EXERCISE-INDUCED BRONCHOCONSTRICTION IN ATHLETES – A QUALITATIVE ASSESSMENT OF SYMPTOM PERCEPTION

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ABSTRACT

Background: A poor relationship between perceived respiratory symptoms and objective evidence of exercise-induced bronchoconstriction (EIB) in athletes is often reported; however, the reasons for this disconnect remain unclear. The primary aim of this study was to utilise a qualitative-analytical approach to compare respiratory symptoms in athletes with and without objectively confirmed EIB. **Methods:** Endurance athletes who had previously undergone bronchoprovocation test screening for EIB were divided into sub-groups, based on the presence or absence of EIB +/- heightened self-report of dyspnoea: (i) EIB-Dys- (ii) EIB+Dys+ (iii) EIB+Dys- (iv) EIB-Dys+. All athletes underwent a detailed semi-structured interview. **Results:** Twenty athletes completed the study with an equal distribution in each sub-group (n = 5). Thematic analysis of individual narratives resulted in four over-arching themes: 1) Factors aggravating dyspnoea, 2) Exercise limitation, 3) Strategies to control dyspnoea, 4) Diagnostic accuracy. The anatomical location of symptoms varied between EIB+Dys+ athletes and EIB-Dys+ athletes. All EIB-Dys+ reported significantly longer recovery times following high-intensity exercise in comparison to all other sub-groups. Finally, EIB+Dys+ reported symptom improvement following beta-2 agonist therapy, whereas EIB-Dys+ deemed treatment ineffective. **Conclusion:** A detailed qualitative approach to the assessment of breathlessness reveals few features that distinguish between EIB and non-EIB causes of exertional dyspnoea in athletes. Important differences that may provide value in clinical work-up include (i) location of symptoms, (ii) recovery time following exercise and (iii) response to beta-2 agonist therapy. Overall these findings may inform clinical evaluation and development of future questionnaires to aid clinic-based assessment of athletes with dyspnoea.

Key words: Athletes; Exercise-induced bronchoconstriction; Dyspnoea; Perception; Qualitative methods; Respiratory symptoms.

INTRODUCTION

The development of breathlessness and a degree of respiratory discomfort is an expected and appropriate response to vigorous physical activity and reflects the heightened ventilatory drive, mandated to successfully undertake such activity (1). In some athletic individuals however these sensations can become uncomfortable, cause distress and as a result directly impair exercise performance, i.e. they may be considered excessive, inappropriate or maladaptive.

In the assessment of an athletic individual presenting with troublesome exertional respiratory symptoms, clinicians thus face a challenge in differentiating what may be considered a physiologically appropriate airway response (i.e. normal) from breathlessness associated with an underlying abnormality or pathological condition (2).

The most common cause for abnormal or excessive exertional respiratory symptoms in young athletic individuals is exercise-induced bronchoconstriction (EIB); a condition characterised by transient airway narrowing that occurs in association with physical activity (3). The diagnosis of EIB in athletes, is often suspected by clinicians following an assessment of symptoms alone; with treatment frequently commenced without objective confirmation (4). This is despite evidence from several studies indicating that there is a poor relationship between the presence of respiratory symptoms and objective evidence of EIB (5-8). It is thus recommended that respiratory symptoms should not be relied upon and that objective testing (e.g. bronchoprovocation testing) is employed to establish a secure diagnosis (9).

The reasons underlying the poor precision of a symptom-based approach for the diagnosis of EIB in athletic individuals is currently unclear (10). Individual symptom reporting and the means by which a clinician establishes the clinical history may both influence diagnostic accuracy (11). Moreover, it may be that clinical focus, with a tendency to depend on standard asthma-type questions (e.g. does cold weather provoke your symptoms?), may impair diagnostic precision in the athletic population.

To date, there has been very little research specifically addressing these factors and qualitative research has not been robustly employed in this setting. A qualitative approach offers an opportunity to better understand how an athlete may perceive their breathing and respiratory sensations and this may then provide valuable insight to help direct clinical assessment tools, to improve the diagnosis of EIB.

The primary aim of this study was therefore to utilise a qualitative-analytical approach to compare respiratory symptoms in athletes, with and without, objectively confirmed EIB. A secondary aim was to explore the perception of breathing in athletes with evidence of EIB but without excessive or inappropriate dyspnoea; a common finding reported in studies 'screening' athletes (12). In order to achieve these objectives, perceptions and experiences during and following exercise were explored in athletes, to provide a detailed insight into potential reasons for the dissociation between symptoms and clinical test results.

METHODS

Study design

The present study employed a qualitative interview approach in athletes whom had previously been screened for EIB using the indirect bronchoprovocation test, eucapnic voluntary hyperpnoea (EVH) challenge and had completed the Allergy Questionnaire for Athletes (AQUA) (13) and Dyspnoea-12 (D-12) questionnaire (14). The AQUA has previously been validated as a reliable tool to quantify respiratory symptoms in athletic populations (13), whereas the D-12 quantifies both the physical and affective components of breathlessness (14). A component of the data reported here regarding EVH screening results has been reported previously, including details regarding EVH test methodology (8).

All athletes attended the laboratory, blinded to their objective test results (i.e. EIB status) prior to attending the laboratory to complete a semi-structured interview. The time between tests (i.e. laboratory testing and interview) was approximately one month and all assessments occurred within the same season. Ethical approval was obtained from the local universities research ethics committee and participants provided written informed consent (Ethics ID: RE20-01-12590).

Study population

Thirty-two athletes from a variety of sporting disciplines; i.e. runners, cyclists, triathletes (≥6 hours training/week) from a previously screened population of recreational and elite endurance athletes (8) were contacted through letter of invitation. Athletes were considered suitable for participation based on their previous diagnosis of EIB and perception of dyspnoea during exercise; (i) EIB positive (i.e. ≥10% fall in FEV_1) or (ii) EIB negative (i.e. <10% fall in FEV_1), with or without a heighted perceived dyspnoea score evidenced by a positive response to the relevant symptom based assessment component in the AQUA questionnaire; i.e. Q10 - “Did you ever feel tightness of your chest and/or wheeze” and Q13 – “Have you ever had shortness of breath, cough and/or itching of the throat following exercise”.). In addition, the D-12 score was employed to characterise the impact of the athlete’s respiratory symptoms and to ensure that athletes without dyspnoea had an entirely normal D-12 score; confirming their asymptomatic status (Table 2).

Athletes were approached for inclusion through purposive sampling, on the basis of how closely they met the desired characteristics of each sub-group. This allocation principle resulted in four sub-groups: (i) EIB negative without dyspnoea (EIB-Dys-); (ii) EIB positive with dyspnoea (EIB+Dys+); (iii) EIB positive without dyspnoea (EIB+Dys-); (iv) EIB negative with dyspnoea (EIB-Dys+). All athletes were non-smokers, free from respiratory, cardiovascular, metabolic and psychiatric disease, and any other significant medical condition, except EIB or mild asthma.

Semi-structured interview

Semi-structured interviews lasting approximately 45 minutes were conducted face-to-face by OP within the Clinical Research Facility at Northumbria University. A pre-devised semi-structured interview framework was employed, which was designed by healthcare professionals; namely, exercise physiologists, respiratory physicians and clinical psychologists with experience in the diagnostic assessment of athletes and patients with unexplained perceived breathlessness (Table 1). The framework consisted of open-ended questions designed to elicit and explore athletes' perceptions of dyspnoea but also invited participants to raise other pertinent issues that they considered important. All interviews were audio recorded, transcribed verbatim and anonymised.

Data analysis

Interview data were analysed by OP using thematic analysis according to the methods described by Braun and Clarke (15) to explore athletes individual experiences, perceptions and understanding of breathlessness. This process consisted of (i) familiarisation of the data by repeated listening to the interviews and reading of transcripts, (ii) generating initial codes, (iii) searching for themes, (iv) reviewing and refining themes, (v) defining and naming themes (vi) reporting examples of each transcript to highlight components of themes. Data was managed using NVivo 10 (QSR International, Victoria, Australia) qualitative data management and analysis software. Agreement of themes and sub-themes were discussed and revised with CE to ensure methodological rigour and analytical accuracy.

RESULTS

Study population

Thirty-two endurance athletes met the desired characteristics of each sub-group defined for this study and were invited to participate. Twelve athletes (38%) declined to participate or failed to respond to the invitation and thus twenty athletes (62%) (runners: $n = 9$, cyclists: $n = 3$ and triathletes: $n = 8$) who were competitive at either elite (i.e. either national or international standard ($n = 5$)) or recreational level (i.e. training/competing ≥6 hours/week) ($n = 15$) completed the study. An equal distribution of athletes formed each sub-group ($n = 5$). Clinical characteristics of each sub-group are presented in Table 2. To maintain anonymity, athletes were numbered 1 - 20: (i) EIB-Dys- **(P.1 - P.5**); (ii) EIB+Dys+ **(P.6 - P10)**; (iii) EIB+Dys- **(P.11 - P.15)**; (iv) EIB-Dys+ (**P.16 - P.20**).

Thematic analysis

Thematic analysis of individual narratives resulted in four overarching themes: 1) Factors aggravating dyspnoea, 2) Exercise limitation, 3) Strategies to control dyspnoea, 4) Diagnostic accuracy. The following section will provide a detailed overview of the themes and associated sub-themes that emerged during analysis. Direct quotations are provided to illustrate how specific examples correspond to each group. Parentheses following each quotation indicate participant number. A schematic of the cyclic nature of these themes is provided in Figure 1. The words printed in italics are contextualized examples of words pronounced by the athletes and contained in the meaning units. A comprehensive list of quotations is presented in Table 3 and throughout the results focus on findings that inform differentiation of EIB from non-EIB in those with dyspnoea.

Theme 1: Factors aggravating dyspnoea

Narrative assessed under this theme refers to scenarios or conditions associated with heightened perceived breathing discomfort during and/or post exercise. This theme consisted of two sub-themes: (i) Environment, (ii) Exercise intensity.

(i) Environment

The majority of athletes in all sub-groups reported breathing discomfort when exercising in dry cold conditions and importantly, all athletes with dyspnoea, regardless of EIB status (i.e. EIB+Dys+ and EIB-

Dys+) described dry cold air as a major stimulus to induce dyspnoea *"Cold weather really aggravates my breathing"* (**P.6-P.10; P.16-P.20).** However, only those with a positive diagnosis of EIB (i.e. EIB+Dys+ and EIB+Dys-) reported that exposure to aeroallergens (e.g. grass and pollen etc.) was a key trigger resulting in breathing discomfort: *"My chest is especially bad in high pollen counts"* **(P.10)**. Of note, all EIB+Dys- athletes provided comparable descriptions to EIB+Dys+ athletes regarding their perception of breathing when exposed to either cold air or aeroallergen: *"I feel like my airways are pulling in on each other"* **(P.15 - P.20).** In contrast however, EIB-Dys- athletes did not consider the perceived discomfort of breathing dry cold air to be uncomfortable or to have a detrimental impact on exercise performance: *"I actually prefer the cold"* **(P.5 -** EIB-Dys-**)**.

(ii) Exercise intensity

Low to moderate intensity exercise was not reported to cause breathing discomfort in any of the sub-groups of athletes. During high-intensity exercise, EIB-Dys- athletes described an increased effort and/or work of breathing, but this was not considered a limiting factor: *"My breathing rate increases and feels like it reaches a threshold, however I don't think it's limiting me in anyway, it doesn't cause any pain"* **(P.4).** In contrast, in all athletes reporting heightened dyspnoea (i.e. EIB+Dys+ and EIB-Dys+), high-intensity exercise was associated with performance limiting discomfort: *"My breathing is limiting me - I can't push as hard"* (**P.6-P.10; P.16-P.20).** In terms of the descriptors used, EIB+Dys- athletes provided similar descriptions to EIB+Dys+ athletes, however they did not perceive this degree of discomfort as abnormal or distressing.

Theme 2: Exercise limitation

A second theme was 'Exercise limitation'. This was related to factors resulting in a reduction in athletic performance. This consisted of two sub-themes: (i) Respiratory vs. muscular discomfort, (ii) Impact.

(i) Respiratory vs. muscular discomfort

Muscular discomfort was the main factor limiting exercise capacity in all EIB-Dys- athletes: *"It's your legs or your arms that go first rather than your lungs"* **(P.1-P.5).** In contrast, all athletes with dyspnoea reported breathing discomfort as the main exercise-limiting component: "*It's my lungs rather than my legs that limit me"* (**P.6-P.10; P.16-P.20).** The site of respiratory discomfort varied between all

EIB+Dys+ athletes (i.e. discomfort reported in the chest): *"The discomfort usually occurs at the top of my chest when I breathe in"* **(P.6)** and all EIB-Dys+ athletes (i.e. discomfort reported around the larynx/voice box region): *"I don't feel like it's in the lungs"* (**P.17)**. Despite EIB+Dys- athletes not reporting dyspnoea at study entry, the description of breathing discomfort was once again comparable with EIB+Dys+ when discussed in detail: *"Now I think about it, the limiting factor is probably my lungs - I feel tightness around my chest when I work hard"* **(P.12).**

(ii) Impact

All athletes, other than those who were EIB-Dys-, considered their breathing to inhibit athletic performance: *"I feel my speed is impeded as I can't really push as hard"* **(P.12).** The increased effort or work of breathing was considered distracting in most athletes: *"I would like to think it doesn't affect my performance but inevitably it does because you are concentrating on something other than the task. You're concentrating on one more thing than you need to"* **(P.9).**

Theme 3: Strategies to control dyspnoea

Strategies to control dyspnoea describe the techniques employed by athletes to reduce symptoms. This theme consisted of two sub-themes: (i) Breathing regulation and recovery, (ii) Treatment.

(i) Breathing regulation and self-reported recovery

Regardless of EIB status or perception of dyspnoea, all twenty athletes reported employing breathing techniques (e.g. slow, deep, controlled breaths) to either regulate breathing or alleviate dyspnoea during and following exercise: *"If I'm breathing in and out every third stride it regulates my breathing pattern"* **(P.5).**

Recovery time following high-intensity exercise in EIB-Dys- athletes was approximately 1-2 minutes. In contrast, recovery time was longer in both EIB+Dys+ and EIB+Dys- groups (range: 2-10 minutes). Of note, all EIB-Dys+ reported significantly longer recovery times (range: 10-60 minutes) in comparison to all other sub-groups.

(ii) Treatment

No strategies other than warming-up (e.g. light jogging and stretching etc.) prior to training and/or competition were reported by EIB-Dys- athletes. EIB+Dys- did not consider their breathing as 'abnormal' at study entry and had therefore not sought treatment. In contrast, all EIB+Dys+ and EIB-Dys+ athletes were prescribed inhalers; i.e. short-acting beta2-agonist (SABA) and/or inhaled corticosteroid (ICS), by either their primary care physician or sports medicine specialist; many on the basis of self-report (Table 2). EIB+Dys+ reported symptom improvement with medication: *"I've really got the medication side of things down to an art now"* **(P.6)**, however EIB-Dys+ deemed their treatment ineffective: *"I don't think my inhalers are helping me"* **(P.20)**.

Theme 4: Diagnostic accuracy

The fourth theme was 'Diagnostic accuracy'. This theme encompassed two sub-themes: (i) Prediction of EIB status, (ii) Knowledge of the condition.

(i) Prediction of EIB status

The majority of EIB-Dys- (5/5) and EIB+Dys+ (4/5) correctly predicted their EIB status. In contrast, the diagnostic accuracy of EIB was poor in both EIB+Dys- (1/5) and EIB-Dys+ athletes (0/5); i.e. in groups where misdiagnosis frequently occurs.

(ii) Knowledge of the condition

The twenty athletes across all four sub-groups provided a similar description of the 'typical' symptoms they associated with EIB (e.g. breathlessness, chest tightness, wheeze, cough etc.). The majority of athletes believed EIB would have a negative impact on airway health and also impede athletic performance if misdiagnosed and/or remained untreated *"If you can't manage it then it will likely have a negative effect on both health and exercise performance"* **(P.20).**

DISCUSSION

This study is the first to employ a qualitative research methodology to investigate the perception of breathing in athletes, with contemporaneous objective testing for EIB. Following thematic analysis of our dataset, four overarching themes arose that were considered relevant to the perception, impact and control of respiratory symptoms during exercise: 1) Factors aggravating dyspnoea, 2) Exercise limitation, 3) Strategies to control dyspnoea, 4) Diagnostic accuracy. Our findings highlight the complexity and intra-individual differences that exist in the subjective respiratory response to vigorous physical exertion, in athletic individuals.

As may be expected, the principal cause of exercise limitation reported by athletes with a normal dyspnoea questionnaire score was muscular fatigue and limb discomfort described as *"burning in the legs"* rather than any breathing / respiratory discomfort. In contrast, in athletes reporting dyspnoea (i.e. both those with and without EIB) respiratory limitation was reported as the principal factor limiting exercise capacity. This difference was only apparent from questions concerning vigorous intensity exercise; none of the groups reported troublesome or distressing respiratory symptoms during low intensity exercise. Asymptomatic athletes without EIB (i.e. a state that may be considered normal) reported that their breathing did require 'effort' but caused no other distress. In contrast with this, athletes with dyspnoea (i.e. EIB+ or EIB-) detailed a sensation of respiratory constraint, for example *"not getting enough air"* and *"feels like my airways are closing"*. Moreover, the heightened D-12 score in these participant's highlights both the physical and affective impact of this respiratory distress. Indeed, the scores reported on this questionnaire, by symptomatic athletes, are similar to that reported in other chronic respiratory disease states (16).

A key focus of this study was to determine, utilising the qualitative-analytical approach, whether any clinically relevant descriptors provide information in terms of differentiating those with and without EIB who present with dyspnoea. In this respect it was of note that anatomical location of the dyspnoea varied between sub-groups. Indeed, the majority of EIB+Dys+ athletes reported respiratory breathing discomfort in the chest (i.e. pectoral region and sternum), whereas in contrast, all EIB-Dys+ athletes reported symptoms in the upper airway around the neck (i.e. voice box region).

These differences, in the site of breathing discomfort, are consistent with previous literature (17) and may indicate the presence of upper airway closure precipitating dyspnoea and more specifically may indicate the presence of exercise-induced laryngeal obstruction (EILO); a mimic of asthma caused by closure of the laryngeal inlet, which does not respond to asthma medication (18-21).

Although some athletes in the present study may have had undetected EILO, this remains speculative given objective testing for EILO (i.e. continuous laryngoscopy during exercise) was not performed. Whilst it should be acknowledged that EIB and EILO may co-exist in the same patient (18), the observed differences in the origin of dyspnoea may provide utility in the context of referral for specialist lung function testing (e.g. indirect bronchoprovocation challenges and/or continuous laryngoscopy during exercise testing) (22).

It is important to acknowledge that the higher proportion of female athletes in the EIB-Dys+ sub-group may account, at least in part, for the heightened perception of dyspnoea. It is well established that sex-related differences exist in pulmonary mechanics during exercise (i.e. females perceive heightened breathlessness at the same relative intensity of exercise) (23).

The possibility also exists that some EIB-Dys+ athletes experiencing dyspnoea may have functional syndromes such as dysfunctional breathing, and may benefit from non-pharmacological approaches such as physiotherapy and/or breathing re-training techniques (24). Indeed posture and core stability exercises and/or inspiratory muscle training interventions have previously been shown to provide utility in eliminating dyspnoea in athletes when dysfunctional breathing is suspected (25, 26).

A commonly employed question in the clinical work-up of EIB is whether symptoms are affected by environmental factors (i.e. weather conditions) and specifically if dry cold air precipitates dyspnoea. It is of note that the majority of athletes reported worsening of symptoms in cold weather, irrespective of whether EIB was present on objective testing. This underlines the poor diagnostic value of this question; one that is often felt to have diagnostic utility; i.e. cold weather is a recognised trigger for asthma and thus deemed useful in the diagnosis of EIB. Similarly, the majority of athletes, across all groups, reported employing techniques to regulate their breathing during exercise, and thus closed questions concerning the rate and depth of breathing (e.g. *"is your breathing rapid?")* would appear to provide

limited diagnostic value. In contrast, questions regarding recovery time and response to inhaled therapy were diagnostically informative.

A secondary aim of this study was to explore the perception of breathing in athletes with evidence of EIB but without dyspnoea. Indeed in studies where athletic teams are screened for EIB it is common to encounter athletes who have EIB yet report few symptoms (12). The explanation for this disconnect is not currently clear and may be considered akin to the asymptomatic airway-hyper-responsiveness observed in the general population (27). In the current study, when comparing these sub-groups, we found that the majority of EIB+Dys- athletes consistently provided very similar descriptions of breathing sensations during exercise as EIB+Dys+ athletes. There are perhaps two plausible explanations for this. Firstly, EIB+Dys- athletes may have experienced EIB since they were young (i.e. childhood asthma) and therefore become accustomed to such breathing sensations during exercise and thus associate the sensation of dyspnoea during exercise as 'normal'. Secondly, personality and trait anxiety may play an important role in symptom perception (28). For example, one EIB+Dys- described becoming breathless earlier than expected during exercise, however associated this with *"having a bad day"* rather than cause for concern. This observation provides support for the argument that athletic squads may benefit from screening to ensure that respiratory health is optimised and maintained. This is particularly important for certain athletic populations at high-risk of developing EIB, e.g. elite level swimmers (3).

The difficulty in differentiating between athletes experiencing heightened dyspnoea with and without EIB is underlined in primary health care. In the current study all athletes with perceived dyspnoea reported having previously discussed their breathing with their doctor and all had previously been prescribed inhalers. These observations are supported by previous research detailing that primary care physicians in the United Kingdom and United States often prescribe medication without objective evidence of EIB. As might be expected, the majority of EIB-Dys+ athletes who had been prescribed inhaler therapy, reported that this treatment was ineffective (29).

Methodological considerations / future research

In the current study, qualitative interviews were used for data collection, however as with all interview studies the kind of data generated is limited to the perspective of a self-selected group of participants. Nevertheless, this perspective offers useful insight into experiences and views that can help to explain findings from larger studies. Moreover despite our modest sample of 20 interviewees we did reach analytic saturation and many of the perspectives discussed in this study resonate with other relevant studies (30), thereby increasing confidence in the credibility and transferability of the findings.

Finally, it is also important to acknowledge that some of the athletes in the current study experiencing dyspnoea without objective confirmation of EIB (i.e. EIB-Dys+) may have had underlying disease (e.g. undetected cardiac abnormality). Although none of the participants reported a prior history of cardiovascular or metabolic disease, neither electrocardiogram exercise testing nor echocardiography stress testing was performed to rule out other clinically relevant causes of exertional dyspnoea (e.g. heart valve disease or haemodynamic disturbances etc.). This is an important consideration for future studies appraising the perception of breathing during exercise in symptomatic athletes.

Conclusion

In summary, this detailed qualitative approach to the assessment of breathlessness reveals that there are few features that are helpful in distinguishing between EIB and non-EIB dyspnoea in athletes. Important differences that may provide value in the clinical work-up, observed in this study, include (i) location of symptoms (ii) recovery time following exercise and (iii) response to beta-2 agonist therapy. In contrast, questions classically employed regarding environmental triggers (i.e. breathing dry cold air) appear to be of limited diagnostic value. Overall the findings from this study should inform clinical evaluation and the development of future questionnaires and risk prediction algorithms to aid the clinic-based assessment of athletes with troublesome exertional respiratory symptoms.

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COMPETING INTERESTS

The authors have no real or perceived conflict of interest in respect of this manuscript.

CONTRIBUTION STATEMENT

OP, JH, LA, CE involved in the conception and design of study. OP, JH, LA, MT, CE involved with drafting and critical revision of manuscript and final approval of the version to be published.

GUARANTOR STATEMENT

OP confirms full responsibility for the content of the manuscript.

TABLE HEADERS

Table 1. Semi-structured interview framework.

Table 2. Clinical characteristics.

Table 3. Example quotations describing the perception of breathing during exercise.

Table 1.

Open ended questions
How would you describe your sensations of breathing during exercise?
- How would you describe normal breathing during exercise?
- What physical breathing sensations do you associate with exercise?
- How does your breathing sound during exercise?
- Describe your breathing during low intensity exercise.
- Describe your breathing during high intensity exercise.
- What cues do you associate with exercise at low, moderate, high intensity – differentiate?
Describe a time when breathing–either during or after exercise–has felt unusual.
- At what intensity of exercise did this occur?
- Sporting discipline?
- Where did this occur?
- When: Training? Competition?
- How often does this occur?
- Environmental conditions?
- How long does it last?
- How did you recover?
When do you think about your breathing during exercise?
- Why?
- How does this affect your breathing?
- How does this affect your performance?
- What internal sensations do you think about during exercise?
How do you control your breathing during exercise?
- Slow down?
- Breathing regulation/timing?
- Breathing techniques?
- Count strides?
- Other individually devised techniques?
Recovery - How long does it take to recover?
- What would you consider normal recovery after exercise?
- Describe the difference in your breathing post exercise?
When symptoms do you associate with EIB?
- Do you think athletes with EIB are at a disadvantage during sport?
Do you know anyone with EIB?
- How do they describe their symptoms?
- Describe their experiences and/or situation when this occurs.
- How does this affect their life and/or performance?
Is there anything else you would like to discuss that we have not covered?
On reflection do you expect to be diagnosed with EIB?

Table 2.

Variables	EIB-Dys- (P.1 – P.5)	EIB+Dys+ (P.6 – P.10)	EIB+Dys- (P.11 – P.15)	EIB-Dys+ (P.16 – P.20)	Total
Sex (M:F)	5 : 0	4 : 1	5 : 0	2 : 3	20
Age (years)	31 ± 7	33 ± 7	36 ± 9	32 ± 8	33 ± 8
BMI ($kg \cdot m^{-2}$)	22.8 ± 2.7	24.8 ± 2.3	25.1 ± 2.1	22.2 ± 1.4	23.7 ± 2.4
Hours training/week	8 ± 2	7 ± 1	7 ± 2	8 ± 2	7 ± 2
FEV_1 (L)	4.64 ± 1.11	4.14 ± 0.87	4.02 ± 0.74	3.67 ± 0.26	4.12 ± 0.82
FEV_1 (% predicted)	111.8 ± 18.8	101.9 ± 12.3	95.6 ± 8.8	100.9 ± 10.2	102.5 ± 13.4
FVC (L)	5.48 ± 1.38	5.45 ± 1.00	5.40 ± 0.89	4.57 ± 0.57	5.22 ± 1.00
FVC (% predicted)	110.3 ± 20.6	113.1 ± 12.8	106.1 ± 9.7	107.0 ± 11.3	109.1 ± 13.4
FEV_1/FVC	85.4 ± 5.8	75.6 ± 3.6	74.4 ± 3.3	80.6 ± 4.9	79.0 ± 6.1
Post EVH fall in FEV_1 (%)	2.1 ± 1.9	21.7 ± 4.5	17.8 ± 2.8	4.1 ± 2.3	11.5 ± 6.1
D-12 Score	0 ± 0	14 ± 2	0 ± 0	13 ± 2	7 ± 7
Treatment					
- Short-acting beta2-agonist (SABA)	Nil	3	Nil	1	4
- Inhaled corticosteroid (ICS)	Nil	Nil	Nil	Nil	Nil
- SABA + ICS	Nil	2	Nil	4	6

Table 3

Themes / sub-themes	Sub-group	Example quotations
Factors aggravating dyspnoea		
(i) Environment	EIB-Dys- **(P.1 – P.5)**	*"When it is colder and I'm running hard I do tend to struggle a bit. I tend to perform better in warmer temperatures. However I wouldn't consider the cold to impair my performance"* **(P.3).**
		"I actually prefer the cold rather than exercising in high temperatures such as high teens or above twenty degrees" **(P.5).**
	EIB+Dys+ **(P.6 – P.10)**	*"Cold weather really aggravates my breathing. I just know that [the cold] is one of my triggers and although in the last couple of years I've not had a problem training outside when it has been cold, when I was in my teens it used to affect me a lot"* **(P.6).**
	EIB+Dys- **(P.11 – P.15)**	*"I suppose symptoms occur when I'm performing very hard efforts in cold conditions. My breathing starts sounding wheezy and other athletes can hear me when I'm on their shoulder. I feel like my airways are pulling in on each other"* **(P.15).**
		"Freshly cut grass does affect my breathing slightly" **(P.13).**
	EIB-Dys+ **(P.16 – P.20)**	*"In the winter I get a lot of flare ups. I think it's the cold air that acts as a trigger. When riding my bike in the cold air I struggle quite a lot. I always need to carry my inhaler in the winter whereas in the summer if I forget I can get away with it"* **(P.19).**
(ii) Exercise intensity	EIB-Dys- **(P.1 – P.5)**	*"I'd probably say moderate intensity exercise is on the verge of just losing the ability to hold a conversation"* **(P.1).**
		"Breathing rate increases and feels like it reaches a threshold where you can't physically breathe any faster. However I don't think that's limiting me in anyway, it doesn't cause any pain" **(P.4).**
	EIB+Dys+ **(P.6 – P.10)**	*"It seems however fit I am once I get into a certain sort of intensity my breathing is just not there. However much I train I don't seem to get past a certain point because my breathing is limiting me – I can't push as hard"* **(P.8).**
	EIB+Dys- **(P.11 – P.15)**	*"You do become aware of it [work of breathing] and it's something that sort of limits you. It's something that you have to consciously control I suppose, trying to get into a rhythm of breathing"* **(P.14).**
	EIB-Dys+ **(P.16 – P.20)**	*"I only start to struggle when I'm doing hard efforts. I feel like my airways are tightening and sucking in on each other every time I try to breathe so I can't get enough air"* **(P.20).**
Exercise limitation		
	EIB-Dys- **(P.1 – P.5)**	*"No I wouldn't say there was discomfort in breathing but it's difficult. It's sometimes difficult to regulate but it's more muscular. I think it's your legs or your arms that go first rather than your lungs"* **(P.5)**.
		"Not in terms of sound, it gets louder due to the amount of air you're taking in. The sort of depth of the inhale and exhale, it doesn't change in tone, just gets louder and becomes more frequent" **(P.5)**.
	EIB+Dys+ **(P.6 – P.10)**	*"It's my lungs rather than my legs that limit me. Last weekend, my legs were great but the breathing just wasn't there"* **(P.8)**.
		"The discomfort usually at the top of my chest when I breathe in" **(P.6).**

(i) Respiratory vs. muscular discomfort	EIB+Dys- **(P.11 – P.15)**	*"I would definitely say I get a wheezing sound from the chest when I start to struggle to breathe"* **(P.8).** *"When the chest tightness starts, I also get headaches in some short races"* **(P.7).** *"When I get to the point where I can't continue it's more due to muscle ability as opposed to the lungs"* **(P.13)**. *"Now I think about it, the limiting factor is my lungs - I feel tightness around my chest when I'm working hard. If I'm doing a time-trial and feeling fresh it will be my lungs that are the limiting factor"* **(P.12).** *"Normally I don't have any sort of symptoms of breathlessness other than what you would expect from exertion. However, occasionally I do feel more breathless than I would expect to be at certain intensity. I just put it down to having a bad day"* **(P.14).** *"I would say the slight wheeze and soreness I experience is a direct consequence of that [chest tightness]"* **(P.11).**
	EIB-Dys+ **(P.16 – P.20)**	*"It's my breathing that starts to go first. It's my opinion that if I can't get a full breathe of air I'm not getting enough oxygen in my body and it starts affecting my muscles"* **(P.16).** *"It feels like, it's hard to describe, almost a constriction, not in the chest it's more here [points to throat] when I inhale. I don't feel like it's in the lungs"* **(P.17).**
(ii) Impact	EIB-Dys- **(P.1 – P.5)**	*"I don't consider my breathing to affect my performance - it's not limiting"* **(P.3).**
	EIB+Dys+ **(P.6 – P.10)**	*"I would like to think it doesn't affect my performance but inevitably it does because you are concentrating on something other than the task. You're concentrating on one more thing than you need to"* **(P.9).** *"I'd say into my twenties, the last two or three years it's gradually got worse and affected my performance to a greater extent"* **(P.10).**
	EIB+Dys- **(P.11 – P.15)**	*"I feel my speed is impeded as I can't really push as hard"* **(P.12).**
	EIB-Dys+ **(P.16 – P.20)**	*"Yes, an example would be where I got to halfway on the course and had no pace. I was just plodding round slowly, I was going light and I just couldn't get a breath, struggling to move the pedals. It was right down the gear set where it would normally be. I just couldn't breathe. I ended up dropping out of the race. I just couldn't catch my breath at all"* **(P.19).** *"I've got quite an active job and I like to be quite active so at times it can ruin my quality of life"* **(P.19).**
<u>Strategies to control dyspnoea</u>		
(i) Breathing regulation and self-reported recovery	EIB-Dys- **(P.1 – P.5)**	*"Quickly, easily within a minute, probably less than that and it would be back to normal, comfortable breathing"* **(P.4).**
	EIB+Dys+ **(P.6 – P.10)**	*"My training partners recover a lot quicker. I'd say I take longer to recover"* **(P.9).** *"I'd usually recover within ten minutes, but sometimes when I've trained in the cold weather, I can be a little wheezy and tight chested afterwards sat at home"* **(P.9).**
	EIB+Dys- **(P.11 – P.15)**	*"I would be back to a decent level of breathing in a couple of minutes which I would think is a normal length of time"* **(P.13).** *"If that tightness is there, I might be coughing for an hour after I've finished my session"* **(P.12).**

(ii) Treatment	EIB-Dys+ **(P.16 – P.20)**	*"At least ten minutes minimum [recovery] in terms of my breathing regulation, but sometimes later on it still feels tight for a while"* **(P.16).**
	EIB+Dys+ **(P.6 – P.10)**	*"I've really got the medication side of things down to an art now. I've been using it for the last four or five years"* **(P.6).**
		"My doctor suggested that I take quite high doses of salbutamol – about three times per day. To a certain point it was effective when I first started using it, however it now seems less effective and I'm using it just for the sake of it" **(P.10).**
		"I think if anything, the exercise really helps because it builds you, it strengthens your respiratory system. The training has benefited me and keeps my asthma under control" **(P.6).**
		"I would definitely consider supplementing my diet – in fact I think I would prefer to do that instead of using my inhaler" **(P.7).**
	EIB-Dys+ **(P.16 – P.20)**	*"I don't think my inhalers are helping me"* **(P.20).**
Diagnostic accuracy		
(i) Prediction of EIB status	EIB+Dys+ **(P.6 – P.10)**	*"I think I just panic due to lack of confidence, I think it's in my head"* **(P.8).**
	EIB+Dys- **(P.11 – P.15)**	*"Possibly yes, because when I took part in the first part of the experiment [EVH challenge] I did feel as though I had chest tightness. I wasn't expecting to, but it did feel tight"* **(P.12).**
	EIB-Dys+ **(P.16 – P.20)**	*"I don't think so because I go through long periods where I don't have any symptoms, whereas there are certain situations like the cold weather where my chest becomes tight"* **(P.18).**
		"I would like to think so because if that's not the case then I'm a bit concerned what the matter is" **(P.19).**
(ii) Knowledge of the condition	EIB+Dys+ **(P.6 – P.10)**	*"Being tight chested during exercise and wheezing after exercise. Those are the two signs that would make me think someone is suffering with asthma"* **(P.9).**
	EIB-Dys+ **(P.16 – P.20)**	*"It depends if you can manage it. If you can manage it then you will be on a level playing field. If you can't manage it then it will likely have a negative effect on both health and exercise performance"* **(P.20).**

FIGURE LEGENDS

Figure 1. Themes and associated sub-themes related to perceived dyspnoea.

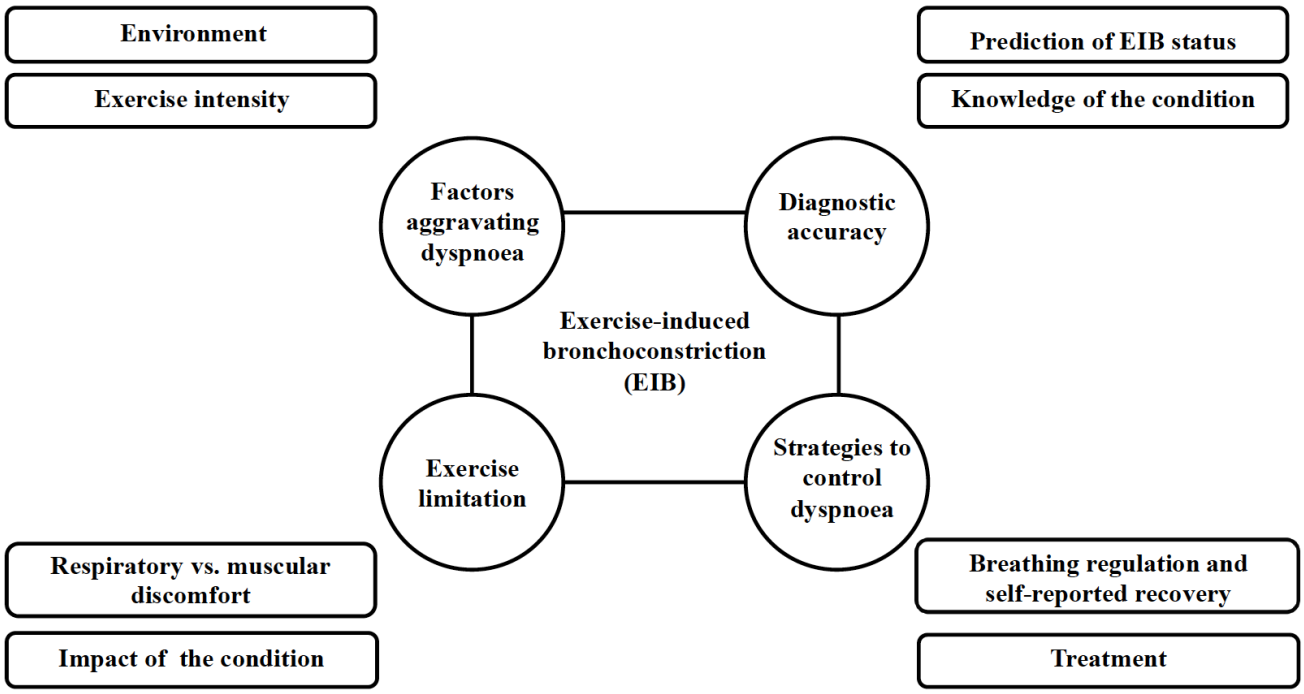
Environment
Exercise intensity
Prediction of EIB status
Knowledge of the condition
Factors aggravating dyspnoea
Diagnostic accuracy
Exercise-induced bronchoconstriction (EIB)
Exercise limitation
Strategies to control dyspnoea
Respiratory vs. muscular discomfort
Impact of the condition
Breathing regulation and self-reported recovery
Treatment

Figure 1.

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