Ventilation and sleep quality

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ABSTRACT

We sleep more than twenty years during our lives. Sleep is essential for physical and psychological health. Yet, nearly no standards define indoor environmental quality conditions for optimal sleep. In this paper, we present a summary of studies examining the effects of bedroom ventilation on sleep quality. The results suggest that the current ventilation standards for dwellings are inadequate concerning requirements of outdoor air supply rates in bedrooms and need to be revised. They suggest that the traditionally agreed level of carbon dioxide at 1,000 ppm to achieve good air quality should be revisited, and the lower levels need to be maintained to ensure that sleep quality is not disturbed. Furthermore, the traditional recommendation of 0.5 air changes per hour also needs to be revised, as the bedroom ventilation should most likely be twice this rate. There is a need for further research and validation of these results, as well as rethinking how the ventilation air is distributed within the dwelling so that the health and sleep of building occupants are not compromised.

KEYWORDS

Dwellings, Bedrooms, Sleep quality, Carbon dioxide, Ventilation requirements.

1 INTRODUCTION

Sleep is essential for human health as it allows the body to recover and function effectively by promoting various physiological and cognitive processes. The sleep-wake cycle is generally regulated by the homeostatic physiology of circadian rhythm, which is very complex.

Sleep is traditionally monitored by measuring biological responses. For this purpose, polysomnography (PSG) is used. Although there is no accepted definition of the 'quality' of sleep, it is generally derived from the objective measurements made by PSG or subjective ratings using questionnaires. Sleep quality can be quantitatively assessed by a collection of indicators recommended by the US National Sleep Foundation.

People spend approximately one-third of their lifetime sleeping, mostly in bedrooms. Bedroom indoor air quality (IAQ) can be affected by many factors. The air pollutants present in bedrooms can have their origin outdoors or indoors.

Ventilation is commonly used to remove and dilute pollutants and is thus assumed to improve IAQ. Given the importance of ventilation in bedrooms in determining the levels of pollutants, it is surprising that only a few studies have focused on measuring ventilation rates in bedrooms. Summaries of the studies that measured bedroom ventilation rates observed that the mean air change rate (ACH) measured in bedrooms was between 0.2 to 4.9 $h^{-1,}$ with most cases lower than 0.5 h^{-1}, traditionally considered base ventilation in dwellings.

Many standards and guidelines stipulate ventilation and IAQ requirements for buildings. However, they do not have specific ventilation requirements for bedrooms; bedroom ventilation results from the overall ventilation requirements for residential dwellings. There is no evidence of whether the prescribed ventilation requirements that are acceptable for the dwellings during the daytime are also sufficient to avoid disturbing sleep at night.

The objective of this work was to answer the following question: What is the bedroom ventilation rate to ensure undisturbed sleep?

2 METHODS

We summarized studies in which ventilation and sleep quality were measured. They included laboratory and field experiments, and cross-sectional and intervention studies. As a measure of ventilation efficiency, the measured concentration of carbon dioxide (CO_2) was used. Bedroom ventilation was obtained by a mechanical system, window, or door opening. Sleep quality was measured objectively using wrist-worn actiwatch sleep trackers and by collecting ratings of participants using the Groningen Sleep Quality Scale (GSQS). The effect on any of the objective indicators of sleep quality or an increase in GSQS score was considered an effect on the overall sleep quality. The objective measures included sleep efficiency, sleep onset latency, wake time after sleep onset, and the length and % of deep, light, and REM sleep. We did not assess the physiological consequences of the observed effects. The studies involved mainly young adults but also seniors and children.

3 RESULTS

Figure 1 shows the results of studies that measured sleep quality objectively. Figure 2 shows the results of studies that measured sleep quality using GSQS. Generally, sleep was undisturbed at the levels of CO_2 below 1,000 ppm.

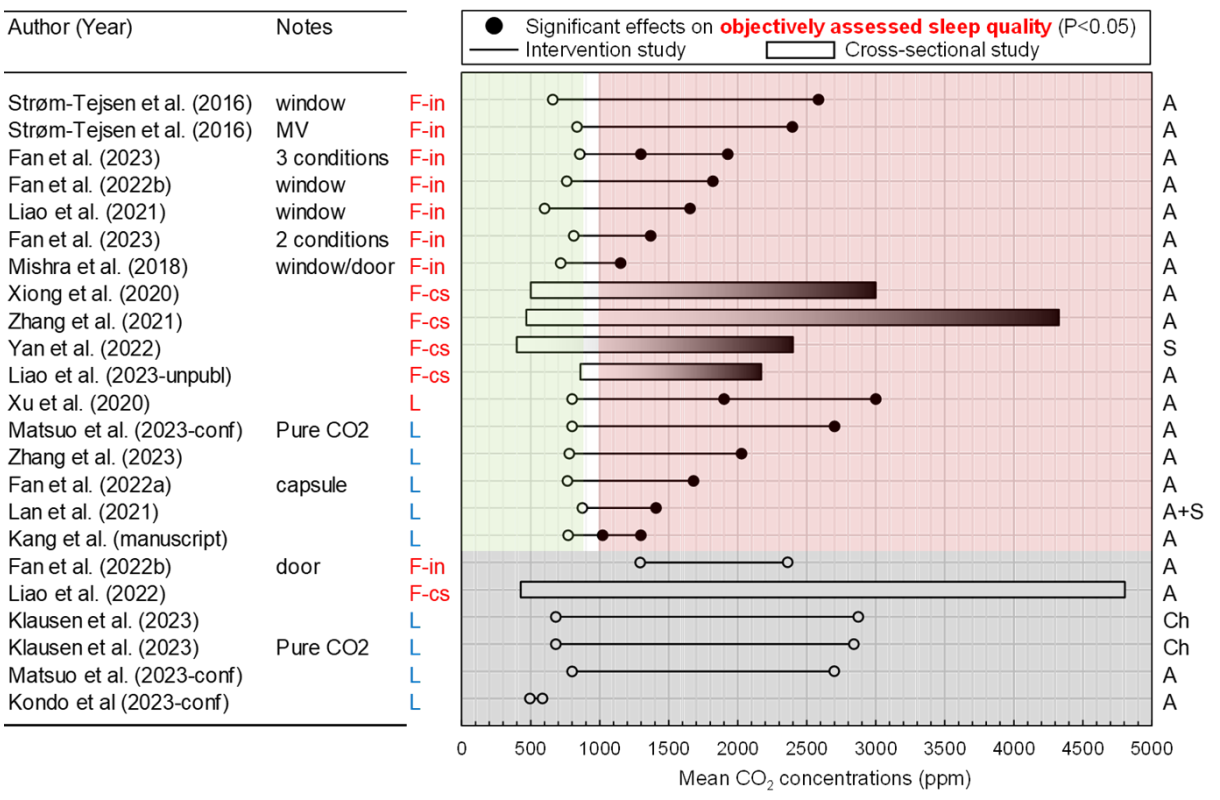

Figure 1: The relationship between sleep quality measured objectively and the concentration of CO_2, either the primary exposure or the marker of ventilation efficiency; dark dots indicate significant adverse effects, and white dots no effects.

4 CONCLUSIONS

Present results suggest that to keep undisturbed sleep quality, the ventilation rate should be above 6 L/s per person and most likely closer to 10 L/s per person (Figure 3); the latter rate is recommended for bedrooms by the standard EN16798-1 in the highest category I of indoor environmental quality. It was assumed that the emission rate of CO_2 during sleep is around 11 L/h per person, independent of age. Taking the typical size of a bedroom, this rate would

correspond to about one air change per hour, which is twice the air change rate traditionally recommended rate in dwellings. These results, however, require further validation and detailed analyses as the shape of the relationship below 1,000 ppm CO_2 is not well defined (Figure 1). Nevertheless, it is essential to note that recommendations for bedroom ventilation rates must be revisited if they exist or clearly defined if they do not exist. Additionally, advanced and novel methods securing adequate yet sustainable ventilation of bedrooms and dwellings should be developed.

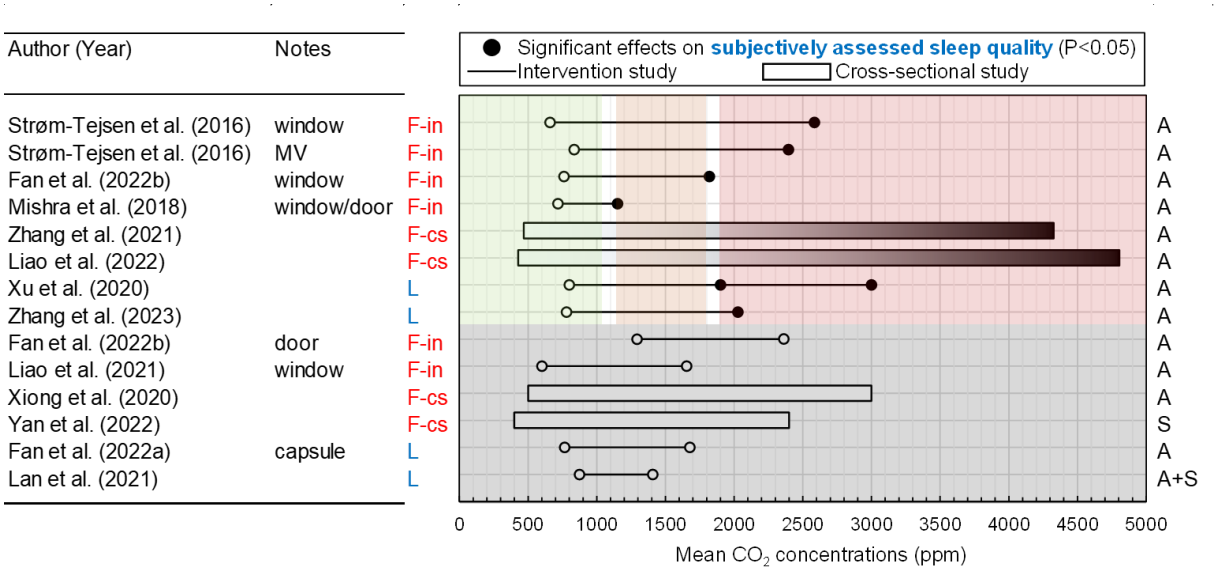

Figure 2: The relationship between sleep quality measured subjectively and the concentration of CO_2, either being the primary exposure or marker of ventilation efficiency; dark dots indicate significant adverse effects, and white dots no effects.

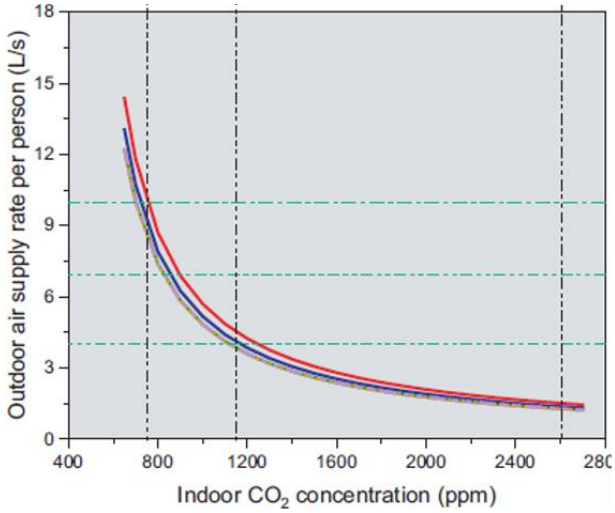

Figure 3: Estimation of ventilation rate for undisturbed sleep quality

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