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Usage of and attitudes toward heat- and moisture-exchanging breathing devices among adolescent skiers

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Abstract

Heat- and moisture exchanging breathing devices (HME) humidify and heat inhaled air and prevent exercise-induced bronchoconstriction. HMEs have potential as primary preventers against airway damage and asthma induced by exercise in sub-zero temperatures. HME usage among athletes has not been previously investigated.

This study surveyed the usage of and attitudes towards HMEs among elite skiers.

We invited all 347 students from Swedish National Elite Sports Schools in cross-country skiing and biathlon to participate in a web-survey. The response rate was 55%, 53% were women, 30% had asthma, and 87% were cross-country skiers. Their mean (range) age was 17 (15-19) years.

HMEs were used often or occasionally by 71% of respondents, while. 68% reported respiratory symptoms while training in sub-zero temperatures. The most common temperature threshold for using HMEs was −15 °C. Almost all participants believed that HMEs prevent airway problems induced by training in cold. The participants were motivated, and confident in succeeding, to increase their HME usage during exercise in −10 °C or colder, if recommended.

Swedish adolescent skiers commonly use HMEs and have positive attitudes towards increased HME usage. HMEs may constitute a simple and effective prevention strategy against airway symptoms and asthma among winter endurance athletes.

Keywords: heat- and moisture exchanging breathing devices, asthma, cross-country skiing, exercise-induced asthma, winter sports, cold temperatures

1. Introduction

The prevalence of asthma is high among winter endurance athletes, such as cross-country skiers and biathletes, and it is time to intensify preventive measures against airway morbidity in this population. In fact, the prevalence of asthma among Swedish elite cross-country skiers appears to have increased over the past twenty years, from 15%in 1994[1] to 27% in 2019[2]. In comparison, prevalence in the 2019 age-matched reference group was 19%, but is typically around 10% in the general population[3,4]. The high prevalence of asthma among winter endurance athletes is believed to be caused by repeated and prolonged drying of the airways. Inhalation of cold and dry that, through water loss from the lower airways, increase intracellular osmolarity, cell shrinkage, and release of inflammatory and bronchoconstrictive mediators that over time damage the airways, inducing bronchial hyperresponsiveness and asthma[5].

Asthma onset among elite cross-country skiers and Olympic athletes has previously been reported to occur during adulthood after several years of hard training[6,7]. Our group has recently shown that asthma onset among cross-country skiers and biathletes occurs mostly during adolescence, early in their athletic career[2,8]. It is thus evident that over these past decades, physicians, scientists, and other responsible for athletes' health have failed to prevent this "occupational disease" among winter endurance athletes.

Based on the assumed pathophysiology of asthma among winter endurance athletes, a heat- and moisture exchanging breathing device (HME) might be a simple and suitable preventive intervention. An HME increases the temperature and the humidity in inhaled air[9] and can alleviate exercise-induced asthma (EIA) during physical activity in sub-zero air [9-11], room temperature[12] or dry[13] air, as effectively as premedication with a bronchodilator[14]. Recently, use of an HME by healthy winter endurance athletes was shown to attenuate lung function decrements and respiratory symptoms induced by heavy exercise in -20°C[15]. HMEs can be used without large inconvenience and do not appear to limit exercise capacity[15,16,17].

Increased or improved HME usage could constitute a simple and effective preventive strategy against airway morbidity among winter endurance athletes. A first step would be to map the current situation. Hence, the aim of the present study was to survey the usage of and attitudes towards HME usage among Swedish elite junior cross-country skiers and biathletes.

2. Materials and methods

2.1 Subjects

All students (n=347), from Swedish National Elite Sports Schools in cross-country skiing and biathlon, hereafter referred to as skiers, were invited to participate in the survey. These upper secondary sports schools are located in 10 cities throughout the country, except for the southernmost part of Sweden. A total of 191 (55%) students responded to the study questionnaire. The National Elite Sports Schools were divided into three geographical groups with mean temperatures in January 2015-2020 ; South (Ulricehamn [−0.7 °C] , Torsby, Mora [−4.4 °C]), Middle (Åsarna, Östersund [−5.2 °C], Sollefteå , Järpen) and North (Lycksele [−10.0 °C], Boden [−10.3 °C], Gällivare [−12.7 °C])[18] .

2.2 Study design

The study was conducted between autumn 2017 and winter 2018 as a cross-sectional web-survey. The survey contained questions about sex, age, respiratory symptoms, asthma, allergies, asthma medication usage, main sport, and the skiers' usage of and attitudes towards HME usage. One reminder was sent out. The recruitment and survey of athletes were performed in collaboration with The Swedish Ski Federation, The Swedish Biathlon Federation, and teachers/trainers at the schools. The study was approved by the Ethical Review Board in Umeå, Sweden. Written informed consent was obtained from all study subjects.

2.3 Key study variables

Asthma was present if the participant answered "Yes" to the question "Has a doctor ever said you have asthma?".

Current asthma was defined if the participant had *asthma* and answered "Yes" to "Have you used any asthma medication, including inhalers, sprays or tablets in the last 12 months?"

"Have you ever experienced any wheeze or whistling from the airways during the last 12 months?" ("yes", "no"),

Presence of *cold-related respiratory symptoms* was based on the question "Do you experience respiratory problems when exercising in cold/sub-zero temperatures?". Responses were dichotomized into "yes" ("often" or "occasionally") and "no" ("never").

Exercise-induced respiratory attack; "Have you had a respiratory attack connected to exercise in the last 12 months?" (yes, no).

Hay fever; "Do you suffer from hay fever or other allergies with symptoms affecting the eyes and/or nose?" (yes, no).

Usage of HME: “Do you use an HME in cold temperatures?”. Responses were dichotomized into “yes” (“yes, often” or “yes, occasionally”) and “no” (“never”).

Belief was based on the question “Do you think an HME can prevent respiratory problems?” Responses were dichotomized into “yes” (“yes, often” or “yes, partly”) and “no” (“never”).

Motivation was based on the question “If you were recommended to use an HME every time you exercise at −10 °C or colder, how motivated would you be to do that?” and reported from an ordinal scale from 1 to 10. Responses were arbitrarily dichotomized at group medians to high (≥7) and intermediate-low (<7) motivation.

Confidence was based on the question “Would you succeed to follow a recommendation to use an HME every time you exercise in −10 °C or colder?” and reported on an ordinal scale from 1 to 10. Responses were also arbitrarily dichotomized at group medians to high (≥8 points) and intermediate-low (<8 points) confidence.

Temperature threshold was based on the question “At what temperature, or colder, do you often or always use an HME?”. From a drop-down list, participants could choose any temperature between − 5 °C and −20 °C.

Relief was based on the question “Does using an HME relieve airway symptoms when exercising in cold/sub-zero temperatures?” and reported on an ordinal scale from 1 to 10, where 1 correspond to “not at all” and 10 to “very much”. The question was only answered by HME users.

Hindrance was based on the question “Does using an HME affect your training negatively?” and reported from an ordinal scale from 1 to 10, where 1 correspond to “not at all” and 10 to “very much”. The question was only answered by HME users.

Additional questions were:

“At what type of exercise do you usually use an HME?” (“Low intensity”, “High intensity” or “Both”).

“Which brand of HME do you use most?” (“Airtrim®”, “Lungplus®”, “Buff® or similar” or “Other brand”).

“Have you ever used an HME during a competition?” (“yes”, “no”).

Exercise was reported on an ordinal scale from <6, 6-7, 8-9, and so on up to >19 hours/week and based on the question “In the last 12 months, how many hours per week on average do you usually exercise/compete so much that you get short of breath or start sweating?”.

2.4 Statistics

Data analysis was done in R version 3.6.0. Pearson Chi-square test was used for group comparisons of categorical variables, HME usage by age and school groups. Median, interquartile ranges (IQR), and Mann-Whitney-Wilcoxon test was used for group comparisons of ordinal variables, such as temperature threshold and motivational score. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Study population

Of the 191 responding skiers, 167 (87%) were cross-country skiers, and the remaining 24 (13%) were biathletes. The respondents had a mean (range) age of 17 (15-19) years; 101 (53%) were women. A majority of the skiers (55%) trained 10-13 hours/week, while six skiers trained <6 hours/week, and three skiers trained ≥18 hours/week. Current asthma was reported by 30% of the skiers, with no difference between the sexes. Most of the skiers, 68%, reported having respiratory symptoms related to exercise in cold temperatures often or occasionally (**Table 1**).

3.2 Usage of HME

A total of 136 (71%) skiers reported usage of an HME often (n = 20) or occasionally (n = 116), with no difference between sexes (**Table 1**). Also, HME usage did not differ between those with and without current asthma. A higher proportion of skiers with current asthma reported cold-related symptoms and exercise-induced respiratory attacks compared to skiers without current asthma (**Table 2**).

The median (range) temperature threshold for using an HME was −15 °C (−5 °C to −20 °C). The threshold did not differ between skiers with and without current asthma (p=0.919) nor between sexes (p=0.175) .

Skiers who never used an HME were slightly younger, and a lower proportion reported cold-related respiratory symptoms than those using an HME often or occasionally (**Table 3**). The proportion of skiers using an HME increased from south to north; South 57%, Middle 75%, and North 89%, p<0.001.

Among the 136 skiers using an HME, 60 (44%) used it predominantly during low-intensity training, 7 (5%) predominantly during high-intensity training, and 69 (51%) during both types of training. Among the HME users, 10 (7%) reported use of an HME during competition. The most common HME brand was Airtrim® (Vapro Produktutveckling AB, Sweden), used by 111 skiers (81%). The proportion of skiers using an HME increased with age: 2 (40%) age 15, 39 (61%) age 16, 34 (79%) age 17, 32 (71%) age 18, and 29 (85%) age 19, p=0.036.

3.3 Attitudes towards HME usage

Almost all skiers, 189 (99%), believed that an HME may, at least partly, prevent airway problems. Confronted with the question “If you were recommended to use an HME every time you exercise at −10 °C or colder, how motivated would you be to do that?”, the skiers had a median (IQR) motivational

score of 7.0 (5.0-8.5), without differences between skiers without and with current asthma, p=0.086, or between sexes, p=0.304.

Confronted with the question "Would you succeed to follow a recommendation to use an HME every time you exercise at −10 °C or colder?", the skiers had a median (IQR) confidence of achievement of 8.0 (5.5-9.0), with no difference between skiers with and without current asthma, p=0.573 or between sexes, p=0.779.

Skiers with high motivation (score ≥7) to use an HME during at every training session at −10 °C or colder reported to a greater extent exercise-induced respiratory attacks (p=0.045) and experienced relief using an HME to a greater extent (p=0.005) compared to skiers with intermediate-low motivation (score <7) (Supplementary **Table 1**).

Skiers with high confidence (score ≥8) to be able to follow a recommendation to use an HME during every exercise session at −10 °C or colder experienced relief using an HME to a greater extent (p<0.001) and experienced less hindrance from an HME (p=0.048) compared to skiers with intermediate-low confidence (score <8) (Supplementary **Table 2**).

4. Discussion

This study surveyed usage of and attitudes towards heat- and moisture exchanging breathing devices usage among adolescent skiers aged 15-19 from the Swedish National Elite Sports Schools. A total of 191 (55%) of all 347 skiers responded.

Among the responders, 71% used HMEs often or occasionally, both during low- and high-intensity training. A small proportion of the skiers had used an HME during competition. The most common temperature threshold for using HME was −15 °C. Non-HME users were younger and less troubled by cold-related respiratory symptoms than athletes using HMEs often or occasionally.

Almost all skiers believed that HMEs may prevent airway problems. If recommended, the skiers were motivated to increase their HME usage during exercise in −10 °C or colder, and were confident that they would succeed to do so. Overall, the usage of and attitudes towards HMEs did not differ between skiers with and without current asthma.

4.1. Skiers with asthma

Among the skiers with current asthma, 79% used HMEs often or sometimes. Given HMEs can prevent EIA[9-14], we find it reasonable to expect high usage among the skiers with asthma. We also find it reasonable that not all athletes with current asthma used HMEs. A large proportion of Swedish skiers have well-controlled asthma[19] and thus little need of HMEs. Also, some of the skiers in the present study did not experience relief by HMEs or felt HMEs hindered their training.

4.2 Skiers without asthma

Surprisingly, a majority (68%) of the skiers without asthma used HMEs. Until recently, we had no evidence to suggest that HMEs prevent cold-air induced airway injury among athletes without asthma. Therefore, we have lacked evidence-based arguments to recommend HME usage during training in cold air to healthy athletes. However, a recent study showed that HMEs totally attenuated bronchoconstriction induced by 8 min high-intensity exercise in −20 °C among healthy subjects[15]. The frequent use of HMEs among healthy skiers can potentially be explained by the finding that almost all skiers, irrespective of asthma, believed that HMEs may prevent airway damage in cold air, and that a large proportion of the athletes felt that HMEs provided relief during training in cold. We have personal testimony that some skiers without asthma use HMEs as they feel less troubled by sub-zero temperatures when they use HMEs. HME usage in general was also higher among skiers in the northernmost region, who would have likely been exposed to lower environmental temperatures.

4.3 Athletes not using HMEs

Athletes not using HMEs at all were less likely to report symptoms and were younger than those using HMEs. The increase in HME usage with age might be due to the development of airway symptoms with age. Starting at the Swedish National Elite Sports Schools coincides with an increased training load and thus an increased risk of exercise- and cold-induced airway symptoms. The increased usage of HMEs with age can also be a consequence of external influence or recommendations by senior skiers and coaches.

It has been suggested that athletes may be most vulnerable to development of asthma during adolscence [2]. Therefore, this age-group of athletes would be of particular importance if HMEs were to prove effective for primary prevention of airway morbidity and asthma among winter endurance athletes in the future.

4.4 Threshold temperature

The most common temperature threshold among Swedish adolescent elite skiers for using HMEs was −15 °C. A probable explanation is that this temperature is the Swedish threshold for cancelling youth competitions at regional and national level[20,21]. Secondly, the specific temperature corresponds well to epidemiological data. A Finnish population-based study showed that cold-related respiratory symptoms start to appear below −14 °C in healthy subjects and below −12 °C among subjects with asthma[22].

However, there was a large variation in the temperature threshold the skiers reported for using HMEs. Possible explanations include a lack of distinct guidelines for temperatures below which HMEs should be used, and subjective thresholds for discomfort.

4.5 HME and performance

A minority of the skiers used HMEs during competitions. This could partly be explained by that HMEs induce breathing discomfort, especially among the athletes with intermediate-low confidence to increase their use of HMEs. The low usage during competitions might also reflect fear of or experience that HMEs will impair performance. However, it has been shown that healthy individuals performing three repeated cycle ergometer sprints in −9 °C, produced better sprint results with use of an HME during the warm-up and recovery periods than without[17]. No negative impact was found among 9 healthy subjects performing an incremental exercise test in −5 °C with respect to subjective assessment of breathing resistance and breathing discomfort, time to exhaustion, and oxygen uptake[16]. In addition, Frischhut et al. found use of an HME did not affect distance covered or heart rate during an 8 min decremental exercise test in −20 °C. In fact, HME use reduced level of perceived exertion and frequency of respiratory symptoms[15].

4.6 HME and training type

In the present study, skiers reported lower rates of HME usage during high-intensity compared to low-intensity training sessions. However, we did not ask about whether these sessions were intermittent or continuous. Two recent studies have highlighted that airway epithelial damage may be more pronounced during continuous work than interval work in healthy participants[23] and that participants with asthma can tolerate intermittent exercise better than moderate-intensity continuous exercise[24]. Therefore, there may be some rationale for increased usage of HME during low-intensity training; however, neither study was performed in a cold environment. The majority of studies that have been conducted in sub-zero environments have shown that higher exercise intensities more commonly induce reductions in lung function in healthy individuals[25]. Further work is required to investigate the effects of different training modalities on airway function in healthy skiers and skiers with asthma, in order to make recommendations about when it is most appropriate to employ preventive strategies.

4.7 Attitudes

In general, the skiers were highly motivated, and confident in their ability to increase their usage of HMEs if recommended to do so. This positive attitude is a pre-requisite to increase the usage of HMEs in this population. Skiers at this level and age rely on and are used to following recommendations from their coaches. Based on the present results, we believe that this population would largely adhere to future concrete recommendations regarding HME use.

4.8 Study limitations

The study had a relatively low response rate of 55%. Since the questionnaire concerned usage of HMEs, a respondent bias towards users of HMEs is possible and therefore an overestimation of HME usage among the study population could have occurred. We have not found any previous studies for comparison. A qualitative study might have provided more answers as to why skiers use or do not use

HMEs. Also, questions can be misunderstood and questionnaires surveying symptoms in the previous 12 months are vulnerable to recall bias. With a cross-sectional study design we are unable draw conclusions regarding cause and effects.

5 Perspectives

HMEs provide effective prevention against exercise/cold-induced bronchoconstriction among healthy athletes[15] and subjects with asthma[9-14].

We found that Swedish elite adolescent skiers aspiring for competitive career had a high use of HMEs, irrespective of current asthma or not, and a positive attitude towards increased use. We therefore believe that this evidence-based intervention might be a simple and potentially effective preventive strategy against the high prevalence of airway symptoms and asthma among winter endurance athletes.

However, in order to increase and improve the use of HMEs among athletes, and the general population, further research is needed to identify suitable thresholds for HME usage, in terms of exercise intensity, duration, and ambient temperature.

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8. Tables

Table 1: A description of the study population; 191 Swedish adolescent skiers. Data presented as n (%).

	Total	Women	Men	P-value
N	191	101	90	
Asthma	65 (34)	34 (34)	31 (34)	0.909
Current asthma	57 (30)	31 (31)	26 (29)	0.786
Cold-related respiratory symptoms	129 (68)	68 (67)	61 (68)	0.947
Exercise-induced respiratory attack	35 (18)	21 (21)	14 (16)	0.350
Hay fever	50 (26)	26 (26)	24 (27)	0.885
Usage of HME†	136 (71)	74 (73)	62 (69)	0.505

† Often or occasionally

Table 2: A description and comparison of the Swedish adolescent skiers with and without current asthma. Data presented as n (%).

	Current asthma	No current asthma	P-value
N	57	134	
Usage of HME†	45 (79)	91 (68)	0.123
Females	31 (54)	70 (52)	0.786
Cold-related respiratory symptoms	55 (96)	74 (55)	**<0.001**
Exercise-induced respiratory attack	21 (37)	14 (10)	**<0.001**
Hay fever	23 (40)	27 (20)	**0.004**

† Often or occasionally

Table 3: A description and comparison of the skiers not using an HME against skiers using an HME often or occasionally. Data presented as n (%) unless stated otherwise.

	Non-HME users	HME users	P-value
N	55	136	
Females	27 (49)	74 (54)	0.505
Age, median (interquartile range**)**	16 (16-18)	17 (16-17)	**0.008**
Hay fever	13 (24)	37 (27)	0.611
Cold-related respiratory symptoms	24 (44)	105 (77)	**<0.001**
Exercise-induced respiratory attack	8 (15)	27 (20)	0.391
Current asthma	12 (22)	45 (33)	0.123