have organised the data, carried out the analyses, drafted the initial manuscript and revised the manuscript. IJH, ME and LPB collected data, carried out initial analyses and have critically reviewed the manuscript for important intellectual content. MV and TH have conceptualised and designed the study and critically reviewed the manuscript for important intellectual content. ODR has conceptualised and designed the study, collected data and critically reviewed the manuscript for important intellectual content. HHC has conceptualised and designed the study, supervised data collection and critically reviewed the study manuscript for important intellectual content. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the 'Methods' section for further details.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval The Medical Research Ethics Committee of Western Norway approved the study (2014/00601). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available on reasonable request. In accordance with the approvals granted for this study by The Regional Committee on Medical Research Ethics and The Norwegian Data Inspectorate, the data files are stored securely and in accordance with the Norwegian Law of Privacy Protection. The data file 3 cannot be made publicly available as this might compromise the respondents' privacy. A subset of the data file with anonymised data can be made available to interested researchers on reasonable request to HHC (hsyh@helse-bergen.no), providing Norwegian privacy legislation and General Data Protection Regulation (GDPR). GDPR is respected and that permission is granted from The Norwegian Data Inspectorate and the data protection officer at Haukeland University Hospital.

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