

Pollen exposure and matriculation exam performance among students in Finland

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► Additional supplemental material is published online only. To view, please visit the journal online (<https://doi.org/10.1136/jech-2025-224112>).

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Received 1 April 2025

Accepted 15 October 2025

ABSTRACT

Background Little is known about the association between direct pollen exposure and cognitive performance. The aim of our study is to investigate the effect of pollen exposure on performance in the Finnish matriculation examination.

Methods The study was conducted among students who participated in the national high school matriculation examinations in the metropolitan area of Helsinki and Turku in southern Finland between 2006 and 2020. Daily regional pollen counts of alder and hazel were monitored throughout the study period as part of the Finnish pollen monitoring network. Extensive data on matriculation examination results were retrieved from Statistics Finland, and air pollution and weather data from the Finnish Meteorological Institute. A fixed effect regression analysis was used to identify the effect of pollen exposure (as independent variables) on matriculation examination results (as dependent variable) controlling for student-semester fixed effects, pollutants and precipitation.

Results The regression coefficients indicated that on average an increase of 10 pollen grains in alder and hazel reduced the matriculation examination score by 0.0034 ($p < 0.01$) and 0.0144 ($p < 0.05$) standard deviations (SDs), respectively. Increasing pollen exposure per additional unit (an increase of 10 pollen grains) especially dropped examination scores in mathematical subjects among males (alder -0.0118 ($p < 0.001$) and hazel -0.0328 ($p < 0.05$) SDs). The association between alder pollen exposure (low, moderate and abundant) and examination scores was inversely U-shaped.

Conclusion Exposure to pollen can hinder a student's performance in the matriculation exam, which strongly determines the future opportunities and emphasises early initiation of medication.

INTRODUCTION

Pollen allergy—one type of seasonal allergic rhinitis—affects the lives of hundreds of millions of people globally.¹ Exposure to pollen grains (ie, allergens) impairs the health and well-being of those suffering from pollen allergies. It has been observed that allergic rhinitis is associated with cardiovascular outcomes, sleep difficulties/sleepiness, concentration, inattention, absenteeism, mood disturbances, psychosocial problems, quality of life and mortality.^{2–6} According to Tamm *et al*⁷ allergic subjects reported increased fatigue and sleepiness and decreased subjective sleep quality during the pollen season compared with the non-pollen season and/or healthy subjects. Environmental stressors such as air pollution and

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Allergic rhinitis (pollen allergy) is known to impair the health and well-being of individuals. In contrast, very little is known about the association between exposure to pollen and academic performance.

WHAT THIS STUDY ADDS

⇒ The study provides robust evidence of the relationship between short-term fluctuations in pollen levels and students' academic performance. Using a panel fixed-effects model, we find that increases in pollen concentrations lead to a statistically significant decline in standardised test scores in these high-stakes matriculation exams. The association is inversely U-shaped on alder. The drop in scores is especially related to mathematical subjects.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ From the point of view of further studies and employment, it is important to be aware that exposure to pollen can impair success in test situations. To create more equal performance conditions, we should find solutions to reduce exposure to pollen and its harmful effects (eg, scheduling exams outside the pollen season), to improve preparedness (eg, more accurate and accessible pollen information) and/or to start medication timely (eg, increasing the awareness of healthcare professionals and students who are allergic).

extreme weather conditions can affect plant growth conditions, pollen production and their properties (allergenic potential) and thus further exacerbate the health effects of pollen exposure.^{8–11}

Increasing evidence has accumulated about the association between allergic rhinitis and deteriorated functional capacity and/or cognitive performance.^{12–18} Impaired cognitive function (ie, more errors and/or longer reaction times) was found in spatial working memory among allergic participants compared with non-allergic participants during the pollen season.^{5 19} However, little is known about the association between direct pollen exposure and cognitive performance. To our knowledge, only three observational studies have examined the relationship between pollen concentration and school performance.^{20–22}



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To cite: Hugg TT, Lehto J, Jaakkola JJK, *et al*. *J Epidemiol Community Health* Epub ahead of print: [please include Day Month Year]. doi:10.1136/jech-2025-224112

The aim of our study is to investigate the impact of pollen exposure on performance in the Finnish matriculation examination. We hypothesise that students' grades are lower on days with high pollen levels compared with days with lower pollen levels.

METHODS

Study areas and populations

The study was conducted in the cities of Helsinki and Turku and in their neighbouring municipalities in southern Finland between 2006 and 2020 (online supplemental figure 1). The study included all students who participated in the national high school matriculation examinations in the Helsinki metropolitan area and the Turku region between 2006 and 2020 (table 1). The study examined high school students' grades in the Matriculation Examination in Mother Tongue, History and Social Studies, and Mathematics, Physics and Chemistry and their change in relation to pollen exposure.

Pollen sampling and analyses

As part of the Finnish pollen monitoring network,²³ daily regional hazel (*Corylus avellana*) and alder (*Alnus*) pollen counts were monitored throughout the study period. Hazel and alders are the only plants that bloom (ie, release pollen grains) in Finland during the study period around the time of the spring matriculation examinations. Airborne pollen data were collected from two sampling locations in southern Finland, Helsinki (60.16986 N and 24.93838 E) and Turku (60.45181 N and 22.26663 E; online supplemental figure 1). The samplers were located on open rooftops at the height of 14–25 m above the ground.

The pollen counts were converted to daily averages per cubic metre of air. The sampling method, slide preparation and data interpretation were performed according to the standard methodology adopted by the Finnish pollen information network following the principles of the European Aeroallergen Network.^{23 24} Pollen concentrations expressed as pollen grains per cubic metre of air were classified as low (1–10), moderate (10–100), or abundant (>100).^{25 26}

Matriculation examination data

Data on matriculation examination results were retrieved from Statistics Finland, encompassing information on all upper secondary matriculation examinations undertaken in Finland between 2006 and 2020. The dataset provided anonymised student identification numbers, sex, municipality of the school, anonymised school ID, year, semester and scores of matriculation exams on mathematics, physics, chemistry, history, social studies, reading and writing. After combining matriculation examination scores with pollen, air pollution and weather measures, and excluding rows with missing observations, our sample consisted of 92 280 students in 20 municipalities over the 15-year period. The students were on average 19.46 years old (range 16–77 years) when they took the exams.

Statistical methods

We used fixed effect regression analysis to identify the effect of pollen exposure (as independent variables) on matriculation examination results (as dependent variable) controlling for student-semester fixed effects, temperature, pollutants (PM_{2.5}, O₃ (ozone), NO₂ (nitrogen dioxide)) and rain. In previous studies, these have been found to be associated with the well-being of individuals and/or the presence of pollen.^{27 28}

The results of the matriculation exams of students in the Helsinki and Turku regions were linked in the analyses to the

Table 1 Descriptive information on the study population, precipitation, air pollution and pollen exposure

Variable	Males	Females	All
Number of observations	81 939	74 120	156 059
Number of individuals	44 629	47 651	92 280
Number of exams by individual			
1	19 920	28 157	48 077
2	14 846	14 066	28 912
3	7482	4199	11 681
4	2115	985	3100
5	194	179	373
6	56	56	112
7	13	9	22
8	‡		‡
Exam score			
Mean (SD)	28.5 (12.4)	30.6 (12.1)	29.5 (12.3)
Median (min, max)	27.0 (0, 66.0)	30.0 (0, 66.0)	30.0 (0, 66.0)
Alnus*			
Mean (SD)	31.9 (77.4)	28.5 (65.2)	30.3 (71.9)
Median (min, max)	1.0 (0, 521)	1.0 (0, 521)	1.0 (0, 521)
Corylus*			
Mean (SD)	3.24 (9.23)	3.11 (8.22)	3.18 (8.77)
Median (min, max)	0 (0, 57)	0 (0, 57)	0 (0, 57)
PM _{2.5} †			
Mean (SD)	8.85 (7.01)	9.26 (7.3)	9.04 (7.15)
Median (min, max)	5.46 (0.643, 28.9)	5.80 (0.643, 28.9)	5.63 (0.643, 28.9)
O ₃ ‡			
Mean (SD)	64.4 (14.1)	64.2 (14.7)	64.3 (14.4)
Median (min, max)	66.0 (33.4, 93.3)	66.1 (33.4, 93.3)	66.1 (33.4, 93.3)
NO ₂ ‡			
Mean (SD)	26.2 (13.2)	26.3 (13.3)	26.2 (13.2)
Median (min, max)	20.9 (6.91, 64.9)	22.5 (6.91, 64.9)	21.9 (6.41, 64.9)
Raining dummy‡			
Mean	0.699	0.723	0.710
Alnus*			
None	37 576 (45.9%)	36 688 (49.5%)	74 264 (47.6%)
1–10	9988 (12.2%)	7146 (9.6%)	17 134 (11.0%)
10–100	29 659 (36.2%)	27 186 (36.7%)	56 845 (36.4%)
100+	4716 (5.8%)	3100 (4.2%)	7816 (5.0%)
Corylus*			
None	60 403 (73.7%)	54 023 (72.9%)	114 426 (73.3%)
1–10	13 998 (17.1%)	12 645 (17.1%)	26 643 (17.1%)
10–100	7538 (9.2%)	7452 (10.1%)	14 990 (9.6%)

*Pollen concentrations (*Alnus* and *Corylus*) are presented as pollen grains per cubic metre of air.

†Pollutants (PM_{2.5}, O₃ and NO₂) are presented as micrograms per cubic metre of air.

‡Raining dummy takes value 1 if there is any precipitation during examination hours. NO₂, nitrogen dioxide; O₃, ozone.

pollen concentrations (exposure) obtained from Helsinki and Turku regional pollen sampling. Given that we observed students taking multiple exams, we incorporated student fixed effects in our regressions to control for individual characteristics. To account for students' skill levels, we focused on exams taking place during the same semester and year. Specifically, we created a concatenated variable from anonymised person ID, year and semester of the exam, employing it as a fixed effect in our regressions.

Table 2 Adjusted regression results on the effect of pollen concentration on standardised exam scores in all matriculation examinations

Dependent variable	Standardised score			
	Alnus	Corylus	Alnus + control†	Corylus + control†
Model: Variable:				
Alnus (SE)	-0.0034** (0.0011)		-0.0037* (0.0015)	
Corylus (SE)		-0.0144* (0.0058)		-0.0199* (0.0091)
Fit statistics				
Number of fixed effects	98 103	98 103	98 103	98 103
Number of observations	156 059	156 059	156 059	156 059
R ²	0.81720	0.81701	0.81820	0.81805

All regressions include student-year-fixed effects.

Significance codes * < 0.05, ** < 0.01

†Controls include averages of temperature, PM2.5, O₃ and NO₂ concentrations during examination hours, and a dummy variable which takes value 1 if there is any rain during the exam and 0 if not. Clustered (school level) standard errors (SE) are in parentheses. NO₂, nitrogen dioxide; O₃, ozone.

The key assumption for identifying the effect of pollen on exam success in our statistical model was that student-semester-fixed effect captures the individual level time-invariant factors (ie, intra-individual variation) affecting the exposure to pollen and success in matriculation examinations. Without individual fixed effects, for example, students sorting into living areas could correlate with pollen exposure as well as matriculation examination results and bias our results. The semester fixed effect was intended to ensure that students' skills are at the same level in each of the exams. Analyses were performed by applying the fixest package in R software.²⁹

A more detailed description of the method can be found in the online supplemental material.

RESULTS

A total of 98 103 student exam round pairs with 156 059 test scores participated in the matriculation exams (table 2). The regression coefficients for Alnus (-0.0034) and Corylus (-0.0144) indicated that on average an increase of 10 pollen grains in Alnus or Corylus dropped the matriculation examination score by 0.0034 or 0.0144 standard deviations (SDs), corresponding to a drop of 0.042 and 0.17 examination points, respectively (on a scale of 0–66). When temperature, air pollution (PM2.5, O₃, NO₂) and rainfall were controlled during exam hours, the drop in the scores of the matriculation exam was even slightly greater. Exposure to alder pollen decreased scores by 0.0037 and, correspondingly, exposure to hazel pollen decreased scores by 0.020 SDs (0.046 and 0.245 drop in exam points, respectively; table 2).

Similar trends were observed between the sexes in the effect of pollen exposure on the score of the matriculation examination (table 3); however, an increase of 10 pollen grains in Alnus exposure dropped the matriculation exam scores statistically significantly only among females (Alder -0.0053 SDs, p < 0.01; corresponding to a drop of 0.0652 exam points).

When the effect of pollen exposure was examined by dividing the data into mathematical and non-mathematical subjects by sex, results indicated that effect was present mainly in mathematical subjects (table 4). An increase of 10 pollen grains of Alnus decreased the maths score by 0.0118 SDs among males and by 0.0121 among females (corresponding to a drop of 0.145 and

Table 3 Adjusted regression results on the effect of pollen concentration on standardised exam scores by sex

Dependent variable	Standardised score			
	Male†	Female†	Male†	Female†
Model: Variable:				
Alnus (SE)	-0.0023 (0.0015)	-0.0053** (0.0019)		
Corylus (SE)			-0.0159 (0.0093)	-0.0170 (0.0139)
Fit statistics				
Number of fixed effects	47 478	50 625	47 478	50 625
Number of observations	81 939	74 120	81 939	74 120
R ²	0.80485	0.83629	0.80481	0.83593

All regressions include student-year-fixed effects.

Significance codes ** < 0.01.

†Controls include averages of temperature, PM2.5, O₃ and NO₂ concentrations during examination hours, and a dummy variable which takes value 1 if there is any rain during the exam and 0 if not. Clustered (school level) standard errors (SE) are in parentheses. NO₂, nitrogen dioxide; O₃, ozone.

0.149 examination points; maximum 66 points). The maximum mean daily Alnus pollen concentration was 521 pollen grains in the cubic metre of air on an examination day. An increase of 10 pollen grains of Corylus decreased the maths score by 0.0328 SDs among males (0.40 drop in exam points). The maximum mean daily Corylus pollen concentration was 57 pollen grains per cubic metre of air.

When Alnus and Corylus pollen concentrations were grouped into groups zero (as reference group), 1–10, 10–100 and over 100 pollen grains per cubic metre of air, especially for Alnus, the results showed an inverse U-shaped association with both maths and all subject matriculation examination scores (figure 1, online supplemental table 1). Both tree species exhibited some effect at low concentrations (1–10). The regression coefficients for Alnus were in maths (-0.168) and in all studied subjects (-0.060), corresponding to a drop of 2.066 and 0.738 examination points, respectively. The regression coefficients for Corylus were in maths (-0.0782) and in all studied subjects (-0.050), corresponding to a drop of 0.962 and 0.615 exam points, respectively. With both tree species, the effect vanished at moderate concentrations (10–100), but with alder, where the concentration of 100 pollen particles was exceeded, the effect was strongest at abundant concentrations (>100). The regression coefficients for Alnus were in maths (-0.4118) and in all studied subjects (-0.113) at abundant concentrations, corresponding to a drop of 5.065 and 1.390 exam points, respectively.

Following a reviewer's suggestion, we conducted a falsification test using pollen counts from 1 week after the test dates. As shown in online supplemental table 2, these lagged exposures had no effect on student performance.

DISCUSSION

Main findings

The results showed that exposure to alder and hazel pollen reduced the scores in the matriculation examination. Increasing pollen exposure, both per additional unit (an increase of 10 pollen grains) and per exposure category (low and abundant), decreased scores in the matriculation exam. The drop in scores was especially related to mathematical subjects.

Table 4 Adjusted regression results on the effect of pollen concentration on standardised exam scores in math versus non-math subjects by sex

Dependent variable	Standardised score			
Model:				
Variable:	Math females† + controls§	Non-math females‡ + controls§	Math males† + controls§	Non-math males‡ + controls§
Alnus (SE)	-0.0121*** (0.0030)	-0.0022 (0.0060)	-0.0118*** (0.0022)	0.0036 (0.0038)
Corylus (SE)	-0.0452 (0.0275)	-0.0161 (0.0399)	-0.0328* (0.0159)	0.0021 (0.0261)
Fit statistics				
Number of fixed effects	34 957	29 375¶/31 817††	37 039	26 428¶/28 683††
Number of observations	40 195	33 205¶/36 985††	49 892	32 047¶/36 007††
R ²	0.95529¶/0.95429††	0.95252¶/0.93652††	0.91981¶/0.91819††	0.93435¶/0.91750††

All regressions include student-year-fixed effects.

Significance codes * < 0.05, *** < 0.001.

†Mathematical subjects include mathematics (advanced and short form), physics and chemistry.

‡Non-mathematical subjects include reading comprehension, writing comprehension, social studies and history.

§Controls include averages of temperature, PM2.5, O₃ and NO₂ concentrations during examination hours, and a dummy variable which takes value 1 if there is any rain during the exam and 0 if not.

¶Alnus.

††Corylus. Clustered (school level) standard errors (SE) are in parentheses.

NO₂, nitrogen dioxide; O₃, ozone.

Validity of results

The results of the matriculation exams have been obtained from the comprehensive registers of the national Statistics Finland. The study period was longer, and the number of tests performed and the number of participants in the tests was significantly higher, than previous studies.^{20 21} Accordingly, the pollen data used in the study is based on nationally established and validated regional pollen monitoring.²³ It should be noted that the regional pollen data used in the study does not directly reflect school-specific and individual-based pollen exposure. However, due to the sampling height and analysis protocol used, the pollen data reflect the average daily pollen concentrations in the wider areas (ie, regional exposure) surrounding the monitoring sites and covering neighbouring municipalities.³⁰ Air quality and weather data were obtained from the Finnish Meteorological Institute’s and municipalities’ monitoring network. The standardised data collected from several monitoring sites reflect

quite comprehensively the air quality and weather (ie, precipitation) conditions of the study area (online supplemental figure 1).

The semester fixed effect statistical model that was used captures the individual level time-invariant factors (ie, intra-individual variation). By doing this, we were able to control for each student’s personal, unchanging characteristics over time. This approach allowed us also to focus specifically on how changes in pollen exposure might affect their performance in exams. In this model, the students participating in the matriculation exams were their own controls in relation to pollen exposure. By comparing each student to themselves across different times, we reduced the risk that individual differences, such as a student’s natural ability or learning style, would influence the results. Therefore, we assume that intra-individual variation does not distort the results. By segmenting the regression into mathematical and verbal subjects, we ensured that our fixed-effect variable genuinely controls for students’ skill in the same

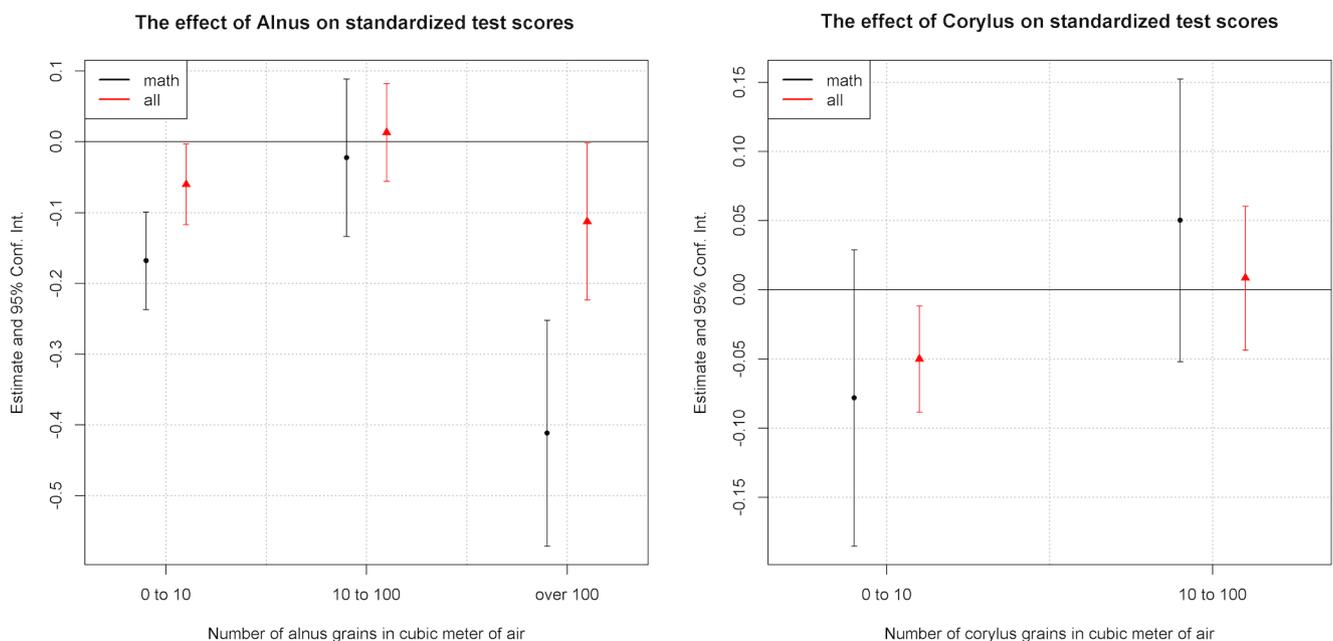


Figure 1 Regression results on the effect of pollen concentration on standardised exam scores using logarithmic scale. Conf. Int., confidence interval.

dimension that the test was measuring. So, the model could better account for the students' skills in each area, giving us a clearer picture of how pollen might affect each type of exam.

A limitation of this study is that we have to study *Alnus* and *Corylus* separately. This follows from the fact that although *Corylus* and *Alnus* have their own distinct flowering peaks, their pollen seasons may partially overlap, and during the overlap, their observed levels are highly correlated. Including highly correlated pollen grains of two plant species in the same model can lead to multi-collinearity issues and make it difficult to draw any conclusions.

Another limitation is that the study was carried out in an unselected population with regard to pollen allergy. We did not have information on the pollen allergy diagnoses of the students. It is known that about 20% of high school students in Finland suffer from allergic rhinitis, and the majority also react to pollen.^{31 32} Because of this, it is likely that the drop in matriculation exam scores observed in the data is largely explained by pollen-induced symptoms among allergic students that adversely affect their performance. It would be likely that those suffering from pollen allergies would have a higher-than-average drop in matriculation exam scores.³³

Comparison with previous studies

According to our results, an increase of 10 pollen grains of alder and hazel in the air dropped the matriculation examination score (table 2). The drop in exam scores remained statistically significant in alder and hazel pollen exposures in the model that took air pollutants, temperature and precipitation into account. Previously, Bensnes²⁰ found that regional daily mean pollen exposure lowered the grades of exams organised in high school in a 4-year study conducted in Norway. Similarly, Marcotte²¹ found that US primary school students' reading and maths test scores were inversely related to pollen exposure. Marcotte found lower maths and reading scores on days with high levels of pollen among first and second grade schoolchildren in the USA.²²

It is likely that poorer performance in matriculation exams requiring cognitive ability is mediated by symptoms that impair well-being due to pollen exposure. Papapostolou *et al*⁵ observed that increased symptoms in allergic children were associated with longer reaction time for simple movement during pollen season. In contrast, they found no difference in stress levels and inflammatory biomarkers between allergic and non-allergic children. The test performance of non-allergic students can be disturbed and the results weakened by symptoms (such as sniffing and sneezing) experienced by allergic students.²⁰

As a possible explanation for poorer cognitive performance, Raguett *et al*³⁴ suggested that aeroallergens like pollen may have an impact on brain function through mechanisms such as systemic inflammation and immune activation, which can affect mood and increase psychological distress. These immune responses, including cytokine release, might influence neurotransmitter regulation, potentially heightening anxiety and depressive symptoms in sensitive individuals.

The lowering effect of pollen exposure on matriculation exam scores was especially related to performance in mathematical subjects (table 4). This could be explained by the fact that completing exact mathematical subjects requires probably greater accuracy and concentration than other subjects.³⁵ If pollen exposure affects the performance of the student attending the matriculation exam, it is likely that this is most strongly reflected in mathematical subjects that require more attention. In contrast, Marcotte²¹ found that pollen exposure was associated

with lower test scores in both mathematics and reading exams among the youngest pupils (3–5th graders).

Maximum mean daily alder pollen concentration was 521 pollen grains in a cubic metre of air on an examination day which, given the regression coefficients, indicated that pollen exposure had potentially economically meaningful effect on examination scores. This is relevant for the student's future, because the scores of the matriculation exams have a reasonably prominent weight value when applying for further education, as well as placement in working life and income depending on these scores.³⁶

The scores of the matriculation exams fell especially on days with low and high pollen concentration compared with days when there was no pollen in the air (figure 1, online supplemental table 1). Marcotte²¹ found that primary school pupils' test scores were the highest in years with the lowest ambient pollen concentrations, but he did not find a clear dose–response relationship between pollen exposure and test performance. The drop in test scores was greater under conditions of moderate (>15) than high (>90) or extremely high (>1500 pollen grains/m³) pollen exposure; however, as a rule, the drop in test scores was statistically significant in all exposure categories (low pollen exposure acted as a reference group).

The inversely U-shaped association in the effect of Alder pollen exposure on matriculation examination scores might indicate that the body's immunological system probably reacts more strongly to exposure to alder and hazel, which starts the pollen season (ie, first pollen bursts) in the research area. A Finnish study³⁷ found that mild and moderate allergy symptoms appeared quickly after the first alder and birch pollen exposures. In an Australian study, the combined relative risk of ocular, nasal and pulmonary symptoms was highest for immediate, same-day pollen exposure.³⁸ Alternatively, non-allergic individuals may react to respiratory tract and ocular conjunctival irritation caused by pollen grains (and other particles and/or chemical compounds carried by them) and/or other inorganic and organic particles simultaneously suspended in the air.³⁹ The results, however, show that pollen exposure has an independent effect on the matriculation exam regardless of air pollution exposure. This results in the appearance of (allergy) symptoms that interfere with daily activities and potential performance in matriculation exams.

Previous studies have not provided a consistent picture of the relationship between pollen concentrations and symptoms. Theoretically, after the first (pollen) particle exposure, the body will probably adapt (ie, symptoms level off), either immunologically or through increasing medication use as pollen concentrations increase (ie, moderate exposure). When the concentration of (pollen) particles exceeds a threshold value (ie, abundant exposure), the body's immunological system is likely to wake up and react again and/or the increasing use of medication is no longer sufficient completely to prevent the harmful effects of the exposure. Luyten *et al*³⁹ did not observe any threshold value of pollen concentration below which symptoms would not appear. Allergy symptoms appeared and their severity increased when the first pollen grains were detected in the air. According to Jones *et al*,³⁸ concentration response curves were often steeper at lower than at higher pollen concentrations, though there was variation between plant taxa. In line with our results, the highest relative risk of combined eye, nose and lung symptoms was dose-dependently associated with the highest exposure category of grasses and birches (50 pollen grains/m³).³⁸ In contrast, Luyten *et al*³⁹ observed that the highest pollen concentrations (>80 pollen grains/m³) no longer significantly appeared as an increase

in symptom scores. In a Finnish study, an increasing number of people with allergies developed more serious symptoms later as alder and birch pollen season progressed.³⁷ The increase in the proportion of medication users was related to the cumulative sum of alder and birch pollen.

There were some differences between the sexes in the effect of *Alnus* and *Corylus* pollen exposure on success in the matriculation exam (tables 1 and 2). Exposure to *Alnus* pollen dropped the matriculation exam scores among female students. Test scores decreased statistically significantly only in the maths test. Alder pollen exposure decreased mathematics test scores in both sexes. In contrast, hazel pollen exposure decreased maths test scores only among males. Previous studies have not provided a clear picture of the differences between the sexes in the occurrence of allergic rhinitis and the severity of symptoms.⁴⁰ According to Bensnes,²⁰ the impact of pollen exposure on cognitive performance was greater among boys than among girls, although the difference was not statistically significant. However, it seems that allergic rhinitis is more common in childhood among boys and correspondingly slightly more common among girls from adolescence to adulthood.⁴¹ Recently, Luyten *et al*³⁹ found no difference between the sexes in the severity of allergic symptoms when exposed to pollen.

CONCLUSIONS

Increasing exposure to hazel and alder pollen decreased the test scores of participants in the matriculation exam among an unselected population. Based on the findings, it should be investigated whether the decrease in scores is strongest among those suffering from pollen allergy. In general, it can be speculated that those who react to pollen exposure are basically in a weaker position than their fellow students who do not react, because the importance of the grades of matriculation examination in terms of admission to postgraduate studies is considerable. Furthermore, studying the pathway by which pollen exposure has an impact on cognitive performance is essential to understanding the biological mechanisms that could link seasonal allergies with neuroinflammatory responses affecting mental clarity, memory and mood. It is important to understand that the first pollen exposure of the pollen season can hinder the performance of students in the matriculation exam, which strongly determines their future opportunities.

Acknowledgements We would like to thank Statistics Finland for obtaining the students' matriculation examination data and HUS Skin and Allergy Hospital for the right to use the pollen data from the Helsinki monitoring sites. We also thank the Finnish Meteorological Institute for the air quality and weather data.

Contributors TTH: conceptualisation, methodology, writing-original draft. JL: conceptualisation, data curation, formal analysis, methodology, software, visualisation, writing-original draft. JJK: conceptualisation. S-PK: conceptualisation, writing-original draft. MK: conceptualisation, data curation, formal analysis, methodology, software, visualisation, writing-original draft. SP: conceptualisation, methodology, production of pollen monitoring data, writing-original draft. AS: conceptualisation, methodology, production of pollen monitoring data, writing-original draft. MK (guarantor): conceptualisation, data curation, formal analysis, methodology, software, visualisation, writing-original draft.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available.

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