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How do occupants rate bedroom air quality?

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Abstract. Poor air quality has been shown to reduce sleep quality. There is a limited number of studies reporting how occupants rate the air quality in their bedrooms. The present study sheds the light on this issue. It was conducted in actual bedrooms and asked occupants to rate air quality once awake in the morning using an online sleep diary. The study was done in Denmark during the heating season. 178 responses from 82 subjects were received. Nearly all respondents rated air quality as acceptable. 28% indicated that the air was stuffy. Measuring CO$_2$ and description of bedrooms would help to explain these results. They are analysed at the moment and will be reported in the subsequent papers.

1. Introduction
Poor air quality due to inadequate ventilation has been recently shown to reduce sleep quality [1-4]. These chamber or intervention studies in bedrooms rarely provide information on how occupants rate the air quality in bedrooms.

A recent field study by Kallawicha et al. (2020) measured perceived air quality (PAQ) to analyze the association between bedroom environment and sleep quality [5]. A four-point Likert Scale of perceived air quality labeled “bad”, “moderate”, “good”, and “very good” was used to rate air quality but the ratings of air quality were not reported. Strom-Tejse et al. (2016) conducted an intervention study and the subjects assessed the quality of air the next morning by rating its freshness/stuffiness on a continuous visual analogue scale. No large differences in the ratings of air quality were observed independently of whether the fan in the bedroom was on or off and the average rating was close to the middle of the scale (neither fresh nor stuffy), yet the air in bedrooms with the fan on was assessed to be fresher [2].

The present study aimed to investigate how occupants assess air quality in their bedrooms the next morning when awake. The study was carried out in real buildings with no interventions to bedroom air quality and in the heating season.

2. Methods
The data were collected in the capital region of Denmark in the heating season from September to December 2020. The participants were asked to reply to an online sleep diary in the morning when awake at least twice a week during the measurements performed from Monday to Friday; this was a part of a much larger campaign of which results will be presented later. They assessed whether the air was
stuffy/fresh and whether it was acceptable/not acceptable. The linear continuous scales were used (Figure 1). Information on sex, age, height, and weight were collected.

Statistical analyses were performed using R Studio (version 1.3.1093, Boston, MA, USA). All analyses were considered statistically significant when the P was less than 0.05 (2-tailed). The ratings of air quality by different groups of subjects were analysed using the Wilcoxon rank-sum or the Kolmogorov-Smirnov test.

Figure 1. The linear continuous scales for air quality assessments.

Figure 2. Frequencies of air quality assessments.

3. Results and discussion
A total of 178 responses from 82 occupants were obtained. Table 1 shows the demographic characteristics of participants. More than half of them were males. The median age was 27 years.

| Characteristic         | Result     |
|------------------------|------------|
| Sex, n (%)             |            |
| Male                   | 45 (54.9)  |
| Female                 | 37 (45.1)  |
| Age, median (IQR), year| 27.0 (24.3 – 32.0) |
| BMI, median (IQR), kg/m²| 22.4 (20.8 – 24.2) |

The median (interquartile range) of the ratings of air freshness/stuffiness and acceptability was 35.0 (19.0 – 52.0) and 23.8 (12.1 – 36.6), respectively. Figure 2 shows that 28.1% of all responses showed the air quality to be stuffy and 3.4% to be not acceptable. This suggests no problems with the air quality as perceived by the occupants of these bedrooms.

Figure 3 shows the air quality assessments for occupants with different personal characteristics. Females tended to rate the air quality as more stuffy compared with males. A higher percentage of the younger participants aged 32 or below perceived air to be more stuffy compared with the older participants. A higher percentage of those with BMI lower than 25.0 perceived air as more stuffy compared with those who were overweight or obese. Older participants, who normally had higher BMI (rho = 0.205, P < 0.006) probably had a better living environment and therefore rated air quality to be better. A higher percentage of the older participants, compared with the younger, rated the air quality to be more acceptable.

Further investigation regarding the specific differences of the living environment, such as building types and ventilation systems in bedrooms, is needed to provide explanations to these results. The analyses are in progress and will be reported later.

4. Conclusion
Occupants rated the air quality in their bedrooms the next morning. The assessments indicated generally good perceived air quality. Older people rated air quality to be better compared with the younger occupants.

Figure 3. The air quality assessments for occupants with different personal characteristics.

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