

Exercise-Induced Inspiratory Symptoms in School Children

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Summary. Background and aims: Exercise-induced inspiratory symptoms (EIS) have multiple causes, one of which is exercise-induced laryngeal obstruction (EILO). There is limited knowledge regarding EIS in children, both in primary care practices and in pediatric asthma clinics. The aim of this study was to describe the feasibility of a diagnostic methodology and its results in a cohort of children with EIS referred to our tertiary pediatric pulmonary center. Methods: This study analyzed consecutively collected data in children from East Denmark and Greater Copenhagen referred during a 3½ years period. The continuous laryngoscopy exercise (CLE) test directly visualizes the larynx using a flexible laryngoscope during a maximal exercise test. A post-test questionnaire evaluated the subjective impact of the examination. Results: The study included 60 children (37 girls/23 boys) with a mean age of 14 years (range 9–18). The feasibility of the CLE test was 98%; 18 children (35%) had EILO, while 33 children (61%) showed no abnormalities. Other laryngeal abnormalities were observed in three children before the exercise test. Asthma medication was successfully discontinued in 13 (72%) children with EILO. A significantly greater proportion of children shown to have EILO in the CLE test reported coping better with their EIS than children with negative test (85% vs. 45%; $P = 0.03$). Conclusions: Continuous laryngoscopy during exercise is feasible and useful for identifying children with EILO. A correct diagnosis of EILO can help relieve patient anxiety, improve their coping with symptoms, and prevent unnecessary long-term and potentially harmful asthma treatments involving high-dose inhaled steroids. **Pediatr Pulmonol.** 2016;51:1200–1205. © 2016 Wiley Periodicals, Inc.

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INTRODUCTION

Respiratory symptoms during physical activity are common in children and adolescents, and the symptoms are frequently considered to be related to exercise-induced asthma (EIA). However, in some cases the standardized exercise test for EIA is negative, or asthma medication has no impact on patient- or parent-reported symptoms. A detailed history might suggest that the individual has exercise-induced inspiratory symptoms (EIS); this topic was extensively reviewed recently by Røksund et al.¹ Primary care physicians and pediatricians often confuse EIS in children with asthma, and there can be co-morbidity with different conditions, including asthma¹; thus, many children receive unnecessary asthma treatment. Although EIS involves a common spectrum of symptoms, it can be caused by several conditions, and currently the important overlap between pediatric pulmonology and otorhinolaryngology (ENT) can delay a correct diagnosis. One of the possible underlying conditions, exercise-induced laryngeal obstruction (EILO), can be observed using continuous laryngoscopy visualization. The definitions used for EILO have been

confusing in the past, so an international task force focusing on inducible laryngeal obstructions was recently created to determine consensus definitions and nomenclature.² EILO is considered to be caused either by a glottic obstruction in which an inappropriate adduction of

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the vocal cords results in sudden obstruction, that is, vocal cord dysfunction (VCD); or by a supraglottic abnormality in which the collapse of the arytenoid regions during inspiration, that is, exercise-induced laryngomalacia (EIL), can be documented or a combination of both.² Due to turbulent airflow, stridor will occur, and dyspnea arises or even progresses to panic reactions in addition to a general feeling of discomfort that is localized to the throat.

It is sometimes possible to use a detailed history to identify EILO, but previous attempts to use baseline flow-volume curves based on spirometry data to diagnose EILO in adolescents have not been successful.³ Hence, the gold standard for an EILO diagnosis is the continuous laryngoscopy exercise (CLE) test in which the laryngeal region is visualized using a flexible video laryngoscope during exercise at maximum effort.⁴ The CLE test is considered to be both time-consuming and demanding because it involves somewhat complex equipment and procedures and because it might not be feasible in children.

The aim of this study was to describe the feasibility and the results of conducting the CLE test in a group of children who were consecutively referred to a tertiary pediatric pulmonary center due to unexplained respiratory complaints during heavy exercise. Here we describe the clinical features, diagnostic conclusions, and interventions and the results of a follow-up questionnaire.

MATERIALS AND METHODS

This study analyzed consecutively collected data in children from East Denmark and Greater Copenhagen referred with EIIS from May 2011 to December 2015. The background population with age between 7 and 18 years in this region was approximately 3,35,000 children and adolescents (Statistics Denmark 2016). Prior to CLE-test, information about symptoms, inducers/triggers and sports activity, current asthma treatment, the results of previous EIA tests, and asthma workup results were obtained in addition to the hospital files or reports from the referring physicians.

The CLE test was performed according to the method originally described in detail by Heimdal et al.⁴ and subsequently implemented in Denmark by Christensen et al.⁵ The CLE test consists of continuous visualization of the laryngeal structures using a flexible laryngoscope, while the subject is exercising at maximum effort by running on a treadmill. We do not use simultaneously audio recording of the breathing sounds during the test and use no mouthpiece with pneumotach during the test to obtain visible tidal-volume curves. Normal mouth breathing was allowed. The workload was adjusted to a maximum intensity (Borg scale <8 and maximum heart rate >190 bpm) until exhaustion or until obvious

symptoms and/or an abnormality in the laryngeal region was observed. In case of concurrent asthma or a suspicion of such, a dose of beta-2 agonist was administered before the test to prevent or diminish any symptoms due to lower airway obstruction.

A positive EILO test was defined as visible mild, moderate to severe obstruction (score 1–3) in the glottic and/or supraglottic regions according to description by Maat et al.⁶ in combination with the patient reporting sensations of “throat obstruction” or their usual individual complaint and/or obvious objective symptoms of upper airway obstruction such as stridor, clutching at the throat, and the appearance of respiratory troubles. Negative tests were defined as no visible obstruction or objective symptoms or only mild (score = 1) visible obstruction, but without reporting any subjective complaints.

CLE tests were digitally recorded in case post-hoc evaluation was necessary. The same physician (FB) plus an assistant (LDP or MB) performed all of the CLE tests.

Spirometry was performed using Jaeger Master Screen Pro (CareFusion, Hochberg, Germany) according to ATS/ERS recommendations⁷ using Growing Lung⁸ as reference and presented in z-scores.

At least 3 months after the CLE test, all children completed a written questionnaire regarding their current respiratory status during physical activity. The entire questionnaire is available as online supplementary material (S-Text 1).

According to Danish law, approval from Institutional Review Board or Ethic committee for the present study is not required as only routine standard clinical data was collected and not primarily collected for this study.

RESULTS

Over the course of 42 months, 60 children (37 girls/23 boys) with a mean age of 14 years (range 9–18 years) were referred to our tertiary pulmonary center from other asthma clinics. Of these, five children did not show up for unknown reasons, and one child, a 13-year-old boy, refused to allow the introduction of the fiberscope though his nostril. Thus, 54 children were eligible for participation in the CLE test (Fig. 1).

The main reasons for referral were EIIS refractory to treatment with asthma medication and/or a previous negative asthma workup ($n=47$; 85%). Constriction in the throat and chest ($n=52$; 95%) were the most frequently reported symptoms. Two children reported episodes with near-syncope, dizziness, or pale skin. All children reported that they were reluctant to perform or had difficulties performing intense physical activity because of their symptoms, although 70% reported that they participated in sports at the elite level. Approximately 50% received asthma medication on the day of the CLE test (beta 2-agonists as needed and/or inhaled

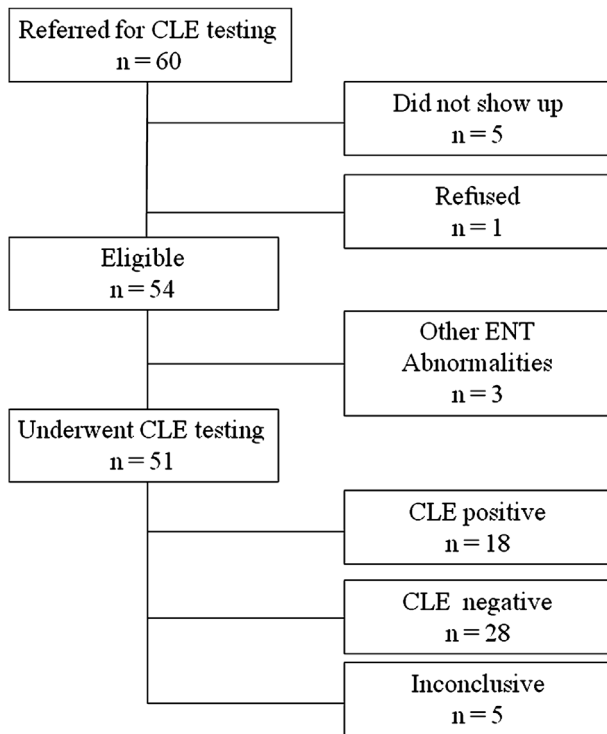


Fig. 1. Patient flowchart.

corticosteroids), despite a negative asthma history or negative asthma diagnosis. Asthma co-morbidity and EILO were suspected in 13% of the cases.

The baseline lung function of the cohort was normal, with a mean z-score (SD) $FEV_1 = 0.11$ (1.03); $FVC = 0.20$ (0.98); $FEV_1/FVC = -0.24$ (0.76), and $FEF_{25-75} = -0.25$ (0.95). The mean BMI (SD) was 19.9 (2.6). Arrangement and mounting of CLE test equipment was conducted with success and without complains in 54 of the 55 available children and thus exhibiting a feasibility of 98%. The CLE test was completed in 51 children while, due to obvious finding of other ENT abnormalities responsible for their symptoms, not in the remaining three children. No adverse events or complications were observed.

Glottic ($n = 2$: severe = 2), supraglottic ($n = 11$: mild = 3; moderate = 6; severe = 2), or combined ($n = 5$: mild = 1; severe = 4) obstruction of the upper airway during maximal exercise was observed in 18 children (35%), whereas no abnormalities were observed in 33 children (61%) (on-line Fig. S1–3). All children with positive CLE tests exhibited rapid (almost immediate) resolution of their symptoms after they stopped exercising during the CLE test. In five children, the results were inconclusive as there was no obvious objective laryngeal obstruction or stridor despite complaints of subjective symptoms; thus, these tests were not only inconclusive but could be considered negative results. In

the remaining three children, other previously unknown abnormalities were observed when they were at rest before initiation of the exercise test: one child had recurrent laryngeal nerve paralysis, one child had a severe laryngomalacia, and one child had a subglottic stenosis.

There was a trend towards an increasing referral rate over time from local pediatric departments for suspected EILO that varied from around 5–10 children per year from 2011 to 2012 to 22 children in 2015, although the relative number of cases with positive CLE tests did not change significantly over time (data not shown).

Combined EILO and asthma was documented in only two children, whereas classic EIA without EILO was documented in one child who showed exercise-induced airway obstruction, cough, and decreased $FEV_1 > 12\%$; in addition, beta-2 agonists substantially reversed the symptoms, and there was no sign of laryngeal obstruction.

No significant differences were found between positive and negative results according to sex, baseline lung function, BMI, or the use of asthma medication (Table 1). The children and their parents were informed about the results of the CLE test. Asthma medication was discontinued in the 13 cases with positive signs of EILO (72%). In six children, an ENT visit was scheduled to obtain a standard ENT evaluation and an evaluation for surgical intervention, and a surgical intervention was performed (arytenoidectomy) in one child with good results. In the remaining children, information about appropriate training programs and controlled respiration were provided.

Follow-up questionnaires were received from 86% of the cohort. After receiving the results of the CLE test and other related information, a significantly larger proportion of children with positive test results reported coping better with symptoms during exercise or reported that they no longer had symptoms compared to the group with negative test results (85% vs. 45% $P = 0.03$). A majority of the cohort (70%) found that in terms of comfort, the test was fairly or completely acceptable, and 86% would recommend that friends undergo a similar CLE test if appropriate. The results of the questionnaire are presented in Table S-1 (online Supplementary material).

DISCUSSION

Here, we report a cohort of Danish school children who were referred by their pediatrician or pulmonary/asthma specialist to our tertiary pulmonary pediatric department. Difficulty breathing during exercise was the primary reason for referral. The CLE test is unique in terms of documenting EILO, and we found high feasibility, acceptability, and yield in this age group. EILO was documented in 35% of the subjects in this highly selected group of children. This is an important finding, as asthma medication was inappropriate for these subjects and could

TABLE 1—Baseline Patient Characteristics

	Negative or inconclusive for EILO	Positive for EILO
n	33	18
Age in years	14.3 (2.2)	13.4 (2.0)
Sex (female/male)	57.5/42.5%	61.1/39.9%
Height (cm)	165.1 (10.5)	154.0 (31.9)
Weight (kg)	55.8 (10.9)	56.0 (25.6)
BMI	20.3 (2.8)	19.0 (2.1)
FEV ₁ (z-score)	0.03 (1.06)	0.29 (0.97)
FVC (z-score)	0.21 (1.05)	0.19 (0.85)
FEV ₁ /FVC (z-score)	−0.36 (0.79)	0.06 (0.58)
FEF _{25–75} (z-score)	−0.35 (1.01)	−0.02 (0.74)
Active participation in sports	73%	78%
Asthma medication	51%	61%

BMI, Body Mass Index; FEV₁, Forced Expiratory Volume in 1 sec; FVC, Forced Ventilatory Capacity; FEF_{25–75}, Forced Expiratory Flow over the middle one half of the FVC.

Data are reported as mean (standard deviation) unless otherwise indicated.

be discontinued in three out of four patients with EILO without worsening of their symptoms. Most children with EILO were very relieved when they were told that they had a harmless condition, and a large proportion reported that they had learned to cope with their EILO symptoms after they underwent CLE testing.

The exact prevalence of EILO is not known. In previous reports from tertiary centers, the proportion of positive cases was as high as 75%,^{9,10} while the estimated prevalence of EILO in young people 14–24 years old was approximately 7.5% in a Danish study⁵ and 5.7% in Swedish adolescents.¹¹ These numbers are uncertain; however, as laryngeal abnormalities may not give rise to any symptoms if the children only participate in low exertion exercise activities. Hence, children with EILO and a sedentary lifestyle may not have any symptoms of upper airway obstruction. The proportion of CLE-positive cases in this study was 35%. The yield of the CLE test is highly dependent on previous pulmonary work-up by the referring department. Intensive work-up prior CLE test may increase the yield and vice versa in a more unselected cohort with all kind of respiratory symptoms during exercise.

Previous studies have shown a higher prevalence of EILO in females, with a female/male ratio as high as 3:1.^{5,12,13} We, too, observed a female predominance; this was statistically non-significant, possibly because of our relatively small cohort. In terms of the clinical presentation, it is interesting and important to note that all of the referred children complained of the same spectrum of symptoms of upper airway obstruction during exercise, although a considerable proportion did not show any objective abnormalities during the CLE test. Hence,

symptom description does not necessarily predict abnormal findings in the airway, highlighting the complexity of these symptoms and conditions. Importantly, detailed questions about inspiratory and expiratory symptoms are key for identifying symptoms that might suggest airway obstruction and for discriminating between EILO and EIA.¹ EIA almost always evolves slowly during the first 3–15 min after exercise termination, and it mainly involves the expiratory part of the respiratory cycle.¹⁴ In contrast, EILO occurs at the peak of exercise intensity¹ and, as we reported here, disappears almost immediately after exercise is stopped. We found that participation in sports that demanded a high level of physical activity frequently caused the symptoms, and there was a trend for participation in elite level sports among the patients. In children, exertion alone can induce some uncomfortable symptoms that have no relation to EILO, asthma, or to other obvious airway disease. This emphasizes the importance of performing the CLE test. All of the included children demonstrated normal spirometry results before the test, and baseline flow volume curves did not predict EILO, which is in line with the fact that there is no evidence to suggest that EILO can be confirmed or rejected by a resting or post-exercise pulmonary function test.³

Interpretation of the CLE test was sometimes difficult, as many children presented with a slightly supraglottic anteromedial motion during peak intensity. If this motion was limited or mild and if no symptoms arose, we regarded this as normal, which has also been proposed by others.¹⁰ We confirmed that supraglottic abnormalities were the primary findings, and the combination of both supra- and infra-glottic obstruction was a secondary finding. This is in accordance with the theory that EILO actually begins within the supraglottic structures and that VCD is a secondary phenomenon¹ that might be seen in a larger proportion of children if the test is continued. In some children, the test was inconclusive, which again underlines the complexity of these cases. It is possible that some external triggers may not be present in the laboratory setting, as laryngeal obstructions can be induced by other triggers as well.² It is also possible that some children were not familiar with the use of a treadmill and did not achieve peak exertion intensity.

Some investigators have tried to validate a way to standardize the degree of obstruction by implementing the EILOMEA score,^{15,16} but we did not use this score because of its complex nature and the current lack of validation for its use for clinical purposes. The proposed scoring system of laryngeal obstruction by Matt et al.⁶ seemed more useful. However, there is certainly a need for standardization and agreement in this field and therefore, we decided only to use a dichotomized simple outcome (positive or negative) in this study.

Referral for EIIS is often due to a negative asthma workup, as EIA might be expected to be more frequent than EIIS/EILO. However, several studies^{5,13,17} have documented asthma and EILO comorbidity in some patients, although this was quite rare in our cohort. In one patient, there was obvious airway obstruction after the CLE test, and EIA was confirmed despite a previous normal finding in an EIA test. We think that the increased exercise intensity level in the CLE test might have triggered the documented bronchospasm, but this finding emphasizes the variability of EIA presentation, which is commonly acknowledged.¹⁸ In addition, children with positive EIA test results might not be referred for a CLE test if co-morbidity with EILO is not suspected by the physician, that is, if the symptoms are interpreted simply as uncontrolled/undertreated EIA.

When EILO is confirmed and asthma is excluded, the use of unnecessary asthma medication can be stopped. Since in this study, most of the patients participated in sports at the elite level, discontinuing the medication means that doping issues related to beta-2 agonists could be avoided. Secondly, the side effects of inhaled corticosteroids, such as growth retardation, hoarseness, and mycosis, are important issues,¹⁹ as there is a risk of high-dose administration in these children because of "intractable asthma." Hence, in this cohort it was actually possible to discontinue asthma treatment in a significant proportion of the participants. This is a very important reason to conduct the CLE test, which has often been dismissed as being too time consuming and possibly unnecessary, as EILO can be diagnosed by a negative asthma workup and characteristic symptoms. However, EILO is far more complex than previously thought. Indeed, EIIS is an umbrella term used for a group of common symptoms in a heterogeneous population of children that may have become reluctant to perform physical activity. Indeed, in some children, no abnormalities can be documented, despite clear subjective symptoms. In this study, we diagnosed abnormalities in the upper airway in some children when they were at rest, which is why we now recommend performing a routine ENT examination before performing the CLE test. This could avoid subjecting some children to CLE tests, and it is important to detect tumors or other extra-laryngeal obstructions before CLE testing.

A correct diagnosis of EILO is important for understanding the underlying symptoms, although the evidence for treatment is quite limited, as no randomized controlled studies have been conducted on therapy for exercise-related conditions such as EILO. The underlying pathology of EILO is heterogeneous, which is why clear definitions are needed. In classic EILO, the main treatments that have been proposed include psychotherapy, speech therapy, inspiratory muscle training, and lung physiotherapy, and these have been used with good

results.¹ However, previous studies have often been biased due to the use of different methods, cohort selection, or a lack of placebo. In our cohort, we explained the benign nature of EILO to the patients and provided information about proper breathing techniques, and this helped the children reduce their symptoms in many cases.

Surgery was performed in only one severe case with total supra-arytenoid collapse, and the result was satisfactory. The positive effects of surgical treatment have been reported previously,^{10,12,20,21} although the criteria for eligibility for surgery are not clear. Both objective and subjective parameters should be evaluated and taken into account. Although doctor-diagnosed mental instability might be suspected in some cases, this is not accepted as a basic and causative reason for the symptoms. Some overlying psychological distress cannot be ruled out, but this is thought to be related to the panic stemming from the very distressful episodes of acute respiratory obstruction that these children experience.

It has been proposed that some patients may experience relief as they grow older, as the laryngeal structure becomes tighter with age.¹ This observation is hampered by the fact that people tend to become more sedentary with age, so long-term follow up studies are needed.

Strengths and Limitations

Our cohort represents a common pediatric population that was referred from general pediatric outpatient clinics. Our results are important to all physicians, including general practitioners who treat children for respiratory problems, especially asthma. Our study did not include highly specialized ENT cases or subjects with known malformations in the upper airways. We cannot provide any information about prevalence as another adult clinic in our region may test adolescents; however, although our cohort is small, it is our impression that EILO is underestimated. Most importantly, many children who do not really have asthma may be using asthma medication. A disadvantage of the CLE test is that it is somewhat subjective; to minimize this, all tests were performed by the same team, which was trained by an experienced professional. This helps decrease intra-observer variability. Cases that were unclear cases could be re-evaluated using the recorded videos of the upper airway.

Since our cohort included younger children, our findings might be biased by premature cessation of exercise or by unfamiliarity with exercise on a treadmill. However, we monitored heart rate and dyspnea using the Borg scale, and most of the children were highly motivated; thus, we are convinced that the children performed the maximum exercise test correctly.

CONCLUSIONS

In conclusion, it is feasible to use the CLE test in school-age children. This method was used to identify children with EILO in a representative pediatric population, who were referred because of exercise-related respiratory symptoms. In cases with exercise-induced symptoms combined with a negative pulmonary workup and ENT examination, the CLE test should be performed to confirm or disprove EILO. A correct diagnosis can relieve patients' anxiety, improve how they cope with symptoms, and prevent unnecessary long-term asthma treatment. Further studies regarding interventional treatment and standardized objective evaluation in EILO are urgently needed.

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REFERENCES

1. Roksund OD, Heimdal JH, Olofsson J, Maat RC, Halvorsen T. Larynx during exercise: the unexplored bottleneck of the airways. *Eur Arch Otorhinolaryngol* 2015;272:2101–2109.
2. Christensen PM, Heimdal JH, Christopher KL, Bucca C, Cantarella G, Friedrich G, Halvorsen T, Herth F, Jung H, Morris MJ, et al. ERS/ELS/ACCP 2013 international consensus conference nomenclature on inducible laryngeal obstructions. *Eur Respir Rev* 2015;24:445–450.
3. Christensen PM, Maltbaek N, Jorgensen IM, Nielsen KG. Can flow-volume loops be used to diagnose exercise induced laryngeal obstructions? A comparison study examining the accuracy and inter-rater agreement of flow volume loops as a diagnostic tool. *Prim Care Respir J* 2013;22:306–311.
4. Heimdal JH, Roksund OD, Halvorsen T, Skadberg BT, Olofsson J. Continuous laryngoscopy exercise test: a method for visualizing laryngeal dysfunction during exercise. *Laryngoscope* 2006;116:52–57.
5. Christensen PM, Thomsen SF, Rasmussen N, Backer V. Exercise-induced laryngeal obstructions: prevalence and symptoms in the general public. *Eur Arch Otorhinolaryngol* 2011;268:1313–1319.
6. Maat RC, Roksund OD, Halvorsen T, Skadberg BT, Olofsson J, Ellingsen TA, Aarstad HJ, Heimdal JH. Audiovisual assessment of exercise-induced laryngeal obstruction: reliability and validity of observations. *Eur Arch Otorhinolaryngol* 2009;266:1929–1936.
7. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, Crapo R, Enright P, van der Grinten CP, Gustafsson P, et al. Standardisation of spirometry. *Eur Respir J* 2005;26:319–338.
8. Stanojevic S, Wade A, Stocks J, Hankinson J, Coates AL, Pan H, Rosenthal M, Corey M, Lebecque P, Cole TJ. Reference ranges for spirometry across all ages: a new approach. *Am J Respir Crit Care Med* 2008;177:253–260.
9. Roksund OD, Maat RC, Heimdal JH, Olofsson J, Skadberg BT, Halvorsen T. Exercise induced dyspnea in the young. Larynx as the bottleneck of the airways. *Respir Med* 2009;103:1911–1918.
10. Nordang L, Moren S, Johansson HM, Wenngren E, Nordvall L. Exercise-induced asthma could be laryngeal obstruction. Not uncommon among young sportsmen—avoiding the wrong treatment is important. *Lakartidningen* 2009;106:2351–2353.
11. Johansson H, Norlander K, Berglund L, Janson C, Malinovski A, Nordvall L, Nordang L, Emtner M. Prevalence of exercise-induced bronchoconstriction and exercise-induced laryngeal obstruction in a general adolescent population. *Thorax* 2015;70:57–63.
12. Maat RC, Hilland M, Roksund OD, Halvorsen T, Olofsson J, Aarstad HJ, Heimdal JH. Exercise-induced laryngeal obstruction: natural history and effect of surgical treatment. *Eur Arch Otorhinolaryngol* 2011;268:1485–1492.
13. Nielsen EW, Hull JH, Backer V. High prevalence of exercise-induced laryngeal obstruction in athletes. *Med Sci Sports Exerc* 2013;45:2030–2035.
14. Carlsen KH, Carlsen KC. Exercise-induced asthma. *Paediatr Respir Rev* 2002;3:154–160.
15. Christensen P, Thomsen SF, Rasmussen N, Backer V. Exercise-induced laryngeal obstructions objectively assessed using EILOMEA. *Eur Arch Otorhinolaryngol* 2010;267:401–407.
16. Norlander K, Christensen PM, Maat RC, Halvorsen T, Heimdal JH, Moren S, Rasmussen N, Nordang L. Comparison between two assessment methods for exercise-induced laryngeal obstructions. *Eur Arch Otorhinolaryngol* 2016;273:425–430.
17. Bjorck G, Bergstrom H, Nygren U, Hedlin G. Vocal cord dysfunction—differential diagnosis of asthma. Symptoms description and treatment suggestions. *Lakartidningen* 2006;103:3835–3836.
18. Randolph C. Pediatric exercise-induced bronchoconstriction: contemporary developments in epidemiology, pathogenesis, presentation, diagnosis, and therapy. *Curr Allergy Asthma Rep* 2013;13:662–671.
19. Kelly HW, Sternberg AL, Lescher R, Fuhlbrigge AL, Williams P, Zeiger RS, Raissy HH, Van Natta ML, Tonascia J, Strunk RC. Effect of inhaled glucocorticoids in childhood on adult height. *N Engl J Med* 2012;367:904–912.
20. Mandell DL, Arjmand EM. Laryngomalacia induced by exercise in a pediatric patient. *Int J Pediatr Otorhinolaryngol* 2003;67:999–1003.
21. Norlander K, Johansson H, Jansson C, Nordvall L, Nordang L. Surgical treatment is effective in severe cases of exercise-induced laryngeal obstruction: a follow-up study. *Acta Otolaryngol* 2015;135:1152–1159.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.



Figure E-1 Normal appearance of the larynx during exercise



Figure E-2 Supraglottic obstruction



Figure E-3 Glottic obstruction

Table E-1. Results of the follow-up questionnaire

	All	Positive for EILO	Negative for EILO
	n = 44	n = 13	n = 31
Question 1			
a.	16%	23%	15%
b.	18%	15%	15%
c.	36%	31%	39%
d.	30%	31%	31%
Question 2			
a.	14%	0%	23%
b.	86%	100%	77%
Question 3			
a.	2%	0%	0%
b.	70%	61%	77%
c.	23%	24%	23%
d.	5%	15%	0%
Question 4			
a.	43%	24%	50%
b.	36%	53%	30%
c.	11%	15%	8%
d.	10%	8%	12%
Question 5			

a.	32%	8%	39%
b.	46%	69%	35%
c.	11%	15%	11%
d.	11%	8%	15%

Question 6

a.	18%	23%	19%
b.	55%	61%	50%
c.	16%	8%	23%
d.	11%	8%	8%

E-text 1: Follow-up questionnaire

1. Overall, how would you describe the comfort level associated with undergoing the CLE test?

- a. Very uncomfortable
- b. Slightly uncomfortable
- c. Fairly acceptable
- d. Fully acceptable

2. Would you recommend that others who are your age undergo a CLE test?

- a. No, never
- b. Yes, absolutely

3. Did your chest/throat symptoms during exercise change after you underwent the CLE test?

- a. My symptoms have become worse
- b. My symptoms are unchanged
- c. My symptoms have improved
- d. I no longer have any symptoms

4. Did the CLE test result make any difference in how you cope with your symptoms during exercise?

- a. No not at all
- b. Yes, now I can control my symptoms better
- c. Yes, because I no longer have symptoms
- d. I do not know because I do not perform the same type or intensity of sport/physical activity

5. Did the information you received along with the CLE test make any difference in how you cope with your symptoms during exercise?

- a. No, not at all
- b. Yes, now I can control my symptoms better
- c. Yes, because I currently have no symptoms
- d. I do not know, because I do not perform the same type or intensity of sport/physical activity

6. Do you perform the same sport/physical activity as before undergoing the CLE test?

- a. No, I stopped performing that sport/physical activity
- b. Yes, I perform the same sport/physical activity
- c. Yes, but I perform it at a lower activity level
- d. Yes, I have resumed the sport/physical activity after the test