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Indoor environmental quality in school buildings, and the health and wellbeing of students

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ABSTRACT

Poor indoor environmental quality (IEQ) in classrooms may be a risk for health symptoms and cause absence from school. We conducted a comprehensive study in order to assess the connection between IEQ in Finnish elementary school buildings and the health and academic performance of sixth grade students. The specific aim of the present paper was to study the school- or grade-level prevalence of symptoms in relation to IEQ. The school- or grade-level (i.e. group level) prevalence of self-reported symptoms and perceived IEQ was studied using data collected by a health questionnaire comprising 37 questions. The health questionnaire was sent to all 6th grade students in a stratified random sample of 355 elementary schools in Finland. Indoor environmental conditions were assessed with measurements of ventilation rate and thermal conditions of classrooms in a subsample of 56 schools. Altogether 297 elementary schools participated in the health questionnaire study and a total of 4248 questionnaires were returned (estimated response rate 62.6%). The most common weekly symptoms in the spring semester were fatigue (7.7%), stuffy nose (7.3%), and headache (5.5%). However, both mean prevalence values for different symptoms among all 6th grade students and group-level prevalence values for specific symptoms varied considerably. On the group level, the prevalence values most frequently found above 95% CI (calculated for $N = 15$) were wheezing, cough with wheezing, and fever over 37 °C. The most frequently reported IEQ factors causing daily inconvenience in classrooms were noise (11.0%) and stuffy air/poor indoor air quality (IAQ) (7.0%), which were also found most frequently above 95% CI on the group level (calculated for $N = 15$), together with self-reported high indoor temperature and dust or dirtiness. Self-reported daily stuffiness/poor IAQ was significantly correlated with measured mean temperatures and ventilation rates in classrooms. High prevalence of students' self-reported stuffiness/poor IAQ may indicate high indoor temperature or low ventilation rate in classrooms. Also high group level prevalence of other IEQ factors and certain symptoms may be indicative of IEQ problems that should be further studied. The results of this study can be used as a reference for assessing the questionnaire-based prevalence of self-reported symptoms among 6th graders, and their association with IEQ in classrooms. For such assessment, the number of students responding to the questionnaire must be carefully considered, also bearing in mind that prevalence values are symptom specific.

Introduction

Children spend a significant part of their time in a school environment. In Finland, children attend school from Monday to Friday, up to 8 h a day. In 2007 there were a total of 3263 primary and secondary schools with approximately 570,700 students (Statistics Finland, 2007).

Indoor environmental quality (IEQ) of schools is influenced by the location of the building and its environmental quality, and

Abbreviations: CI, confidence interval; CO, carbon oxide; CO_2, carbon dioxide; csv, comma separated values; FPRC, Finnish Population Register Center; IEQ, indoor environmental quality; SPSS, a computer program used for survey authoring and deployment (IBM SPSS Data Collection); THL, National Institute for Health and Welfare; US EPA, United States Environmental Protection Agency; VOCs, volatile organic compounds.

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by various building-related factors, such as the condition, maintenance, and cleaning of the school building (US EPA, 2010). IEQ is also affected by pollutants that are generated indoors. Pollutants that may worsen indoor air quality (IAQ) in classrooms include molds, bacteria, allergens, particles, volatile organic compounds (VOCs), and formaldehyde (Zhao et al., 2008).

Different building types and their IEQ characteristics can be partly attributed to building age and construction materials. For example, old school buildings may have asbestos in them (Flynn et al., submitted for publication), and they may have less insulation, and leakier structures (Espejord, 2000). Their ventilation system may be old, or they perhaps rely on natural ventilation, which is difficult to control during the various activities occurring in classrooms during a normal school day. Palonen et al. (2009) reported that the median age of ventilation systems in Finnish schools is 30 years, which means that in many cases, the system may not be able to function up to the current standards. In the same study, the measured average ventilation rate was 3.5 l/s per person (or 1.2 l/s per square meter), which is lower than the currently required minimum of 6 l/s per person (Ministry of the Environment, 2012).

According to Daisey et al. (2003), poor IEQ can lead to health symptoms and absence from school and it can also cause decreased performance while at school. They reported a statistically significant, partial correlation between headache, dizziness, heavy head, tiredness, difficulties concentrating, unpleasant odor, and high CO_2 concentrations. Recently, Mendell et al. (2013) reported an association between ventilation and illness-related absence in Californian schools.

As described, the current literature links IEQ in schools with students' health and performance. However, existing knowledge is still limited concerning the desirable levels of air quality, maintenance, cleaning, and other factors affecting IEQ in schools. We also lack a common understanding of the "normal" levels of parameters that can be used in evaluating the health and performance of students. The present study was designed to make a comprehensive evaluation of IEQ and the health and wellbeing of students, and to provide a deeper understanding of the tools that can be used for evaluating the environmental health situation in schools.

The overall aims of the study were to assess IEQ in Finnish elementary school buildings, and to estimate how IEQ in schools affects the health and academic performance of students. In this paper, we report the results of a health questionnaire study. A specific aim was to study the group-level prevalence of symptoms in relation to IEQ. Distributions of school-level prevalence of symptoms reported by 6th grade students are examined, with an underlying assumption that high prevalence of certain symptoms in a school could be associated with IEQ issues, such as thermal conditions and poor ventilation or IAQ.

Material and methods

The data were collected as a part of the study "Indoor Environmental Quality and Academic Performance in Schools" (Haverinen-Shaughnessy et al., 2012). The resulting database included: (1) academic performance data based on a national assessment of mathematics (a math test for 6th grade students), (2) health questionnaire data, (3) measurement data concerning IEQ, as well as data on school buildings based on (4) a school principal questionnaire, and (5) a Finnish Population Register Center (FPRC) dataset.

The math test was organized in a stratified random sample of 355 elementary schools by the Finnish National Board of Education as a part of the national testing program. Shortly after the testing, health questionnaires were sent to the same schools. Some 310 were Finnish speaking and 45 were Swedish speaking schools. The number of students in these schools was approximately 7619, which was the number of 5th grade students in the same schools in the year prior to the testing (current student lists from the schools were not available). A subsample of 56 schools with more than 15 6th grade students was selected to participate in a field study, in which measurements on ventilation rate and thermal conditions were performed in each 6th grade classroom. Background information about all Finnish elementary school buildings was collected from the Finnish Population Register Center and also with a questionnaire sent to all Finnish elementary school principals (2769 schools, data not shown).

Ethical and data security issues

Before starting the data collection, ethical approval was obtained from the National Ethical Committee. Participation in the study was voluntary. Privacy protection was enacted according to the Finnish Personal Data Act and the regulations of the National Institute for Health and Welfare.

Health questionnaire data

The health questionnaire was developed using a validated questionnaire formerly used in several studies at the National Institute for Health and Welfare (e.g. Meklin et al., 2002; Haverinen-Shaughnessy et al., 2004). Some questions concerning students' background and health were added. The final questionnaire included a total of 37 questions as follows:

- 6 questions about socioeconomic status
- 18 questions about students' health and wellbeing
- 1 question about school environment
- 6 questions about home environment
- 4 questions about living habits (e.g. eating and sleeping)
- 2 questions about advantages/disadvantages in learning.

All 6th grade students of the participating schools were invited to participate in the questionnaire study ($N \approx 7619$). Students and their parents could respond by filling in the questionnaire in paper form or via the Internet. Some of the questions were formulated as follows (Fig. 1):

The paper questionnaires were sent to 355 elementary schools in May 2007 and the internet questionnaire was made available between May and August 2007. The internet questionnaire was implemented by means of the Digium Enterprise system (http://www.questback.fi/en/) and it was linked through the research institute's web-site designated for the project (http://www.thl.fi/fi/koulututkimus). The internet connection was secured. Parents were asked to fill in the questionnaire at home together with the child, who then returned the paper questionnaires to the school. The schools collected the paper questionnaires and sent them back to the research institute.

The data from the Internet responses were retrieved from the Digium-system in a csv-format, after which the data were transferred to the SPSS-program. The paper questionnaire data were also compiled into an SPSS-file format. All data were then analyzed with SPSS version 20.0. The student-level data were aggregated into group-level data using the aggregate command in the SPSS-program. Unique school codes were used as break variables.

The 95% confidence intervals for the prevalence values were calculated by using the formula: $p - 1.96 \times \sqrt{((p \times (1-p))/n)} \leq \mu \leq p + 1.96 \times \sqrt{((p \times (1-p))/n)}$, where n is the sample size and p is the percentage value of the sample. We calculated the 95% confidence intervals for the whole sample (N = all students) and also separately for a sample size $N = 15$, which was assumed to be a minimum sample size for