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How student perceptions of stuffy air and unpleasant odour are associated with students' well-being: Cross-level interaction effects of school climate

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ABSTRACT

It has been suggested that group-level factors affect how perceived indoor air quality (IAQ) is associated with well-being. Therefore, we analysed how student-perceived social climate at the school-level modified the student-level association between student-perceived unpleasant odour/stuffy air and well-being. The well-being indicators were seven self-reported anxiety symptoms (such as nervous, anxious, or on edge) and two somatic symptoms (headache and tiredness). We analysed a representative sample of Finnish school students (N = 678 schools, N = 71,392 students) by using multilevel modelling and testing cross-level interactions. At the student-level, both unpleasant odour and perceived stuffy air were significantly but weakly associated with increased anxiety and somatic symptoms. At the school-level, these IAQ indicators were significantly but weakly associated with increased anxiety and moderately with somatic symptoms. Furthermore, a good social climate at the school-level modified the student-level association between perceived stuffy air and anxiety symptoms. Those students who reported stuffy air were more anxious if they studied in a school with poor social climate than good social climate. Our results provide robust evidence that group-level factors may differently modify the relationships between different IAQ indicators and components of well-being.

1. Introduction

Many school buildings are relatively old. Ventilation is sometimes inadequate, and dampness and mould are commonplace (WHO, 2015). Children spend many hours per day in these conditions, and complaints about poor indoor air quality (IAQ) are common (Bluyssen, Zhang, Kurvers, Overtoom, & Ortiz-Sanchez, 2018; Finell et al., 2017; Wang, Smedje, Nordquist, & Norbäck, 2015). Various factors affect child-perceived IAQ. Kim, Li, Senick, and Mainelis (2020) found that children largely rely on visual, olfactory and thermal cues when evaluating IAQ (see also S Kim, Senick, & Mainelis, 2019; Korsavi, Montazami, & Mumovic, 2021). In addition, children often experience air as stuffy because of high concentrations of carbon dioxide (CO_2) (Järvi, Vornanen-Winqvist, Mikkola, Kurnitski, & Salonen, 2018; Korsavi et al., 2021) and some odours (Bluyssen et al., 2018).

Although children's IAQ perceptions can also be influenced by psychosocial factors (Finell et al., 2018), their evaluations seem relatively reliable. In a study of more than 300 primary school students, Armijos Moya and Bluyssen (2021) asked participants to identify different smells (e.g. perfume, mint leaves, medium-density fibreboard) under laboratory conditions. The study's main conclusion was that although chemical measurements could not detect emissions from most of the tested materials, most of the children were able to smell them. There is also evidence that associations between child-perceived school IAQ and expert measurements or observations in the same buildings are often significant (Chatzidiakou, Mumovic, & Summerfield, 2015; Mečiarová, Vilčeková, KrídlováBurdová, Kapalo, & Mihaľová, 2018).

Although schoolchildren commonly complain about poor IAQ, it remains unclear whether and how this environmental stressor is related to their well-being. With regard to the relationship between perceived IAQ and somatic symptoms, most of the research to date has focused on adult populations (Dascalaki, Gaglia, Balaras, & Lagoudi, 2009; Kim et al., 2019; Tsantaki, Smyrnakis, Constantinidis, & Benos, 2022) and only a few studies have targeted schoolchildren. For example, Korsavi et al. (2021) found that air evaluated as stale predicted fatigue among schoolchildren. Similarly, Finell, Tolvanen, Ikonen, Pekkanen, and Ståhl

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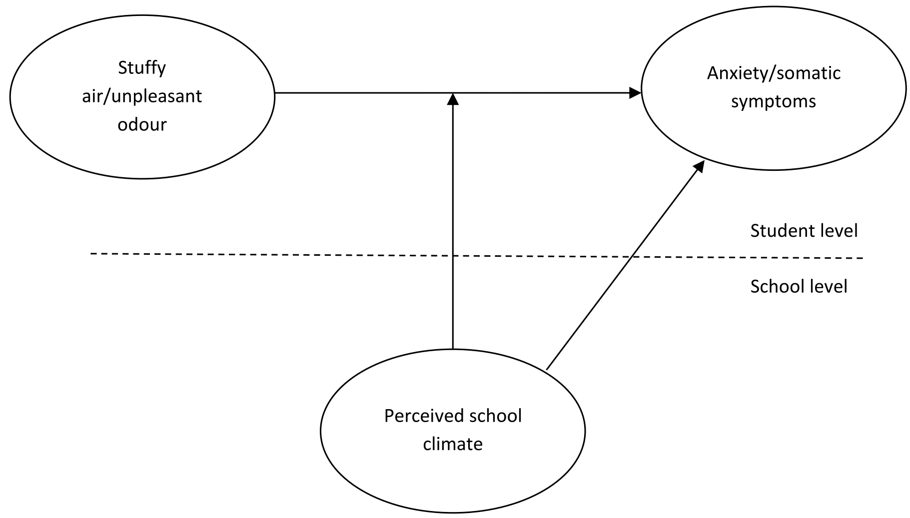

Fig. 1. Conceptual model.

Table 1
Descriptives of background variables, predictors and outcome variables from raw data.

	N	Mean (SD) or %	Min.–max.
Unpleasant odour	70,691	1.79 (0.71)	1–3
Stuffy air	70,719	1.98 (0.71)	1–3
Somatic symptoms	70,059	2.15 (0.88)	1–4
Anxiety	68,840	3.84 (4.85)	0–21
Social climate	70,672	2.16 (0.48)	1–4
Gender (female)	35,871	51	
Age (years)	71,392	14.85 (0.72)	13–18
Father's education			
Primary level	5671	9	
Secondary level	21,226	34	
Secondary level and additional education	13,865	22	
Tertiary level	21,846	35	

Table 2
Within and between variance, ICC and DEFF of main variables.

	N_w	N_b	σ^2w	σ^2b	ICC	DEFF
Unpleasant odour	70,691	678	0.456	0.045	0.090	10.29
Stuffy air	70,719	678	0.452	0.061	0.119	13.29
Somatic symptoms	70,059	678	0.763	0.009	0.012	2.23
Anxiety	68,840	678	23.306	0.266	0.011	2.11
Social climate	70,672	678	0.223	0.010	0.042	5.34

Note: Nw = sample size at student-level. N_b = sample size at school-level. σ^2w = student-level variance. σ^2b = school-level variance. ICC = intraclass correlation. DEFF = design effect.

(2021) reported a significant correlation between perceived IAQ (i.e. bad odour and stuffy air) and mucosal and respiratory symptoms. These findings align with studies of both adults and schoolchildren based on 'objective' measurements (Azuma, Kagi, Yanagi, & Osawa, 2018; Schiffman & Williams, 2005; Shusterman & Murphy, 2007). The research on the effects of perceived IAQ on schoolchildren's mental well-being remains even more scarce. Experimental and field studies in adult populations indicate that malodour influences mood and stress levels (Dalton, Claeson, & Horenziak, 2020), and elevated CO_2 levels induce stress and even panic attacks (Beemer et al., 2021; Vickers, Jafarpour, Mofidi, Rafat, & Woznica, 2012). It seems likely, then, that poor perceived IAQ has a negative effect on mental well-being also in child populations.

Table 3
Pairwise correlation coefficients between main variables estimated using Bayes estimator.

Student-level	1	2	3	4
1 Unpleasant odour	–	–	–	–
2 Stuffy air	0.519*	–	–	–
3 Somatic symptoms	0.212*	0.261*	–	–
4 Anxiety	0.182*	0.208*	0.540*	–
5 Social climate	0.233*	0.227*	0.267*	0.304*
School-level	**1**	**2**	**3**	**4**
1 Unpleasant odour	–	–	–	–
2 Stuffy air	0.785*	–	–	–
3 Somatic symptoms	0.471*	0.588*	–	–
4 Anxiety	0.303*	0.291*	0.794*	–
5 Social climate	0.342*	0.259*	0.437*	0.423*

Note: *$p < 0.001$. Student-level N = 70,715–71257. School-level N = 678.

1.1. *Social climate as a buffer*

The relationship between child-perceived IAQ and well-being is likely to be more complex than in the account above. For example, while Zhang, Zheng, and Wu (2020) found that poor perceived IAQ was associated with anxiety among people awaiting treatment in a hospital waiting room, they did not observe the same effect among those people who waited for help in the hospital corridors. This finding suggests that the relationship between perceived IAQ and well-being may be modified by other factors.

One such factor may be the social environment in which the IAQ experience occurs. Lazarus and Folkman's (1984) transactional stress model is grounded in the prediction that an individual's stress response is highly dependent on successive processes of primary and secondary appraisal. When confronted by an environmental trigger, one first evaluates its relevance as a stressor and then one's own resources for facing that stressor. If one perceives an environmental trigger (e.g. an odour) as a stressor (e.g. 'disturbing') and then evaluates one's own resources for coping with the situation as low (e.g. 'others cannot help'), this may produce stress.

Organizational psychology research suggests that resources for coping may be, for example, material or based on one's own talents or self-efficacy (Xu & Payne, 2020). In many cases, these resources are social; that is, groups can provide important resources for their members to create a stress-buffering social climate (Alfes, Shantz, & Ritz, 2018; Haslam, Jetten, Cruwys, Dingle, & Haslam, 2018). In a school context, social climate depends on factors such as the quality of interpersonal

Table 4
Random intercept models with perceived unpleasant odour and stuffy air as independent variables, and anxiety and somatic symptoms as dependent variables – models adjusted by age, gender and fathers' level of education.

Unpleasant odour	Anxiety					Somatic symptoms				
	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values
Intercept	3.84					2.15				
Student-level										
Unpleasant odour	1.13	0.03	1.08–1.18	0.16	<0.001	0.25	0.01	0.24–0.26	0.19	<0.001
School-level										
Unpleasant odour	0.68	0.13	0.42–0.94	0.27	<0.001	0.20	0.02	0.16–0.25	0.44	<0.001
Variance components										
Student-level residual variance	20.29	0.11	20.08–20.51			0.66	0.00	0.66–0.67		
School-level residual variance	0.16	0.02	0.12–0.21			0.01	0.00	0.00[a]–0.01		
R^2_w	0.13					0.13				
R^2_b	0.44					0.41				
Stuffy air	**Anxiety**					**Somatic symptoms**				
	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values
Intercept	3.84					2.15				
Student-level										
Stuffy air	1.22	0.03	1.16–1.27	0.17	<0.001	0.29	0.01	0.28–0.30	0.23	<0.001
School-level										
Stuffy air	0.46	0.11	0.24–0.68	0.22	<0.001	0.21	0.02	0.17–0.24	0.54	<0.001
Variance components										
Student-level residual variance	20.22	0.11	20.00–20.43			0.65	0.00	0.65–0.66		
School-level residual variance	0.17	0.03	0.12–0.22			0.01	0.00	0.00 [c]–0.01		
R^2_w	0.13					0.15				
R^2_b	0.41					0.49				

Note: Student-level N = 71,392. School-level N = 678. SD = standard deviation. CI = credible interval.
R^2_w = R-squared at the student-level. R^2_b = R-squared at the school-level.
[a] Unstandardised beta.
[b] Standardised beta.
[c] 0.004.

relationships and teaching practices (Cohen, McCabe, Michelli, & Pickeral, 2009). Most of the existing school research has focused on the perceived social climate at the student-level and confirms that this relates to both psychological (Aldridge & McChesney, 2018) and somatic well-being (Markkanen, Välimaa, & Kannas, 2019). However, the school's perceived social climate is also a group phenomenon that extends beyond any one student's perception (Cohen et al., 2009). Although the literature is relatively scarce, there is some evidence that this contextual factor predicts students' health complaints (Modin & Östberg, 2009) and interacts with student-level factors by buffering the relationship between stressor and strain (Torsheim & Wold, 2001).

The available evidence suggests that social resources may play an important role in the stress responses of children who report poor perceived school IAQ. To date, however, the limited research on this buffer effect has focused mainly on the individual level (Martenies et al., 2022) and on adult populations. In one such study, Finell and Nätti (2019) showed that people who perceived their indoor workplace environment as harmful and did not receive support from their supervisor one to three years ago had more officially registered absence days than those who perceived their workplace's indoor environment similarly but received support from their supervisor.

1.2. The present study

Based on the above-mentioned studies, we built a conceptual model of assumptions (see Fig. 1). We supposed that poor student-perceived IAQ was negatively associated with self-reported well-being. Furthermore, we supposed that supportive and emotionally responsive social climate at the school modified this relationship; those students who reported poor perceived IAQ had better well-being if they studied in a school with good social climate than poor social climate.

This current study was conducted to verify this model by focusing on two components of perceived IAQ: *unpleasant odour* and *stuffy air*. As odour typically has a more distinct (and often more distracting) character than stuffy air (Armijos Moya & Bluyssen, 2021), it seemed possible that the relationship between odour and well-being would be less strongly influenced by the social environment than the relationship between stuffy air and well-being.

Furthermore, we used two well-being indicators - one psychological and one somatic. Our *psychological indicator* was anxiety which is a common psychological response to external stressors that are beyond the individual's control (Grupe & Nitschke, 2013). Stress and anxiety are strongly related, and their neural substrates overlap (Daviu, Bruchas, Moghaddam, Sandi, & Beyeler, 2019). As adolescents in many countries exhibit high levels of anxiety symptoms (Feiss et al., 2019; Racine et al., 2021), it is important to analyse the antecedents. Our somatic indicator

Table 5
Random intercept models with perceived unpleasant odour and stuffy air as independent variables, anxiety and somatic symptoms as dependent variables, and social climate as a moderator – models adjusted by age, gender and fathers' level of education.

Unpleasant odour	Anxiety					Somatic symptoms				
	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	p-values
Intercept	3.84					2.15				
Student-level										
Unpleasant odour	0.74	0.03	0.69–0.79	0.10	<0.001	0.19	0.01	0.18–0.20	0.15	<0.001
School climate	2.50	0.04	2.43–2.57	0.25	<0.001	0.37	0.01	0.36–0.38	0.20	<0.001
School-level										
Unpleasant odour	0.40	0.14	0.13–0.67	0.16	0.004	0.15	0.03	0.11–0.20	0.33	<0.001
School climate	1.91	0.32	1.26–2.52	0.35	<0.001	0.30	0.06	0.19–0.42	0.31	<0.001
Variance components										
Student-level residual variance	19.00	0.10	18.80–19.21			0.64	0.00	0.63–0.64		
School- level residual variance	0.14	0.02	0.10–0.18			0.01	0.00	0.00 [c]–0.01		
R^2_w	0.19					0.17				
R^2_b	0.54					0.49				
Stuffy air	Anxiety					Somatic symptoms				
	Beta [a]	Posterior SD	95% CI	Stand. beta [b]		Beta [a]	Posterior SD	95% CI	Stand. beta [b]	
Intercept	3.85					2.15				
Student-level										
Stuffy air	0.84	0.03	0.79–0.89	0.12	<0.001	0.24	0.01	0.23–0.25	0.19	<0.001
School climate	2.49	0.04	2.41–2.56	0.24	<0.001	0.36	0.01	0.34–0.37	0.19	<0.001
School-level										
Stuffy air	0.25	0.11	0.05–0.48	0.12	0.018	0.18	0.02	0.14–0.22	0.45	<0.001
School climate	2.02	0.31	1.40–2.63	0.38	<0.001	0.30	0.05	0.20–0.41	0.31	<0.001
Variance components										
Student-level residual variance	18.93	0.10	18.74–19.14			0.63	0.00	0.62–0.63		
School-level residual variance	0.14	0.02	0.10–0.18			0.00 c	0.00	0.00 [d]–0.01		
R^2_w	0.19					0.18				
R^2_b	0.53					0.57				

Note: Student-level N = 71,392. School-level N = 678. SD = standard deviation. CI = credible interval.
R^2_w = R-squared at the student-level. R^2_b = R-squared at the school-level.
[a] Unstandardised beta.
[b] Standardised beta.
[c] 0.004.
[d] 0.003.

Table 6
Variances of random slopes.

	σ^2_s	95% CI
Unpleasant odour–anxiety	0.142	0.086–0.216
Stuffy air–anxiety	0.119	0.071–0.180
Unpleasant odour–somatic symptoms	0.003	0.002–0.005
Stuffy air–somatic symptoms	0.005	0.003–0.007

Note: Student-level N = 71,392. School-level N = 678.

comprised two components: *headache* and *fatigue*. Both are related to poor IAQ among school students (Savelieva et al., 2019; Turunen et al., 2014), and both are typical somatic reactions to stress (Bougea, Spantideas, & Chrousos, 2018; Salmela-Aro, Kiuru, Leskinen, & Nurmi, 2009). This can make it difficult to identify the causes of these somatic symptoms in schools with poor IAQ. Our main aim was to test whether student-perceived social climate (see subchapter 1.1.) at the school-level modified the associations between our IAQ and well-being indicators.

This study was conducted in Finland, where about 18% of school buildings' total area suffers from significant problems with IAQ (Salmela et al., 2019) and general awareness of the associated health risks is high.

2. Material and methods

2.1. Data and participants

Our results are based on secondary analyses of School Health Promotion Study (SHP) data collected in 2017 by the Finnish Institute for Health and Welfare (THL). SHP is a nationwide classroom survey that has monitored the health and well-being of Finnish adolescents since 1996. The data were collected during school lessons. The students were informed of the aim and content of the survey, and they had the opportunity to decline to take part. Their parents and guardians were also informed.

In total, 73,680 students in Years 8 and 9 (aged 14–16 years) responded to the questionnaire, and the data cover 63% of Finland's lower-secondary school students. We excluded from our analyses students who did not report their age or reported that their age was less than 13 (N = 911), students who studied in schools that provided special education (or for whom information was missing) (N = 1352), and

Table 7
Random intercept and slope model with perceived stuffy air as an independent variable, anxiety as a dependent variable, and social climate as a moderator – a model adjusted by age, gender and fathers' level of education.

	Anxiety				p-values
	Beta [a]	Posterior SD	95% CI	Stand. beta [b]	
Intercept	3.84				
Student-level					
Social climate	2.49	0.04	2.41–2.56	0.25	<0.001
School-level					
Stuffy air	0.31	0.10	0.10–0.50	0.15	0.004
Social climate	2.06	0.30	1.49–2.66	0.39	<0.001
Cross-level interaction	1.08	0.33	0.44–1.77	0.31	<0.001
Slope intercept	0.86	0.03	0.79–0.92		
Variance components					
Student-level residual variance	18.88	0.10	18.68–19.08		
School-level residual variance	0.15	0.02	0.11–0.20		
Random slope residual variance	0.11	0.03	0.07–0.18		
Intercept-slope covariance	0.11	0.02	0.08–0.15		

Note. Student-level N = 71,392. School-level N = 678. SD = standard deviation. CI = credible interval.
[a] Unstandardised beta.
[b] Standardised beta.

schools with fewer than five students (N = 25). The final data set consisted of 71,392 students from 678 schools. The average cluster size was 105 students, ranging between five and 431 students.

2.2. Measures

2.2.1. Predictors

Unpleasant odour and *perceived stuffy air* (i.e. stuffy air) were measured by a single item: 'have any of the following things bothered you at your school during this school year? (a) Stuffy air (bad indoor air) or (b) unpleasant odour'. The response scale was 1 = not at all, 2 = somewhat, 3 = a lot. We tested these *predictors* separately to attain a more nuanced understanding than we could achieve if we were to compose a summed variable of stuffy air and odour, as some previous studies of perceived IAQ have done (Finell et al., 2018, 2021).

2.2.2. Outcome variables

Anxiety was measured by the Generalised Anxiety Disorder Assessment (GAD-7) (**Spitzer, Kroenke, Williams, & Löwe, 2006**). This indicates how often over the previous two weeks the respondent was bothered by each of seven core symptoms (e.g. feeling nervous, anxious or on edge; not being able to stop or control worrying). These items are measured on a four-point scale (0 = not at all, 1 = on several days, 2 = on most days, 3 = practically every day). A sum of the items is then calculated. The sum score can range from 0 to 21: 0–4 (no anxiety), 5–9 (mild anxiety), 10–15 (moderate anxiety), and 16–21 (severe anxiety) (Spitzer et al., 2006). In this study, we used the measure as a continuous variable. The Cronbach's alpha was good (0.92).[1] GAD-7 has good psychometric properties among adolescents, its internal consistency is good, and the instrument has a unidimensional factor structure (Tiirikainen, Haravuori, Ranta, Kaltiala-Heino, & Marttunen, 2019).

Somatic symptoms were measured by two items: 'in the last six months, have you experienced any of the following symptoms, and how often? (a) Headache, (b) tiredness or dizziness'. The response scale was 1 = seldom or never, 2 = approximately once a month, 3 = approximately once a week, 4 = almost daily. A sum of the items was calculated. No missing items were allowed. The Cronbach's alpha was reasonable (0.70).[2]

2.2.3. Moderator

Student-perceived school climate (i.e. school climate) was measured by six items focusing on teacher-student relations and class spirit (e.g. 'teachers encourage me to express my opinion in class'; 'the pupils in my class get along well'). The response scale was 1 = fully agree, 2 = agree, 3 = disagree, 4 = fully disagree: the higher the score, the worse the social climate. A mean rating of the items was calculated. If the respondent had answered fewer than four items, the score was not calculated. The reliability was reasonable (Cronbach's alpha = 0.71).[3]

2.2.4. Background variables

Father's level of education was used as an indicator of a student's socio-economic status (1 = comprehensive school or equivalent (i.e. primary level), 2 = upper-secondary school, high school or vocational education institution (i.e. secondary level), 3 = occupational studies in addition to upper-secondary school, high school or vocational education institution (i.e. secondary level and occupational studies), 4 = university, university of applied sciences or other higher-education institution (i.e. tertiary level)). In addition, *gender* (0 = boy, 1 = girl) and *age* were controlled. The link to the whole questionnaire is https://thl.fi/documents/189940/9191250/ktk2017_ylakoulu_en_nettiin.pdf/556f2438-f1e5-a560-e65b-8efd7b18efa3?t=1699016579686.

2.3. Analytical methods

We built eight random intercept models, eight random intercept and slope models and a null model for each variable (Hox, 2010) and then estimated them using Mplus statistical software 8.0 (Muthén & Muthén, 1998) and a Bayesian approach (Asparouhov & Muthén, 2021; Muthén, 2010). The proportion of missing values varied between the variables, ranging from 0% to 12% of cases. Socio-economic status (father's education) had the highest percentage of missing values. The Bayesian approach takes missingness into account and asymptotically produces the same results as full information maximum likelihood under the missing-at-random assumption (Muthén & Muthén, 1998).

First, we estimated *a null model* for each variable to estimate the variance at student- and school-levels and the intraclass correlation (ICC). The ICC reports the proportion of variance that belongs to the school-level (Hox, 2010). Then w**e calculated the design effect** (DEFF)[4], which is estimated as a function of the ICC and average cluster size (Muthén & Satorra, 1995). Multilevel modelling is needed if the DEFF of the outcome variable is greater than 1.1 (Asparouhov & Muthén, 2006).

Second, we estimated *eight random intercept models* to test whether stuffy air/unpleasant odour and school climate were associated with

[1] The McDonald's omega was 0.92.
[2] The McDonald's omega cannot be estimated with two items in Mplus, and therefore the omega of the somatic symptoms is not reported.
[3] The McDonald's omega was 0.70.
[4] $DEFF = 1 + (cluster\ size - 1) \times ICC$.

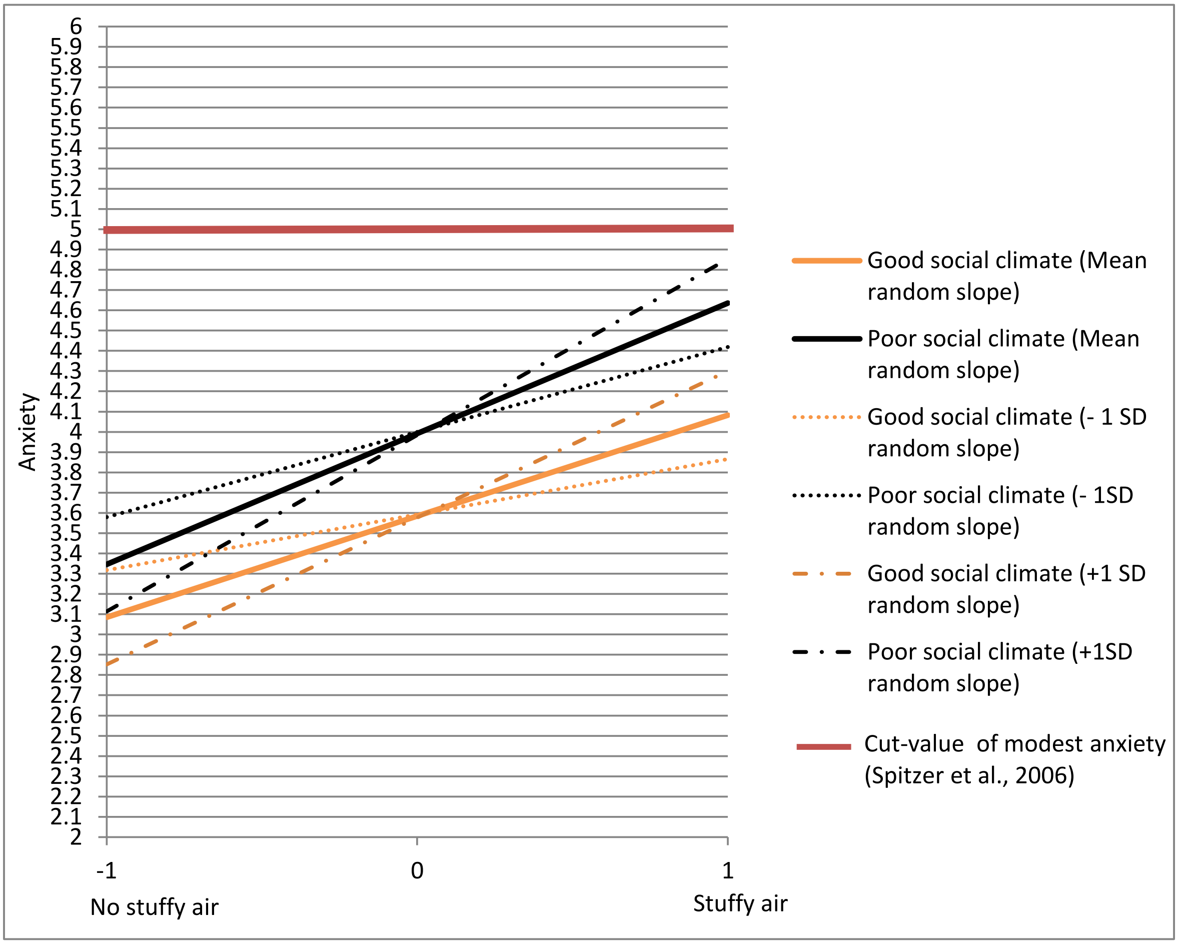

Fig. 2. Cross-level interaction: −1 standard deviation to +1 standard deviation random slopes between student-perceived stuffy air and anxiety modified by student-perceived social climate at the school-level
Note: N = 58,958 students. N = 678 schools.

anxiety and somatic symptoms in separate models. All the models were adjusted by gender, age and fathers' level of education. All the explanatory variables were grand-mean centred, and these observed variables were estimated as latent factors in the models (Muthén, 1998).

Finally, we tested our main hypothesis by building *eight random intercept and slope models*. First, we tested whether there was significant variability between slopes. Then we tested whether perceived school climate at the school-level explained this variability (i.e. cross-level interaction). All these models were adjusted by gender, age and fathers' level of education.

We report both the unstandardised and standardised estimates (i.e. when the predictor increases by one standard deviation, the outcome variable increases by the standardised estimate). We also report separate R-squares for both the student and school-levels in random intercept models provided by Mplus (Muthén, 1998).

3. Results

3.1. Descriptives

The descriptives of all variables are reported in Table 1. Stuffy air in school buildings bothered students more than did unpleasant odour (t (70,489) = 74.39, $p < 0.001$)).

The within and between variance, ICC and DEFF of unpleasant odour, stuffy air, anxiety, somatic symptoms and school climate are reported in Table 2. All the within and between variances were significant at the $p < 0.001$ level. Although the between-school variances of anxiety and somatic symptoms were only 1% of the total variance, their DEFFs were twice as big. For example, the DEFF of 2.23 indicates that variance of the mean under cluster sampling is more than two times larger compared to assumed variance of the mean under simple random sampling. Stuffy air had the biggest ICC (0.12).

The pairwise correlations of the main variables are reported in Table 3. All the correlations were significant at both student and school-level.

3.2. Random intercept models

First, we tested random intercept models with the predictors only. Unpleasant odour and stuffy air were associated with anxiety and somatic symptoms at both levels. At the student-level, the more a student reported unpleasant odour or stuffy air, the more the student suffered from anxiety and somatic symptoms. At the school-level, students who studied in schools with unpleasant odour or stuffy air were more anxious and had more somatic symptoms than those who studied in schools without such problems (Table 4).

Then we inserted the moderator into our random intercept models (Table 5). School climate was associated with anxiety and somatic symptoms at both levels. At the student-level, the worse a student-perceived the school climate to be, the more the student suffered from anxiety and somatic symptoms. At the school-level, students who studied in schools with poor social climate were more anxious and had more somatic symptoms than those who studied in schools without such problems. Unpleasant odour and stuffy air remained statistically significant predictors (Table 5).

3.3. Cross-level interactions

The variances of the random slopes (σ_s^2) are reported in Table 6. All the variances were significant, indicating that schools differed in the degree to which unpleasant odour and stuffy air were associated with anxiety and somatic symptoms. The significant variances allowed us to test the cross-level interactions.

Finally, we tested whether school-level social climate explained the variance of the random slopes. Only the variance of random slope between stuffy air and anxiety was explained by school-level social climate (Table 7). The cross-level interaction estimates of the other models were non-significant (somatic symptoms regressed on stuffy air: unstandardised beta = 0.05, p. = 430, standardised beta = 0.08; anxiety regressed on unpleasant odour: unstandardised beta = 0.61, p = 0.100, standardised beta = 0.16; somatic symptoms regressed on unpleasant odour: unstandardised beta = 0.04, p = 0.522, standardised beta = 0.07).

Comparisons of the stuffy air–anxiety slopes showed that the association between student-level stuffy air and anxiety was weaker in schools where school climate was one standard deviation *below* its mean (i.e. 'good social climate': unstandardised beta = 0.74, standardised beta = 0.10) compared with schools where social climate was one standard deviation *above* its mean (i.e. 'poor social climate: unstandardised beta = 0.96, standardised beta = 0.13).[5] This means that if a student suffered from stuffy air one standard deviation above its mean, the student was less anxious in a school with a good social climate, compared with a similar student in a school with a poor school climate. The mean difference between these students was about 0.6 anxiety scores (Fig. 2: see lines 'Good social climate (Mean random slope)' and 'Poor social climate (Mean random slope)').

The mean difference increased to one score when we compared (a) a student in a school with a good social climate and a slope (anxiety regressed on stuffy air) that was one standard deviation below the mean and (b) a student in a school with a poor social climate and a slope (anxiety regressed on stuffy air) that was one standard deviation above the mean (Fig. 2: see lines 'Good social climate (−1 SD random slope)' and 'Poor social climate (+1 SD random slope)'). School climate explained 6% of the variance in slopes across schools.

4. Discussion

The aim of this study was to analyse whether student-perceived school climate at the school-level buffered the student-level association between perceived IAQ and self-reported well-being. Our main finding was that the association between stuffy air and anxiety symptoms was weaker in schools where the social climate was good than in schools where the social climate was poor. The other cross-level interactions that we tested were not significant.

Our results contribute to at least two literature streams: the literature on students' perceived IAQ and well-being (Järvi et al., 2018; Korsavi et al., 2021) and the limited literature on whether and how school-level social environment buffers the stressor-strain relationship at student-level (Lucas-Molina, Pérez-Albéniz, Solbes-Canales, Ortuño-Sierra, & Fonseca-Pedrero, 2022; Torsheim & Wold, 2001). In the first place, we found that a social climate perceived as good at school-level can protect a student's mental well-being in an indoor air environment that the student perceives as stuffy. One possible explanation is that a good social climate within the school community provides individual schoolchildren with important stress-buffering resources (Lazarus & Folkman, 1984). In addition to social support, one such resource is social trust – the perception that school community members are generally fair and trustworthy (Flanagan & Stout, 2010). Trust includes the idea of predictability, and trust and predictability are closely linked to the sense of control (Maguire, Phillips, & Hardy, 2001). Loss of control is likely to be among the factors that mediate the relationship between poor perceived IAQ and mental well-being (Beemer et al., 2021); that is, a trust-inducing social environment may help a student to feel less anxious about stuffy air.

However, the buffering role of social environment should not be overestimated, as school-level social climate explained only a small proportion of slope variance and we were unable to demonstrate any significant cross-level interaction with unpleasant odour and anxiety. As our data set was large and highly representative, we can reasonably speculate about this non-significant result. One possibility is that it reflects an inherent difference between the two components of IAQ used here. Unlike stuffy air, an unpleasant odour often has a relatively easily identifiable source (e.g. chemicals, foodstuffs, humans) (Armijos Moya & Bluyssen, 2021) and can be very disturbing if negatively interpreted (Smeets & Dalton, 2005). Our findings suggest that the extent to which a positive social environment buffers the association between poor perceived IAQ and anxiety depends on the specific IAQ component in question.

In addition to cross-level effects, we analysed main effects of IAQ indicators on anxiety at both student and school-levels. The mental health effects of poor perceived IAQ have been little analysed to date among children. We found that perceived unpleasant odour and stuffy air were related to anxiety symptoms at both student and school-levels. More precisely, student anxiety increased as perceived IAQ worsened, and students in schools that reportedly suffered from stuffy air or unpleasant odours were more anxious than those attending schools without those problems. To that extent, students' shared perceptions of IAQ at school-level could be said to influence the mental health of individual students, although less so than school-level social climate.

Finally, we tested whether school-level social climate modified the associations between IAQ indicators and somatic symptoms for which there were no significant findings. Only the main effects were significant; both stuffy air and unpleasant odour were associated with somatic symptoms at the student-level. In addition, students more often reported somatic symptoms if they attended a school where students on average reported stuffy air or unpleasant odour than if they attended a school without those problems. In a previous study, we analysed the associations between observed mould and dampness and student-perceived IAQ (a composite variable encompassing stuffy air and unpleasant odour) using the same data as in the present study. We found that observed mould and dampness predicted perceived IAQ with a standardised beta of 0.35 (Finell et al. 2021). To that extent, our indicators of perceived IAQ reflect building conditions, which may partly explain our findings.

In this context, it is also important to consider the causal implications of these findings. Since emotional states and individual differences can influence how we perceive our environment (Finell et al., 2018; Nordin, Aldrin, Claeson, & Andersson, 2017), it is possible that anxiety and bad health prompted students to perceive indoor air as stuffy and to experience odours as unpleasant. Therefore, we estimated a new random intercept and slope model in which anxiety and somatic symptoms predicted IAQ indicators. However, none of the cross-level interactions were significant (p = 0.506–0.684). The school-level social climate explained random slope only if stuffy air was the predictor and anxiety was the outcome variable and not the other way around.

Our study inevitably has some limitations. These include the use of cross-sectional data and the absence of any information about objective measurements of schools' indoor and outdoor air quality, schools' physical conditions and students' understanding of stuffy air and unpleasant odour. In addition, our data set referred to a single country where awareness of building-related health problems is high. Nevertheless, as these were highly representative national data, our findings can be considered robust in that context, indicating that the quality of

[5] Note that the response scale of social climate was 1 = fully agree, 2 = agree, 3 = disagree, 4 = fully disagree; the higher the score, the worse the social climate.

the social environment can impact the relationship between perceived IAQ and well-being. However, that impact is confined to mental rather than somatic health effects and to the specified IAQ components. One practical implication is that when a school's indoor air is perceived as stuffy, students' anxiety symptoms can be reduced by a positive and supportive social climate. Objective measurements of IAQ are needed to address the problem if it persists and if problems are found, they need to be repaired.

5. Conclusions

Our main aim was to analyse whether student-perceived social climate at the school-level modified the associations between our IAQ and well-being indicators by using multilevel modelling and testing cross-level interactions. Our study showed that student-perceived stuffy air and unpleasant odour were associated with self-reported anxiety and somatic symptoms at both the student and school-levels. In addition, it showed that a student-perceived social climate at the school-level modified the student-level association between stuffy air and anxiety symptoms. The associations between stuffy air and somatic symptoms and between perceived unpleasant odour and well-being indicators were not statistically significantly modified by the school-level social climate.

Children spend many hours per day in a school for years. For the children's health and performance, factors related to both the building and the social climate are of importance.

Author statement

Eerika Finell: Conceptualization; Formal analysis; Funding acquisition; Methodology; Visualization; Writing - original draft; Writing - review & editing.

Asko Tolvanen: Formal analysis; Methodology; Writing - review & editing.

Anna-Sara Claeson: Writing - original draft; Writing - review & editing.

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Data availability statement

The data that support the findings of this study are available from the Finnish Institute for Health and Welfare, but were used under licence for the current study and hence are not publicly available. Data are available upon reasonable request and with the permission of the Finnish Institute for Health and Welfare.

Conflict of interest disclosure

None.

Ethics approval statement

Data collection was approved by the Finnish Institute for Health and Welfare's ethical committee (THL/1704/6.02.01/2016).

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References

Aldridge, J. M., & McChesney, K. (2018). The relationships between school climate and adolescent mental health and wellbeing: A systematic literature review. *International Journal of Educational Research, 88*, 121–145. https://doi.org/10.1016/j.ijer.2018.01.012

Alfes, K., Shantz, A. D., & Ritz, A. (2018). A multilevel examination of the relationship between role overload and employee subjective health: The buffering effect of support climates. *Human Resource Management, 57*(2), 659–673. https://doi.org/10.1002/hrm.21859

Armijos Moya, T., & Bluyssen, P. M. (2021). Appraisal and identification of different sources of smell by primary school children in the air quality test chamber of the SenseLab. *Intelligent Buildings International, 13*(2), 142–155. https://doi.org/10.1080/17508975.2019.1682493

Asparouhov, T., & Muthén, B. O. (2006). Constructing covariates in multilevel regression. *Mplus. Web Notes, 11*. www.statmodel.com.

Asparouhov, T., & Muthén, B. O. (2021). Bayesian estimation of single and multilevel models with latent variable interactions. *Structural Equation Modeling: A Multidisciplinary Journal, 28*(2), 314–328. https://doi.org/10.1080/10705511.2020.1761808

Azuma, K., Kagi, N., Yanagi, U., & Osawa, H. (2018). Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance. *Environment International, 121*(1), 51–56. https://doi.org/10.1016/j.envint.2018.08.059

Beemer, C. J., Stearns-Yoder, K. A., Schuldt, S. J., Kinney, K. A., Lowry, C. A., Postolache, T. T., et al. (2021). A brief review on the mental health for select elements of the built environment. *Indoor and Built Environment, 30*(2), 152–165. https://doi.org/10.1177/1420326X19889653

Bluyssen, P. M., Zhang, D., Kurvers, S., Overtoom, M., & Ortiz-Sanchez, M. (2018). Self-reported health and comfort of school children in 54 classrooms of 21 Dutch school buildings. *Building and Environment, 138*, 106–123. https://doi.org/10.1016/j.buildenv.2018.04.032

Bougea, A., Spantideas, N., & Chrousos, G. P. (2018). Stress management for headaches in children and adolescents: A review and practical recommendations for health promotion programs and well-being. *Journal of Child Health Care, 22*(1), 19–33. https://doi.org/10.1177/1367493517738123

Chatzidiakou, L., Mumovic, D., & Summerfield, A. (2015). Is CO_2 a good proxy for indoor air quality in classrooms? Part 2: Health outcomes and perceived indoor air quality in relation to classroom exposure and building characteristics. *Building Services Engineering Research and Technology, 36*(2), 162–181. https://doi.org/10.1177/0143624414566245

Cohen, J., McCabe, E. M., Michelli, N. M., & Pickeral, T. (2009). School climate: Research, policy, practice, and teacher education. *Teachers College Record, 111*(1), 180–213.

Dalton, P., Claeson, A.-S., & Horenziak, S. (2020). The impact of indoor malodor: Historical perspective, modern challenges, negative effects, and approaches for mitigation. *Atmosphere, 11*(2), 126. https://doi.org/10.3390/atmos11020126

Dascalaki, E. G., Gaglia, A. G., Balaras, C. A., & Lagoudi, A. (2009). Indoor environmental quality in Hellenic hospital operating rooms. *Energy and Buildings, 41*(5), 551–560. https://doi.org/10.1016/j.enbuild.2008.11.023

Daviu, N., Bruchas, M. R., Moghaddam, B., Sandi, C., & Beyeler, A. (2019). Neurobiological links between stress and anxiety. *Neurobiology of Stress, 11*, Article 100191. https://doi.org/10.1016/j.ynstr.2019.100191

Feiss, R., Dolinger, S. B., Merritt, M., Reiche, E., Martin, K., Yanes, J. A., et al. (2019). A systematic review and meta-analysis of school-based stress, anxiety, and depression prevention programs for adolescents. *Journal of Youth and Adolescence, 48*(9), 1668–1685. https://doi.org/10.1007/s10964-019-01085-0

Finell, E., Haverinen-Shaughnessy, U., Tolvanen, A., Laaksonen, S., Karvonen, S., Sund, R., et al. (2017). The associations of indoor environment and psychosocial factors on the subjective evaluation of indoor air quality among lower secondary school students: A multilevel analysis. *Indoor Air, 27*(2), 329–337. https://doi.org/10.1111/ina.12303

Finell, E., & Nätti, J. (2019). The combined effect of poor perceived indoor environmental quality and psychosocial stressors on long-term sickness absence in the workplace: A follow-up study. *International Journal of Environmental Research and Public Health, 16*(24), 4997. https://doi.org/10.3390/ijerph16244997

Finell, E., Tolvanen, A., Ikonen, R., Pekkanen, J., & Ståhl, T. (2021). Students' school-level symptoms mediate the relationship between a school's observed moisture problems and students' subjective perceptions of indoor air quality. *Indoor Air, 31*(1), 40–50. https://doi.org/10.1111/ina.12711

Finell, E., Tolvanen, A., Pekkanen, J., Minkkinen, J., Ståhl, T., & Rimpelä, A. (2018). Psychosocial problems, indoor air-related symptoms, and perceived indoor air quality among students in schools without indoor air problems: A longitudinal study. *International Journal of Environmental Research and Public Health, 15*(7), 1497. https://doi.org/10.3390/ijerph15071497

Flanagan, C. A., & Stout, M. (2010). Developmental patterns of social trust between early and late adolescence: Age and school climate effects. *Journal of Research on Adolescence, 20*(3), 748–773. https://doi.org/10.1111/j.1532-7795.2010.00658.x

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: An integrated neurobiological and psychological perspective. *Nature Reviews Neuroscience, 14*(7), 488–501. https://doi.org/10.1038/nrn3524

Haslam, C., Jetten, J., Cruwys, T., Dingle, G. A., & Haslam, S. A. (2018). *The new psychology of health: Unlocking the social cure* (1st ed.). Routledge. https://doi.org/10.4324/9781315648569

Hox, J. J. (2010). *Multilevel analysis. Techniques and applications* (2nd ed.). Routledge.

Järvi, K., Vornanen-Winqvist, C., Mikkola, R., Kurnitski, J., & Salonen, H. (2018). Online questionnaire as a tool to assess symptoms and perceived indoor air quality in a school environment. *Atmosphere, 9*(7), 270. https://doi.org/10.3390/atmos9070270

Kim, J., Jang, M., Choi, K., & Kim, K. (2019). Perception of indoor air quality (IAQ) by workers in underground shopping centers in relation to sick-building syndrome (SBS) and store type: A cross-sectional study in Korea. *BMC Public Health, 19*, 632. https://doi.org/10.1186/s12889-019-6988-6

Kim, S., Li, M., Senick, J., & Mainelis, G. (2020). Designing to engage children in monitoring indoor air quality: A participatory approach. In *Proceedings of the* *interaction design and children conference* (pp. 323–334). https://doi.org/10.1145/3392063.3394395

Kim, S., Senick, J. A., & Mainelis, G. (2019). Sensing the invisible: Understanding the perception of indoor air quality among children in low-income families. *International Journal of Child-Computer Interaction, 19*, 79–88. https://doi.org/10.1016/j.ijcci.2018.12.002

Korsavi, S. S., Montazami, A., & Mumovic, D. (2021). Perceived indoor air quality in naturally ventilated primary schools in the UK: Impact of environmental variables and thermal sensation. *Indoor Air, 31*, 480–501. https://doi.org/10.1111/ina.12740

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping.* Springer.

Lucas-Molina, B., Pérez-Albéniz, A., Solbes-Canales, I., Ortuño-Sierra, J., & Fonseca-Pedrero, E. (2022). Bullying, cyberbullying and mental health: The role of student connectedness as a school protective factor. *Psychosocial Intervention, 31*(1), 33–41. https://doi.org/10.5093/pi2022a1

Maguire, S., Phillips, N., & Hardy, C. (2001). When 'silence = death', keep talking: Trust, control and the discursive construction of identity in the Canadian HIV/AIDS treatment domain. *Organization Studies, 22*(2), 285–310. https://doi.org/10.1177/0170840601222005

Markkanen, I., Välimaa, R., & Kannas, L. (2019). Associations between students' perceptions of the psychosocial school environment and indicators of subjective health in Finnish comprehensive schools. *Children & Society, 33*(5), 488–502. https://doi.org/10.1111/chso.12334

Martenies, S. E., Schill, J., Klimm, M., Cross, J. E., Oliver, S., & Magzamen, S. (2022). Relationships between social climate and indoor environmental quality and frequently reported health symptoms among teachers and staff in a suburban school district. *Journal of Occupational and Environmental Hygiene, 19*(8), 478–488. https://doi.org/10.1080/15459624.2022.2089675

Mečiarová, Ľ., Vilčeková, S., Krídlová Burdová, E., Kapalo, P., & Mihaľová, N. (2018). The real and subjective indoor environmental quality in schools. *International Journal of Environmental Health Research, 28*(1), 102–123. https://doi.org/10.1080/09603123.2018.1429579

Modin, B., & Östberg, V. (2009). School climate and psychosomatic health: A multilevel analysis. *School Effectiveness and School Improvement, 20*(4), 433–455. https://doi.org/10.1080/09243450903251507

Muthén, B. O. (1998). *Mplus technical appendices*. Muthén & Muthén.

Muthén, B. O. (2010). *Bayesian analysis in Mplus: A brief introduction*. www.statmodel.com.

Muthén, B. O., & Satorra, A. (1995). Complex sample data in structural equation modeling. *Sociological Methodology, 25*, 267–316. https://doi.org/10.2307/271070

Muthén, L. K., & Muthén, B. O. (1998). *Mplus user's guide* (7th ed.). Muthén & Muthén.

Nordin, S., Aldrin, L., Claeson, A.-S., & Andersson, L. (2017). Effects of negative affectivity and odor valence on chemosensory and symptom perception and perceived ability to focus on a cognitive task. *Perception, 46*(3–4), 431–446. https://doi.org/10.1177/0301006616686990

Racine, N., McArthur, B. A., Cooke, J. E., Eirich, R., Zhu, J., & Madigan, S. (2021). Global prevalence of depressive and anxiety symptoms in children and adolescents during COVID-19: A meta-analysis. *JAMA Pediatrics, 175*(11), 1142–1150. https://doi.org/10.1001/jamapediatrics.2021.2482

Salmela-Aro, K., Kiuru, N., Leskinen, E., & Nurmi, J.-E. (2009). School Burnout Inventory (SBI): Reliability and validity. *European Journal of Psychological Assessment, 25*(1), 48–57. https://doi.org/10.1027/1015-5759.25.1.48

Salmela, A., Tähtinen, K., Hartikainen, T., Pekkanen, J., Lampi, J., Jalkanen, K., et al. (2019). *Sisäilma ja terveys: Kehitys, nykytilanne, seuranta ja vertailu eri maiden sekä julkisen ja yksityisen sektorin välillä [Indoor air and health: Developments, current situations, monitoring and comparison between the public and private sectors of different countries]. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja* (Vol. 59). Valtioneuvoston kanslia. Retrieved February 15, 2023, from https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161843/59_19_Sis%c3%a4ilma%20ja%20terveys_netti.pdf?sequence=4&isAllowed=y.

Savelieva, K., Marttila, T., Lampi, J., Ung-Lanki, S., Elovainio, M., & Pekkanen, J. (2019). Associations between indoor environmental quality in schools and symptom reporting in pupil-administered questionnaires. *Environmental Health, 18*(1), 115. https://doi.org/10.1186/s12940-019-0555-6

Schiffman, S. S., & Williams, C. M. (2005). Science of odor as a potential health issue. *Journal of Environmental Quality, 34*(1), 129–138.

Shusterman, D., & Murphy, M. A. (2007). Nasal hyperreactivity in allergic and non-allergic rhinitis: A potential risk factor for non-specific building-related illness. *Indoor Air, 17*(4), 328–333. https://doi.org/10.1111/j.1600-0668.2007.00482.x

Smeets, M. A. M., & Dalton, P. H. (2005). Evaluating the human response to chemicals: Odor, irritation and non-sensory factors. *Environmental Toxicology and Pharmacology, 19*(3), 581–588. https://doi.org/10.1016/j.etap.2004.12.023

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Tiirikainen, K., Haravuori, H., Ranta, K., Kaltiala-Heino, R., & Marttunen, M. (2019). Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Research, 272*, 30–35. https://doi.org/10.1016/j.psychres.2018.12.004

Torsheim, T., & Wold, B. (2001). School-related stress, support, and subjective health complaints among early adolescents: A multilevel approach. *Journal of Adolescence, 24*(6), 701–713. https://doi.org/10.1006/jado.2001.0440

Tsantaki, E., Smyrnakis, E., Constantinidis, T. C., & Benos, A. (2022). Indoor air quality and sick building syndrome in a university setting: A case study in Greece. *International Journal of Environmental Health Research, 32*(3), 595–615. https://doi.org/10.1080/09603123.2020.1789567

Turunen, M., Toyinbo, O., Putus, T., Nevalainen, A., Shaughnessy, R., & Haverinen-Shaughnessy, U. (2014). Indoor environmental quality in school buildings, and the health and wellbeing of students. *International Journal of Hygiene and Environmental Health, 217*(7), 733–739. https://doi.org/10.1016/j.ijheh.2014.03.002

Vickers, K., Jafarpour, S., Mofidi, A., Rafat, B., & Woznica, A. (2012). The 35% carbon dioxide test in stress and panic research: Overview of effects and integration of findings. *Clinical Psychology Review, 32*(3), 153–164. https://doi.org/10.1016/j.cpr.2011.12.004

Wang, J., Smedje, G., Nordquist, T., & Norbäck, D. (2015). Personal and demographic factors and change of subjective indoor air quality reported by school children in relation to exposure at Swedish schools: A 2-year longitudinal study. *Science of the Total Environment, 508*, 288–296. https://doi.org/10.1016/j.scitotenv.2014.12.001

WHO. (2015). *School environment: Policies and current status*. WHO Regional Office for Europe.

Xu, X., & Payne, S. C. (2020). When do job resources buffer the effect of job demands? *International Journal of Stress Management, 27*(3), 226–240. https://doi.org/10.1037/str0000146

Zhang, S., Zheng, J., & Wu, Y. (2020). Field study of air environment perceptions and influencing factors in waiting spaces of general hospitals in winter cities. *Building and Environment, 183*, Article 107203. https://doi.org/10.1016/j.buildenv.2020.107203