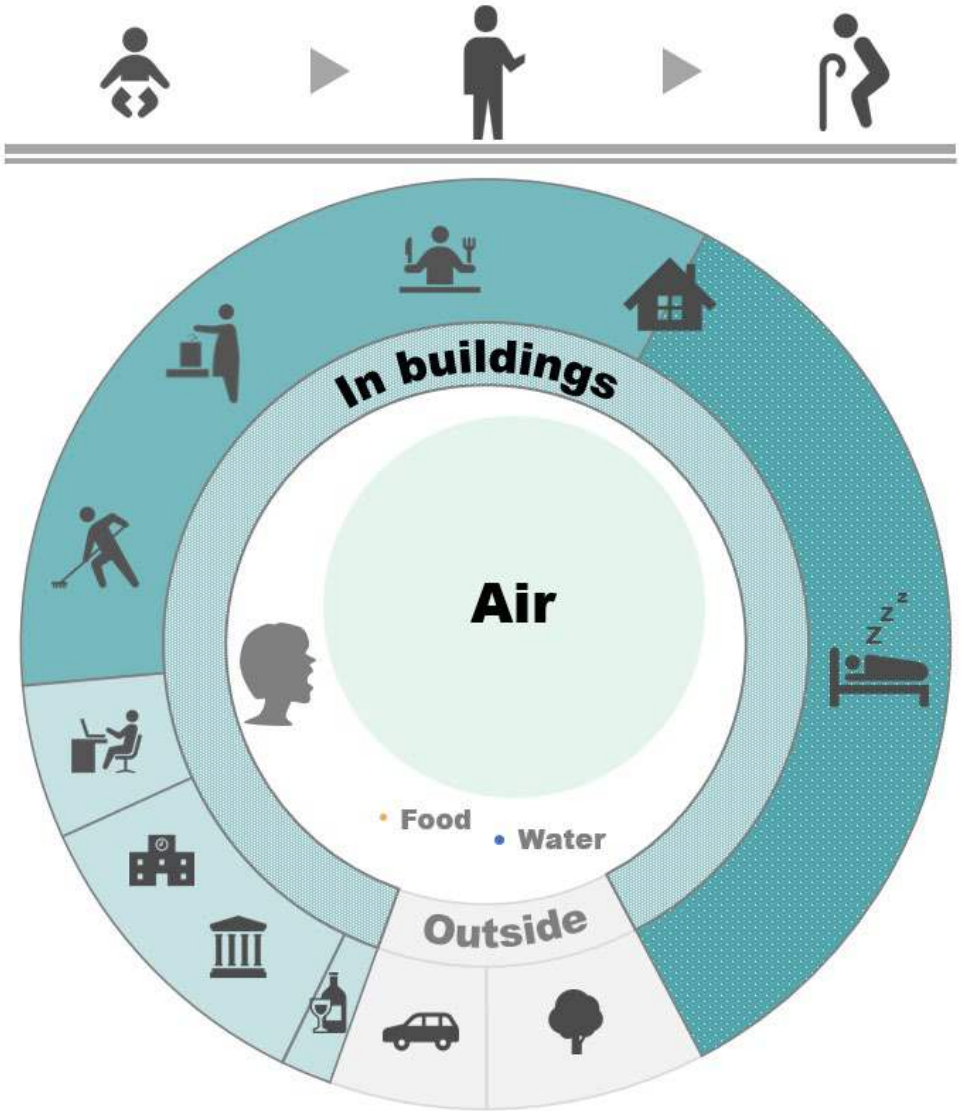
Indeklimaets indvirkning på vores søvn

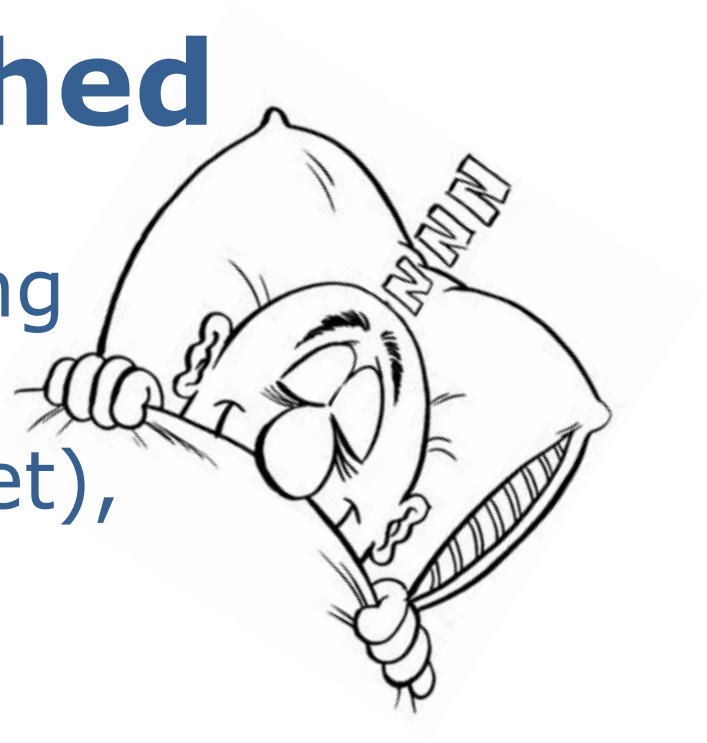
Pawel Wargocki (pawar@dtu.dk)
Danmarks Tekniske Universitet, DTU Sustain

Gennem livet sover mennesket i mere end 20 år



Kilde: Klepeis et al. (2011)

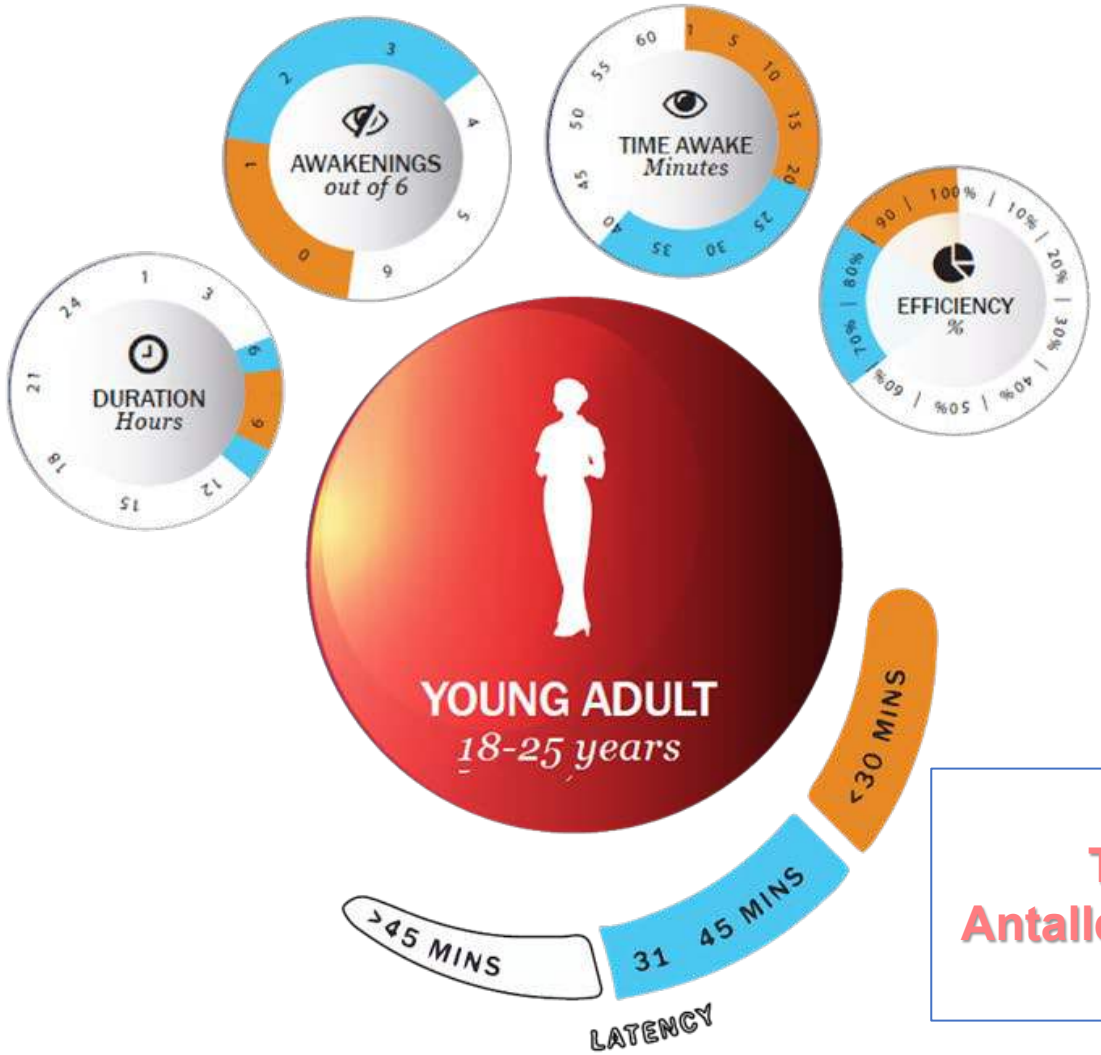
Søvn og sundhed

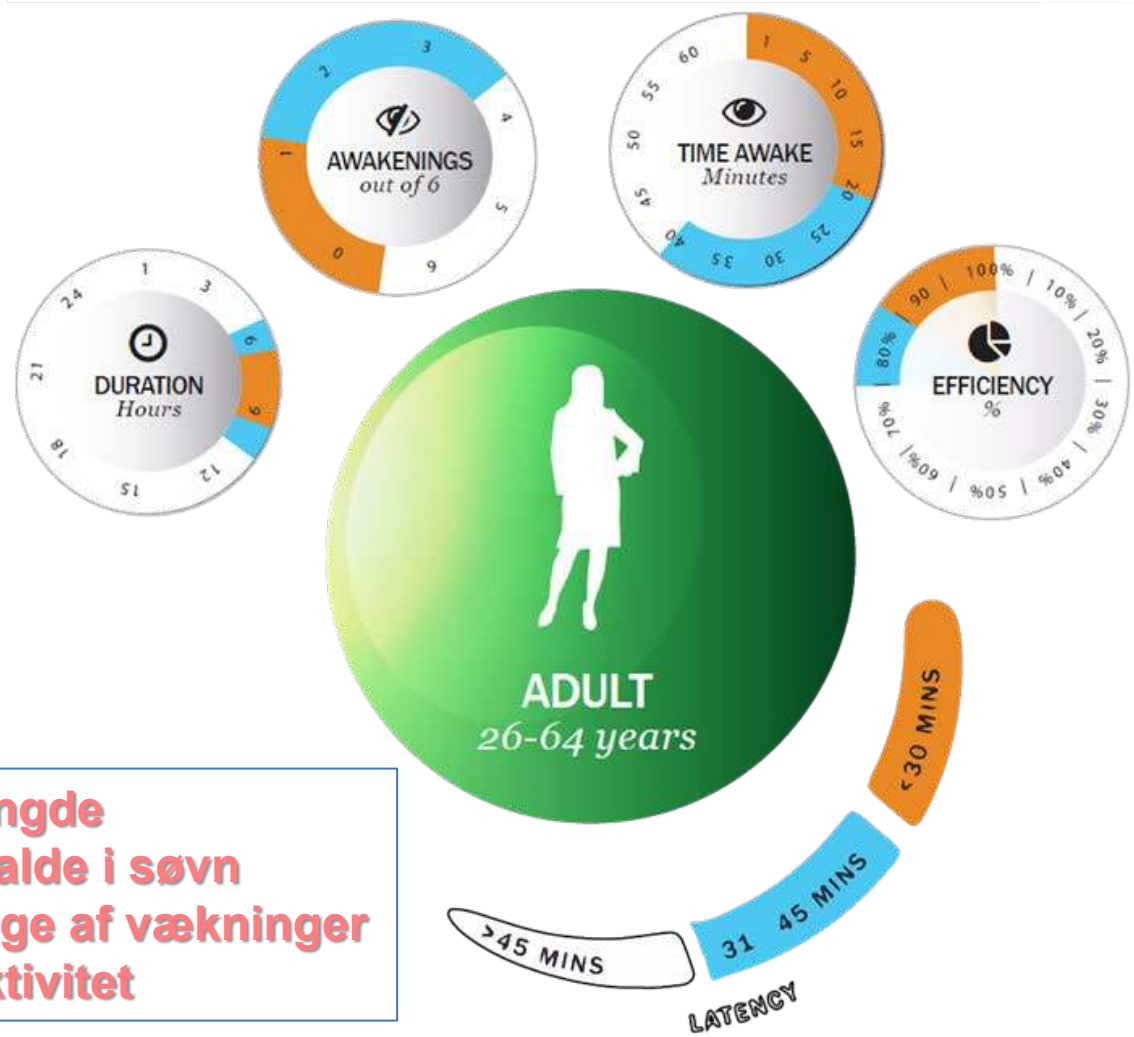


- Høj søvnkvalitet har vital betydning
- Søvn styrker de kognitive evner (hukommelse, læring og kreativitet), nedsætter helbredsrisici (demens, Alzheimers), regulerer appetitten (fedme), reducerer risikoen for trafikuheld, samt øger koncentrationen og den arbejdsmæssige ydeevne
- Mennesket bliver frataget en stigende del af søvnens længde (<7,5 timer) og kvalitet

Kilde: Walker (2017)

Parametre for en høj søvnkvalitet



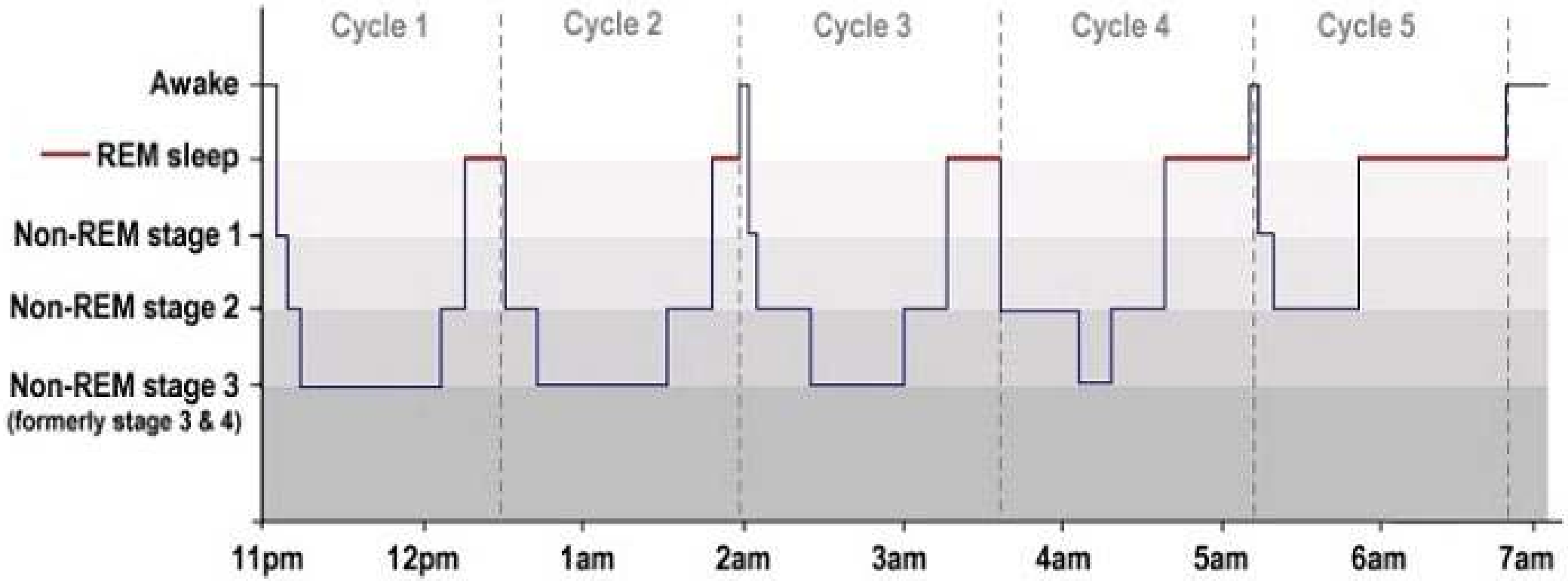


Længde
Tid til at falde i søvn
Antallet og længe af vækninger
Effektivitet

NOT RECOMMENDED | MAY BE APPROPRIATE | RECOMMENDED

Source: National Sleep Foundation's sleep quality recommendations (2017)

Søvnens forløb



Kilde: Walker (2017)

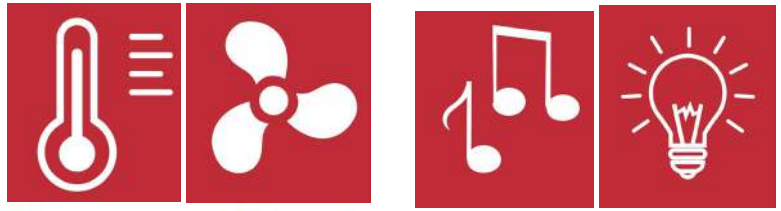
Søvnmåling

Polysomnografi

Aktigrafiske- og søvn trackere

Hvad er betydningen af indeklima?

COLUMN IEQ APPLICATIONS



Thermal Environment, IAQ and Sleep

BY PAWEL WARGOCKI, PH.D., MEMBER ASHRAE; LI LAN, PH.D.; ZHIWEI LIAN, PH.D.; DAVID P. WYON, PH.D., MEMBER ASHRAE

Is sleep becoming so much scarcer than ever before because people do not realize the importance of sleep for health and well-being? All over the world, digital communications now mean that contact with work continues after hours and during weekends and that "friends" are no longer just the people we meet regularly, but the many more we contact regularly. These new contacts compete strongly for our time with online entertainment and news, our leisure activities and our immediate families, and there are still only 24 hours in each day.

The time available for sleep is thus under great pressure. There is widespread concern among health professionals that we are no longer getting enough sleep. It is important to know whether that matters, and if so, how we can efficiently use the time that we reluctantly make available for sleep. Sleep and its importance are briefly summarized in the sidebar, "Why Enough Sleep Is Vital for Well-Being." This column focuses on what ASHRAE engineers can do to ensure efficient sleep.

Question 1 ***What current developments are affecting sleep?***

Increasing work-life stress, social media, mobile communications and online entertainment have greatly reduced the time left over for sleep. The equipment tends to find its way into bedrooms and to be used after bedtime. In the tropics, and elsewhere as the planet warms, split-cooling is increasingly being installed in bedrooms. This reduces temperature and humidity, sometimes by more than is beneficial for sleep, leading to greatly reduced bedroom air quality, as windows are then kept closed. Increasing insulation levels to conserve energy is also causing bedrooms to be too warm even in cool summer weather.

Question 2 ***Which physical factors are likely to affect sleep?***

Security (from intruders, predators and insects), privacy, noise, temperature, humidity, light levels, air quality and air velocity. Every one of these factors is determined by building design and operation. Architects determine security, privacy and light levels, but ASHRAE engineers determine the rest.

Question 3 ***What has research discovered about thermal effects on sleep?***

1) Preferred bedroom air temperatures vary greatly between individuals, not least due to systematic differences in bed-wear insulation and in how the drape of the bedcovers is unconsciously manipulated during sleep;[1] 2) It is difficult to fall asleep and to stay asleep

Pawel Wargocki, Ph.D., is an associate professor and David Wyon, Ph.D., is a professor with the International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark. Li Lan, Ph.D., is an associate professor, and and Zhiwei Lian, Ph.D., is a professor with the Department of Architecture at Jiao Tong University in Shanghai, China.

Spørgeskema undersøgelse i soveværelser (DK)

Science of the Total Environment 798 (2021) 149209

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

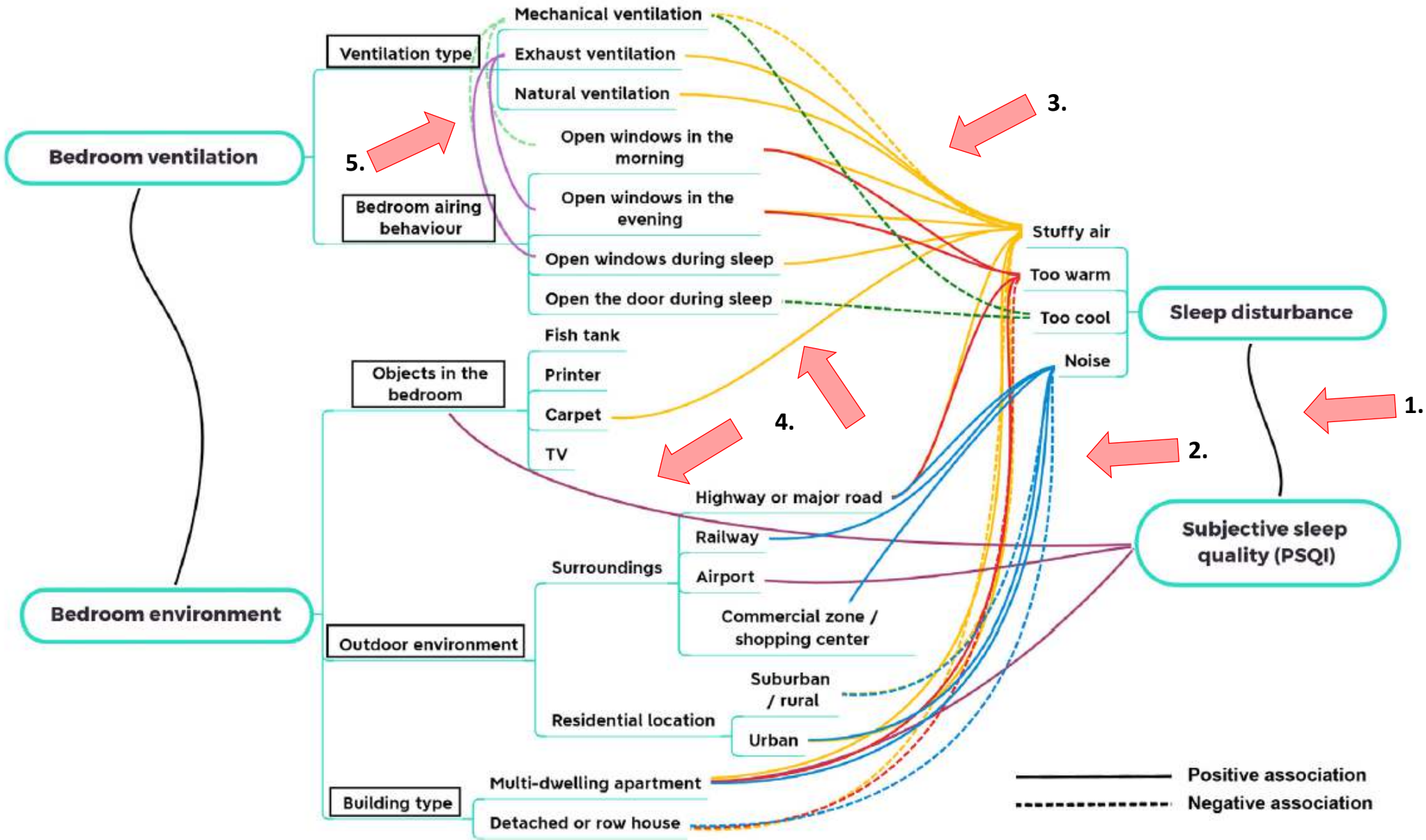
A survey of bedroom ventilation types and the subjective sleep quality associated with them in Danish housing

Chenxi Liao [a,b,*,**], Mizuho Akimoto [b,c], Mariya Petrova Bivolarova [b], Chandra Sekhar [b,d], Jelle Laverge [a], Xiaojun Fan [b], Li Lan [e], Pawel Wargocki [b]

[a] Research Group Building Physics, Construction, and Climat
[b] International Centre for Indoor Environment and Energy, I
[c] Department of Architecture, Waseda University, Japan
[d] School of Design and Environment, National University of
[e] Department of Architecture, School of Design, Shanghai Jia

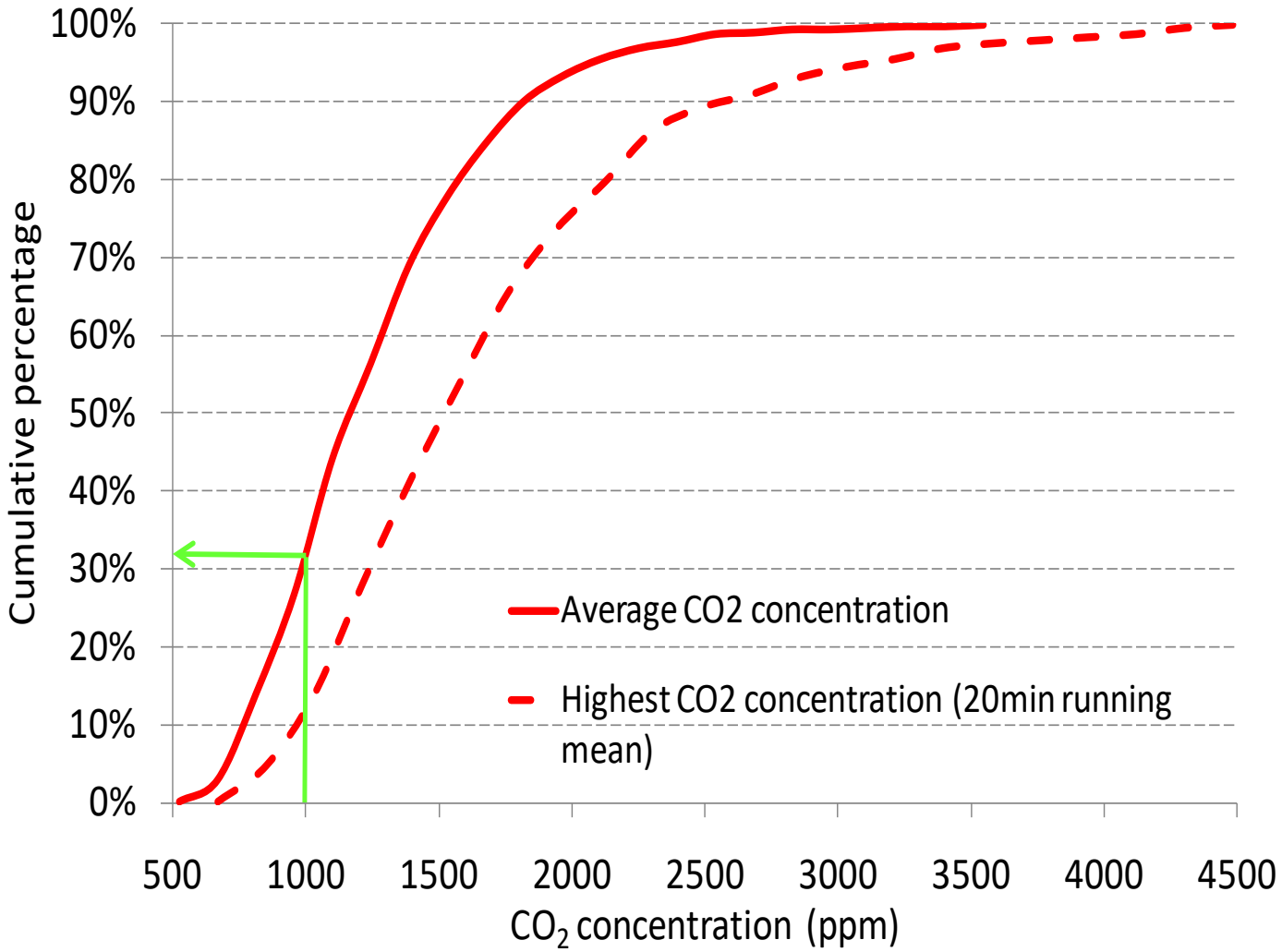
HIGHLIGHTS

- Sleep disturbance caused by stuffy air reduces sleep quality in people's life.
- Mechanical ventilation in bedrooms reduces stuffy air and "too cool" during sleep.
- Fish tank, printer, carpet and TV placed in bedrooms decrease sleep quality.



Kilde: Liao et al. (2021)

Ventilation i soveværelser (DK)



Source: Bekö et al. (2010)

Building and Environment 184 (2020) 107229

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journal homepage: http://www.elsevier.com/locate/buildenv

Bedroom ventilation: Review of existing evidence and current standards

Chandra Sekhar [a,b], Mizuho Akimoto [b,c], Xiaojun Fan [b], Mariya Bivolarova [b], Chenxi Liao [b,d], Li Lan [e], Pawel Wargocki [b,*]

[a] Department of Building, School of Design and Environment, National University of Singapore, Singapore
[b] International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark, Denmark
[c] Department of Architecture, Waseda University, Japan
[d] Department of Architecture and Urban Planning, Ghent University, Belgium
[e] Department of Architecture, School of Design, Shanghai Jiao Tong University, China

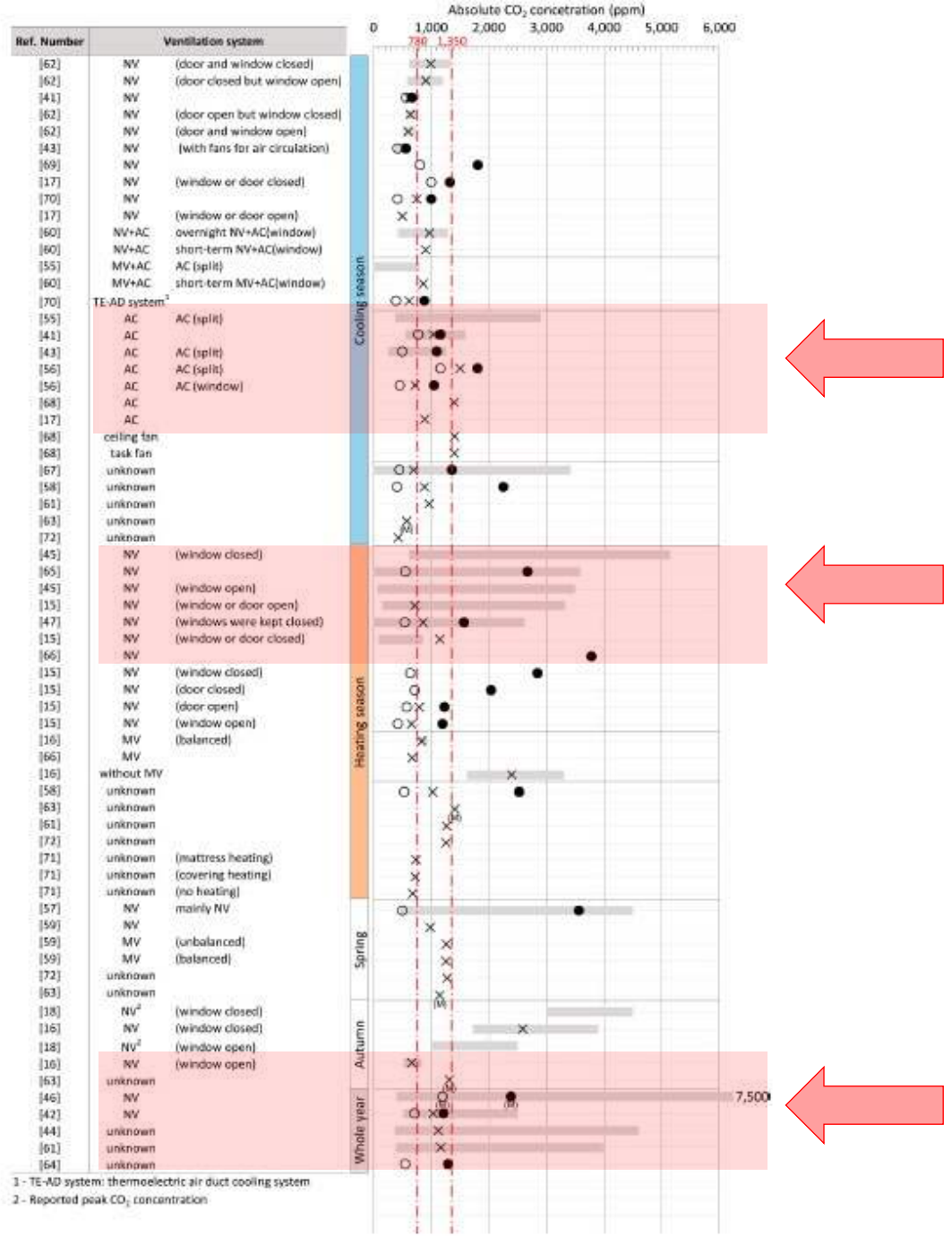
ARTICLE INFO

Keywords:
Dwellings
Bedrooms
Ventilation
CO_2
Air exchange rate
Sleep quality
Standards

ABSTRACT

Sleep is essential for our health and well-being. Some research suggests that air quality influences sleep quality in bedrooms, but the evidence is limited. Research, until now, has focused on how indoor air quality affects health, comfort, and cognitive performance during waking hours. Less information is available on the levels of indoor air quality and ventilation in bedrooms, or on their consequences for sleep quality and next-day performance. This paper addresses the former by reviewing research published in peer-reviewed journals in this millennium. Bedroom ventilation has been chosen as a specific focus of this review paper, which also includes a review of selected international standards for bedroom ventilation. Arising out of this review and a comparison of field data with CO_2 and ventilation benchmarks from widely adopted international standards, an attempt is made to generalize the level of bedroom ventilation that exists in practice in residential dwellings and apartments across different seasons and different parts of the world. Based on a limited number of studies dealing with the impact of bedroom ventilation on sleep quality, an attempt is also made to associate measured field data with its potential impact on sleep quality.

Rapporteret målinger af CO_2 i soveværelser



Kilde: Sekhar et al. (2020)

IEQ APPLICATIONS
Column

ASHRAE TRP 1837

Reviewing How Bedroom Ventilation Affects IAQ And Sleep Quality

BY MIZUHO AKIMOTO, STUDENT MEMBER ASHRAE; CHANDRA SEKHAR, PH.D., FELLOW ASHRAE; MARIYA P. BIVOLAROVA, PH.D.; CHENXI LIAO, STUDENT MEMBER ASHRAE; XIAOJUN FAN, ASSOCIATE MEMBER ASHRAE; JELLE LAVERGE, PH.D., MEMBER ASHRAE; LI LAN, PH.D., MEMBER ASHRAE; PAWEL WARGOCKI, PH.D., MEMBER ASHRAE

Good sleep is essential for our health and daytime functioning; seven to nine hours of sleep each night are recommended for people age 18 to 64.[1,2] Noise, light, temperature and air quality affect our sleep. However, very few regulations address indoor air quality (IAQ) in bedrooms, and even fewer studies examine the relationship between sleep quality, ventilation and IAQ.[3] This column reviews 10 studies reported in nine publications[4–12] that examined whether providing clean air to a sleeping person will result in improved sleep quality. The column also provides information on the expected effects on sleep when bedroom ventilation and IAQ are inadequate.

Hvor meget skal man lufte ud?

<750 ppm CO_2: uforstyrret søvn

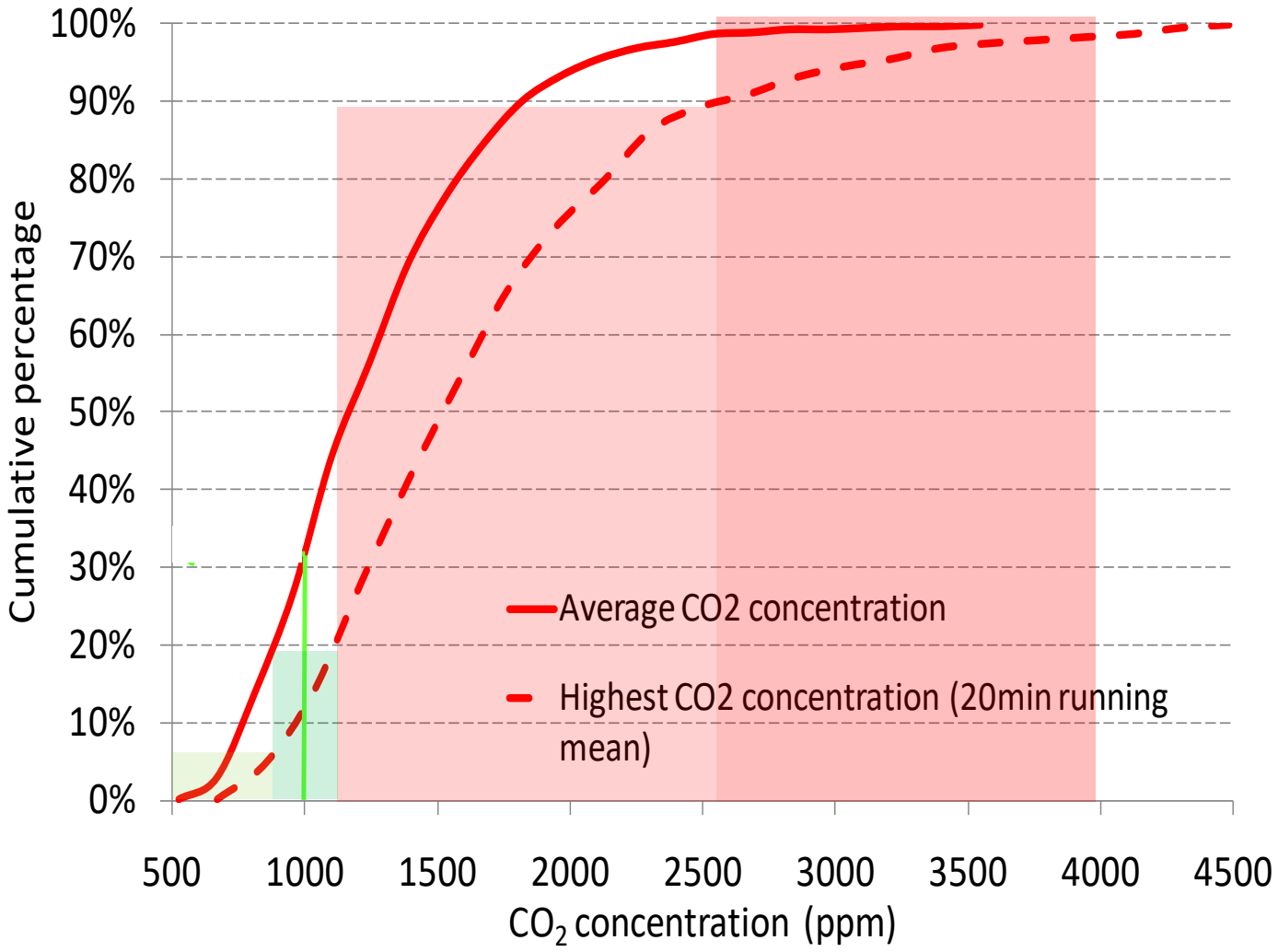
750-1150 ppm CO_2: muligvis forstyrret søvn

1150–2600 ppm CO_2: forstyrret søvn

>2600 ppm CO_2: forstyrret søvn og
næste døgns præstation

Kilde: Sekhar et al. (2020); Akimoto et al. (2020)

Ventilation i soveværelser (DK)



Source: Bekö et al. (2010)

ORIGINAL ARTICLE

WILEY

Emission rate of carbon dioxide while sleeping

Xiaojun Fan[1] | Mitsuharu Sakamoto[2] | Huiqi Shao[3] | Kazuki Kuga[2] | Kazuhide Ito[2] | Li Lan[4] | Pawel Wargocki[1]

[1]International Centre for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark

[2]Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan

[3]School of Chemistry and Biological Engineering, University of Science and Technology Beijing, Beijing, China

[4]Department of Architecture, School of Design, Shanghai Jiao Tong University, Shanghai, China

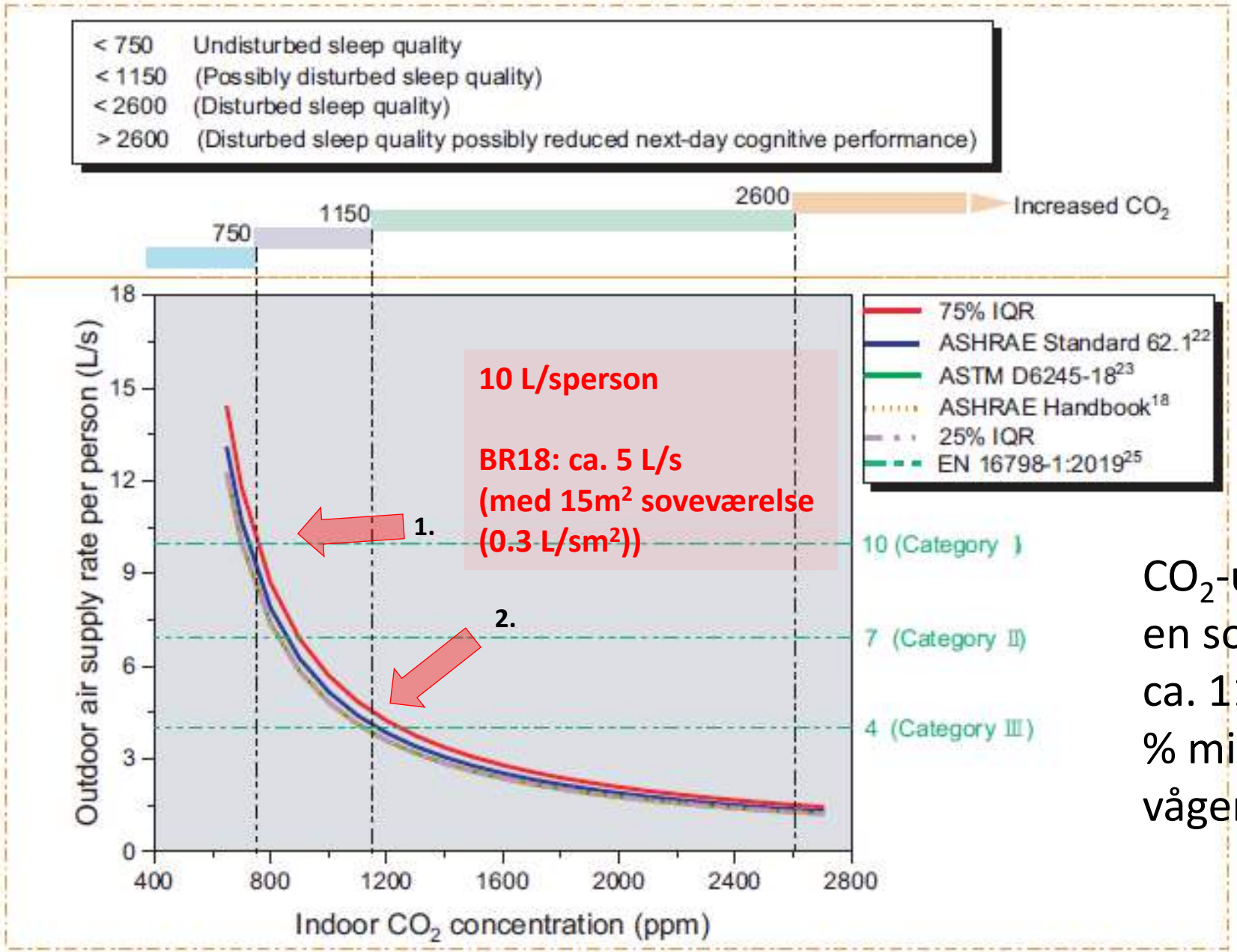
Correspondence
Pawel Wargocki, International Centre for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark.
Email: paw@byg.dtu.dk

Funding information
Otto Mønsteds Fond; American Society of Heating, Refrigerating and Air-Conditioning Engineers; Department of Civil Engineering, Technical University of Denmark; China Scholarship Council

Abstract

Humans emit carbon dioxide (CO_2) as a product of their metabolism. Its concentration in buildings is used as a marker of ventilation rate (VR) and degree of mixing of supply air, and indoor air quality (IAQ). The CO_2 emission rate (CER) may be used to estimate the ventilation rate. Many studies have measured CERs from subjects who were awake but little data are available from sleeping subjects and the present publication was intended to reduce this gap in knowledge. Seven females (29 ± 5 years old; BMI: 22.2 ± 0.8 kg/m^2) and four males (27 ± 1 years old; BMI: 20.5 ± 1.5 kg/m^2) slept for four consecutive nights in a specially constructed capsule at two temperatures (24 and 28°C) and two VRs that maintained CO_2 levels at ca. 800 ppm and 1700 ppm simulating sleeping conditions reported in the literature. The order of exposure was balanced, and the first night was for adaptation. Their physiological responses, including heart rate, pNN_{50}, core body temperature, and skin temperature, were measured as well as sleep quality, and subjective responses were collected each evening and morning. Measured steady-state CO_2 concentrations during sleep were used to estimate CERs with a mass-balance equation. The average CER was 11.0 ± 1.4 L/h per person and was 8% higher for males than for females ($P < 0.05$). Increasing the temperature or decreasing IAQ by decreasing VR had no effects on measured CERs and caused no observable differences in physiological responses. We also calculated CERs for sleeping subjects using the published data on sleep energy expenditure (SEE) and Respiratory Quotient (RQ), and our measured CERs confirmed both these calculations and the CERs predicted using the equations provided by ASHRAE Standard 62.1, ASHRAE Handbook, and ASTM D6245-18. The present results provide a valuable and helpful reference for the design and control of bedroom ventilation but require confirmation and extension to other age groups and populations.

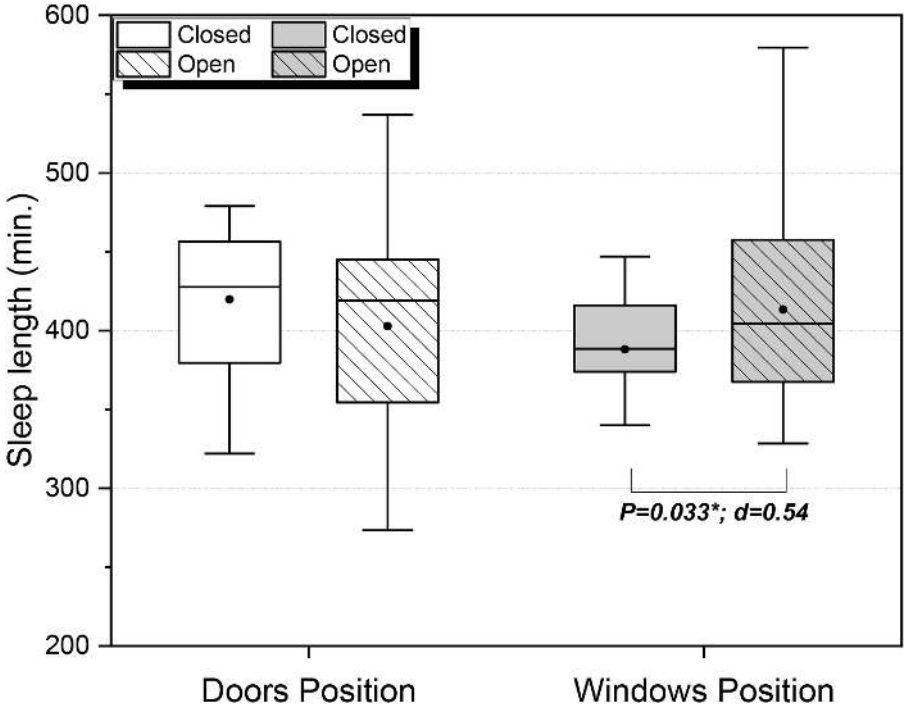
KEYWORDS
human CO_2 emission rates, physiological responses, sleeping conditions, temperature, ventilation

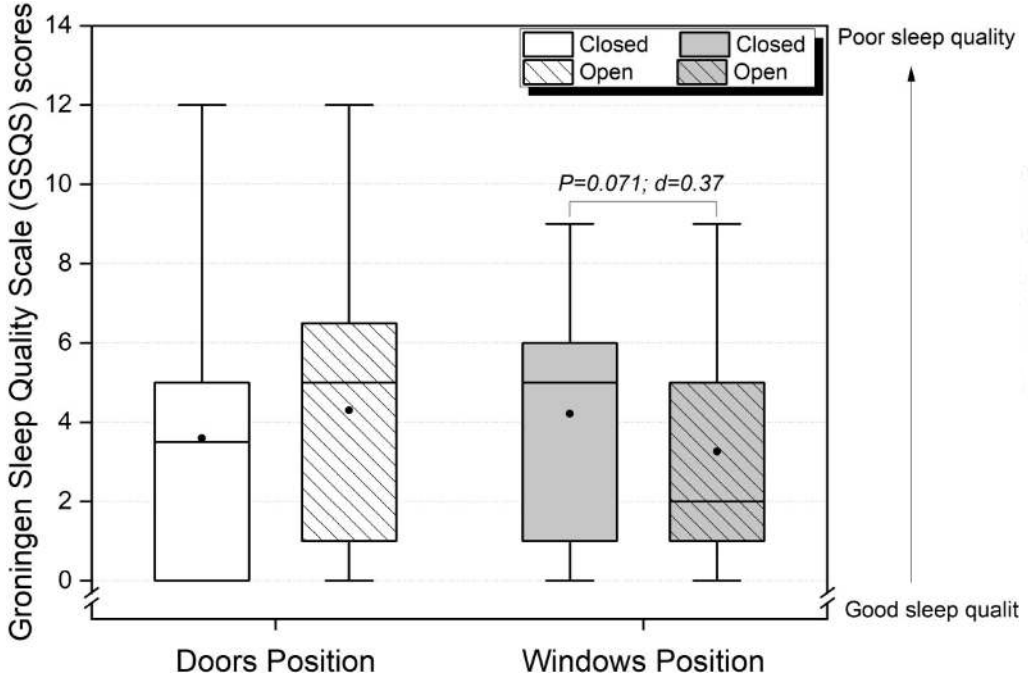


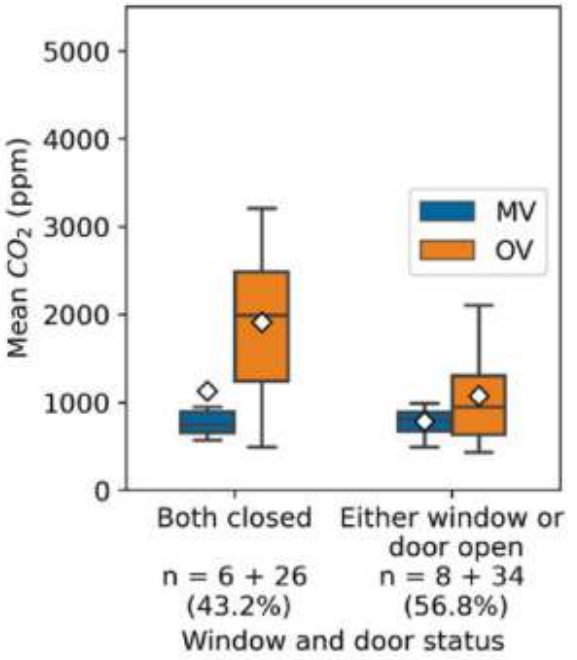
CO_2-udledningen fra en sovende person er ca. 11 liter pr. time (40 % mindre end fra en vågen person)

Kilde: Fan et al. (2021)

Hvordan skal vi lufte ud?







Kilde: Fan et al. (2022; Liao et al. (2022)

Building and Environment 225 (2022) 109630

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A field intervention study of the effects of window and door opening on bedroom IAQ, sleep quality, and next-day cognitive performance

Xiaojun Fan [a,*], Chenxi Liao [b], Mariya P. Bivolarova [a], Chandra Sekhar [c], Jelle Laverge [b], Li Lan [d], Anna Mainka [e], Mizuho Akimoto [f], Pawel Wargocki [a]

[a] International Centre for Indoor Environment and Energy, Department of Environmental and Resource Engineering (DTU Sustain), Technical University of Denmark, Denmark
[b] Research Group Building Physics, Construction, and Climate Control, Department of Architecture and Urban Planning, Ghent University, Belgium
[c] Department of the Built Environment, National University of Singapore, Singapore
[d] Department of Architecture, School of Design, Shanghai Jiao Tong University, China
[e] Department of Air Protection, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Poland
[f] Department of Architecture, Waseda University, Japan

ARTICLE INFO

Keywords:
Bedroom ventilation
Intervention
Air quality
Sleep quality
Next-day cognitive performance

ABSTRACT

Indoor Air Quality (IAQ) and sleep quality measurements over a period of two weeks were performed all night in 40 bedrooms in Denmark during the heating season. In the first week, the bedroom conditions were typical of what participants would normally experience during sleep. In the second week, the participants were asked to open the doors or windows if they had been closed or the opposite. A change in the 95th percentile of the measured CO_2 concentration by more than 200 ppm in the expected direction on the same weekdays of the two-week measurement period was taken to indicate that an effective intervention had taken place. The measurements in the 29 bedrooms that met this criterion were grouped depending on how the windows or doors had been manipulated. Objectively measured and subjectively rated bedroom IAQ improved when the windows were open except that the NO_2 concentration was slightly higher. Sleep was longer under this condition and sleep quality was subjectively assessed to be better. Similar effects were not observed when the doors were open although the 95th percentile of CO_2 concentration decreased by as much as when the windows were open. No effects were seen in the 11 bedrooms in which the change to the bedroom conditions made by the participants did not change the CO_2 concentration by at least 200 ppm, as would be expected. The present study provides evidence that sufficient dilution and/or removal of pollutants is necessary to ensure good bedroom IAQ and good sleep quality.

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Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A cross-sectional field study of bedroom ventilation and sleep quality in Denmark during the heating season

Chenxi Liao [a,b,*], Xiaojun Fan [b], Mariya Bivolarova [b], Jelle Laverge [a], Chandra Sekhar [d], Mizuho Akimoto [c], Anna Mainka [e], Li Lan [f], Pawel Wargocki [b]

[a] Research Group Building Physics, Department of Architecture and Urban Planning, Ghent University, Belgium
[b] International Centre for Indoor Environment and Energy, Department of Environmental and Resource Engineering, Technical University of Denmark, Denmark
[c] Department of Architecture, Waseda University, Japan
[d] Department of the Built Environment, National University of Singapore, Singapore
[e] Department of Air Protection, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Konarskiego 22B, 44-100, Gliwice, Poland
[f] Department of Architecture, School of Design, Shanghai Jiao Tong University, Shanghai, PR China

ARTICLE INFO

Keywords:
CO2
Perceived air quality
Air change rates
GSQS
Sleep tracker
Wrist skin temperature

ABSTRACT

Parameters describing the bedroom environment and sleep quality were measured overnight for one week in 84 randomly selected actual bedrooms in Denmark from September to December 2020. The median age of participants was 26 years (interquartile range (IQR) [24-32] years); 41 were males. Carbon dioxide (CO_2), temperature, and relative humidity were measured continuously. Sleep quality was assessed by the Groningen Sleep Quality Scale (GSQS) on two mornings and was assessed using wrist-worn sleep trackers. Skin temperature was monitored continuously. Bedroom indoor air quality (IAQ) was rated by participants on two occasions just before sleep in the evening and upon waking up in the morning. Measurements from 75 bedrooms were complete. The median [IQR] of mean CO_2, air temperature and relative humidity measured during sleep were 1,120 [741–4,804] ppm, 23.4 [22.3–24.4]°C, and 48.6 [44.7–55.4]%. The median [IQR] of GSQS was 4.0 [1.0–6.0] suggesting medium to poor subjectively rated sleep quality; the objectively measured sleep efficiency, and percentage of light, deep and REM sleep were in normal ranges: 88.1 [86.1–89.5]%, 59.4 [54.9–64.5]%, 18.3 [15.0–21.7]%, and 23.0 [18.4–26.4]%. The subjectively-assessed sleep quality decreased when perceived IAQ was reduced. Opening the bedroom door or window, which is a proxy for enhanced ventilation, also improved subjectively-assessed sleep quality and IAQ. The cross-sectional nature of the study prompts the validation of the present results with protocols that include measurements of other pollutants besides CO_2 as well as the examination of underlying mechanisms. Nevertheless, they strongly suggest that keeping high bedroom IAQ is essential.

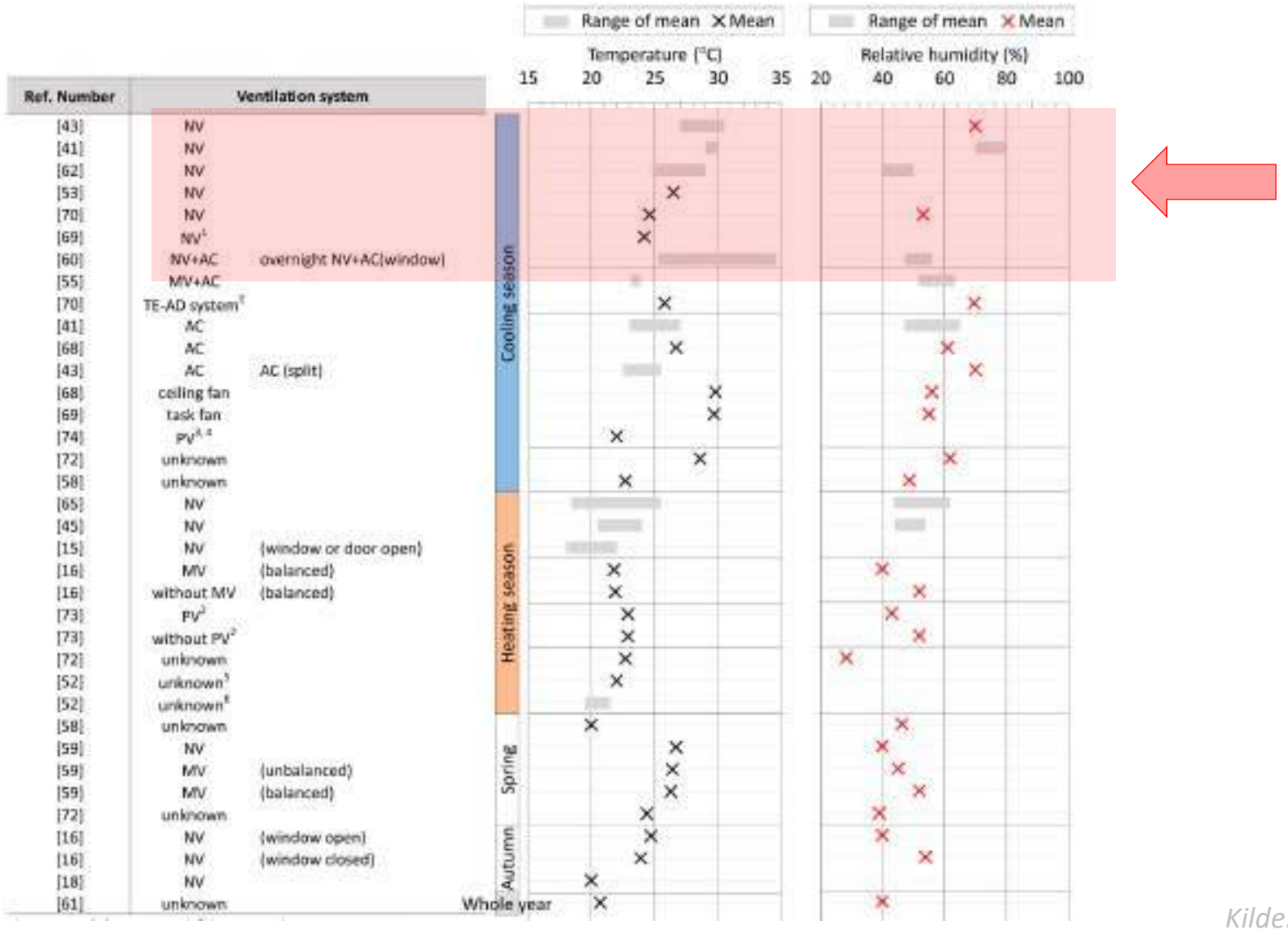
Vigtigste resultater, ventilation

- Nugældende standarder rummer kun lidt information specifikt om ventilation af soveværelser
- Soveværelser med naturlig ventilation har de højeste CO_2–niveauer (laveste luftskifter) om vinteren og de højeste temperaturer om sommeren
- Høj søvnkvalitet ved <750 ppm CO_2 i soveværelset
- Nedsat søvnkvalitet ved >2600 ppm CO_2 i soveværelset
- Luftskifte over 10 liter pr. person pr. sekund (svarende til <750 ppm CO_2) giver uforstyrret søvn
- Mekanisk ventilation i soveværelser nedsætter søvnforstyrrelser pga. indelukket og for kold luft
- Ventilationstandard skal revideres

To enkle råd

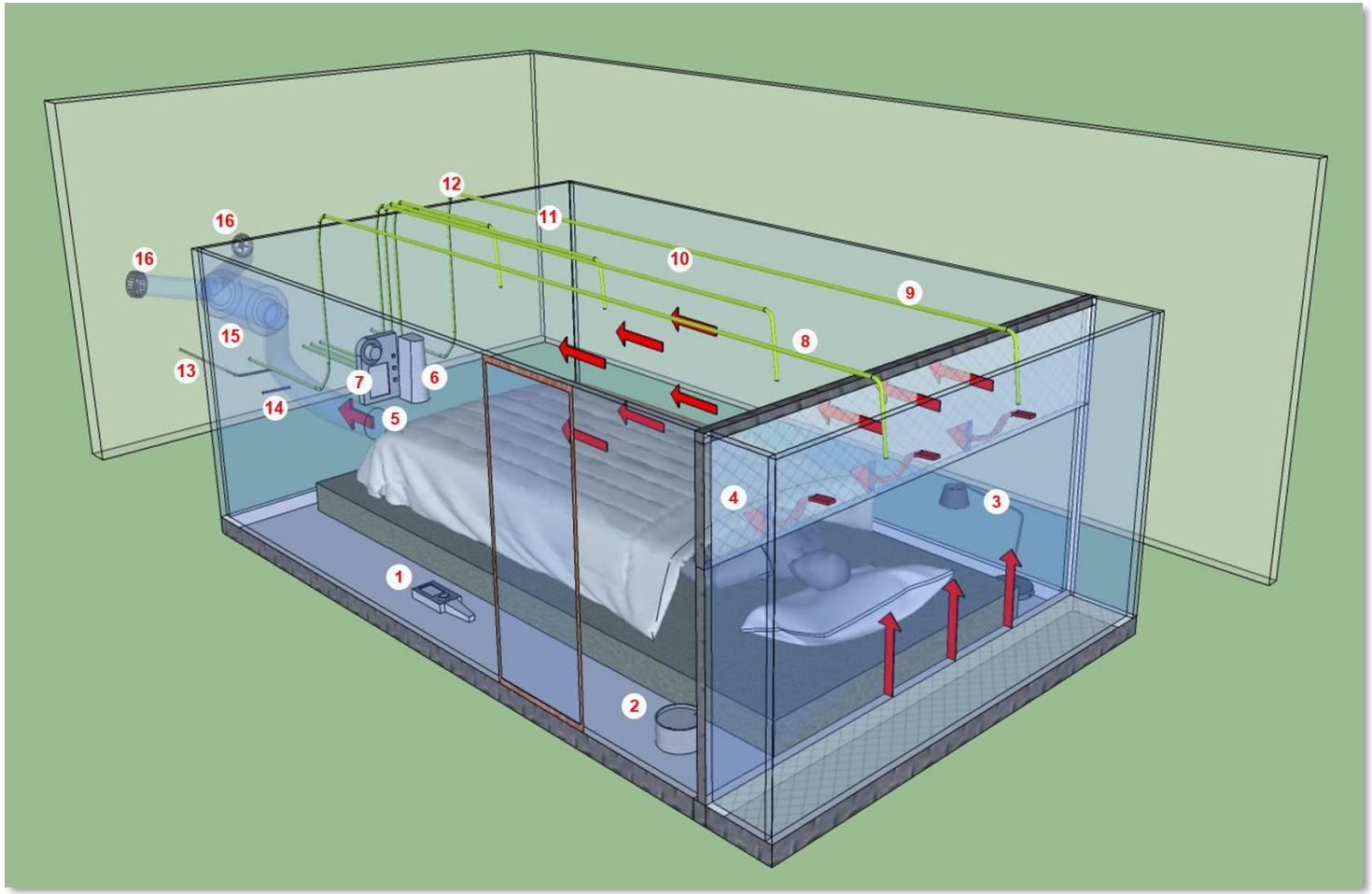
- Sørg for tilstrækkelig ventilation med udeluft
- Undgå at placere forureningskilder i soveværelset

Hvad med temperatur?

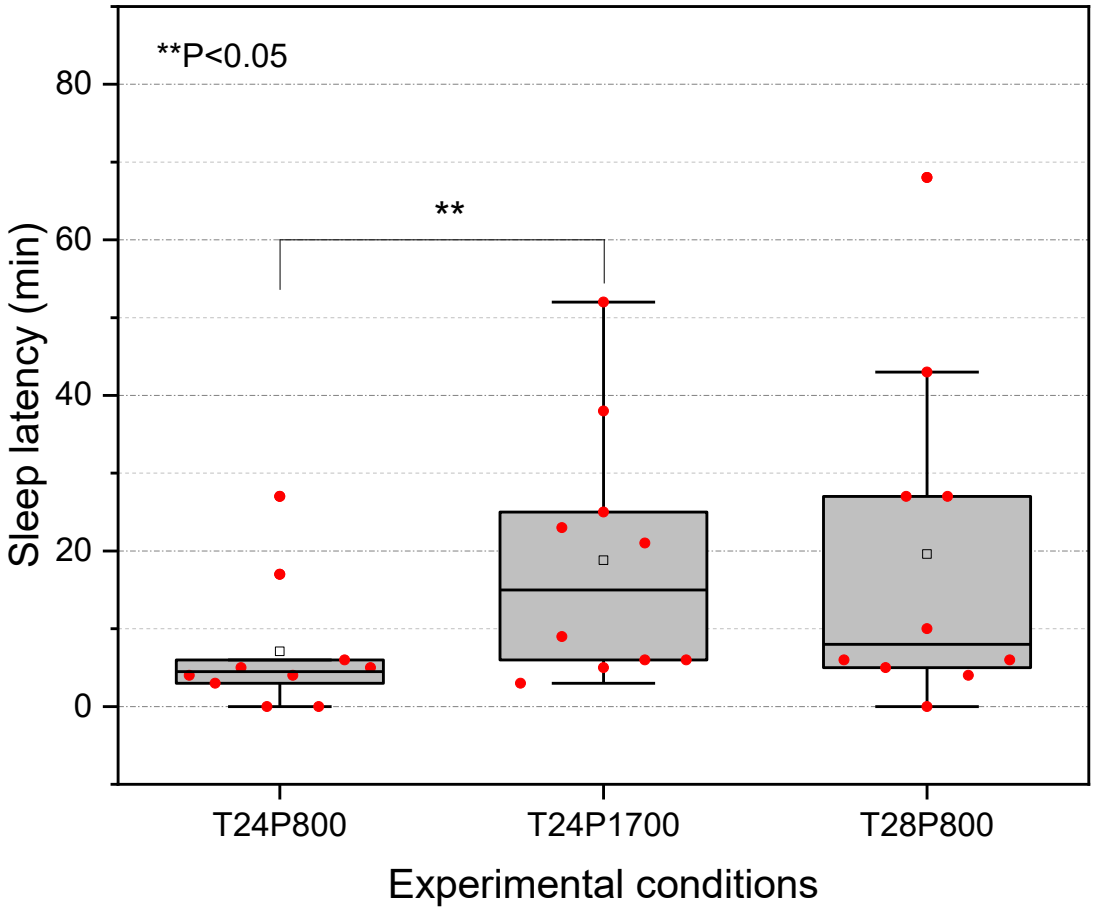


Kilde: Sekhar et al. (2020)

Eksperimenter i klimakamre



Søvnkvalitet, temperatur og indeluftkvalitet



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Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

The effects of ventilation and temperature on sleep quality and next-day work performance: pilot measurements in a climate chamber

Xiaojun Fan [a,e,*], Huiqi Shao [b], Mitsuharu Sakamoto [c], Kazuki Kuga [d], Li Lan [e], David P. Wyon [a], Kazuhide Ito [d], Mariya P. Bivolarova [a], Chenxi Liao [f], Pawel Wargocki [a]

[a] International Centre for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark
[b] School of Chemistry and Biological Engineering, University of Science and Technology Beijing, Beijing, China
[c] Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan
[d] Faculty of Engineering Sciences, Kyushu University, Fukuoka, Japan
[e] Department of Architecture, School of Design, Shanghai Jiao Tong University, Shanghai, China
[f] Department of Architecture and Urban Planning, Ghent University, Ghent, Belgium

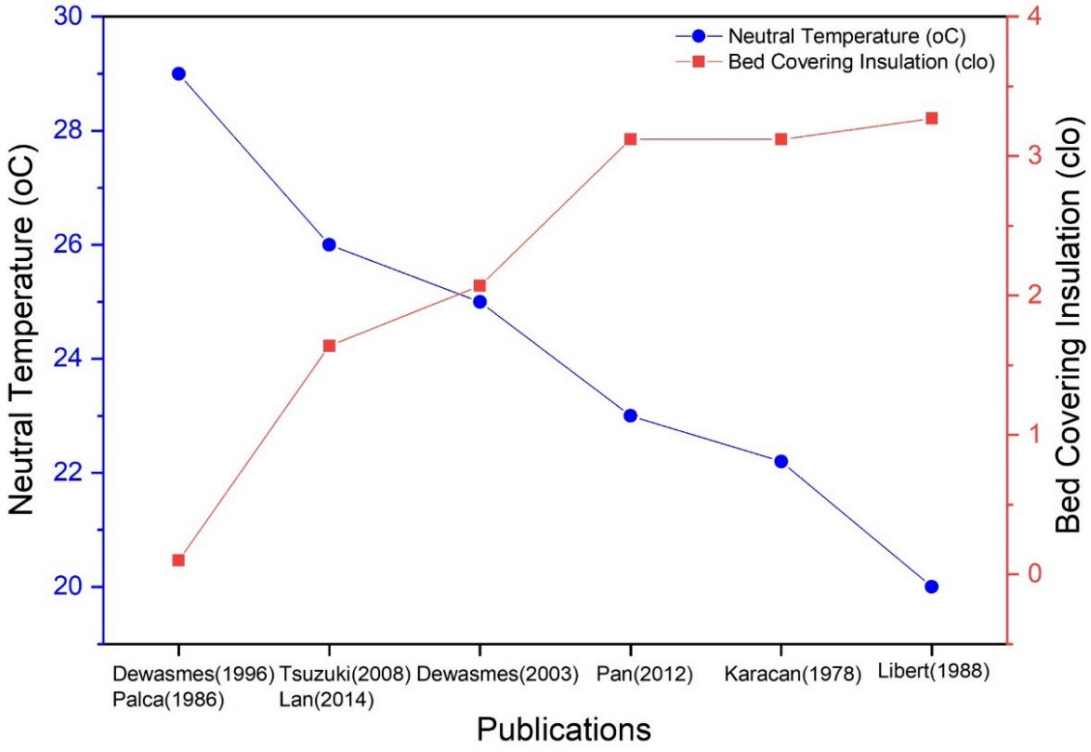
ARTICLE INFO

Keywords:
Temperature
Ventilation
Sleep quality
Next-day work performance
Physiological responses

ABSTRACT

Ten healthy young adults slept one by one in a specially designed and constructed sleep capsule located in a climate chamber at two temperatures (24 °C and 28 °C) and two ventilation rates that ensured that the resulting CO_2 concentrations were 800 and 1700 ppm. Subjectively rated sleep quality was reduced at 28 °C and reduced ventilation, while sleep onset latency was longer under these conditions. Sleep efficiency was lower at 28 °C. Subjectively rated fatigue and sleepiness decreased after sleeping under all conditions but less so after sleeping at 28 °C. The subjects indicated that their work performance improved after sleeping at 24 °C but not when ventilation was reduced and the temperature increased. Both objectively measured and subjectively rated work performance was worse after sleeping in the condition with increased temperature. The subjects felt warmer at 28 °C although the thermal environment was still rated as acceptable but the air in the capsule was rated stuffier, the acceptability of the air quality decreased and the rated odour intensity increased at this condition. The wrist skin temperature was always higher at 28 °C with reduced ventilation but only during the sleep onset latency period. The subjects felt slightly warm and rated the air stuffier when ventilation was reduced. The present results, albeit from a small exploratory pilot study, show that increased temperature and reduced ventilation both have negative effects on sleep quality, which may have consequences for next-day work performance. These pilot experiment results require validation due to the low number of subjects.

Temperatur og søvnkvalitet



Sommer

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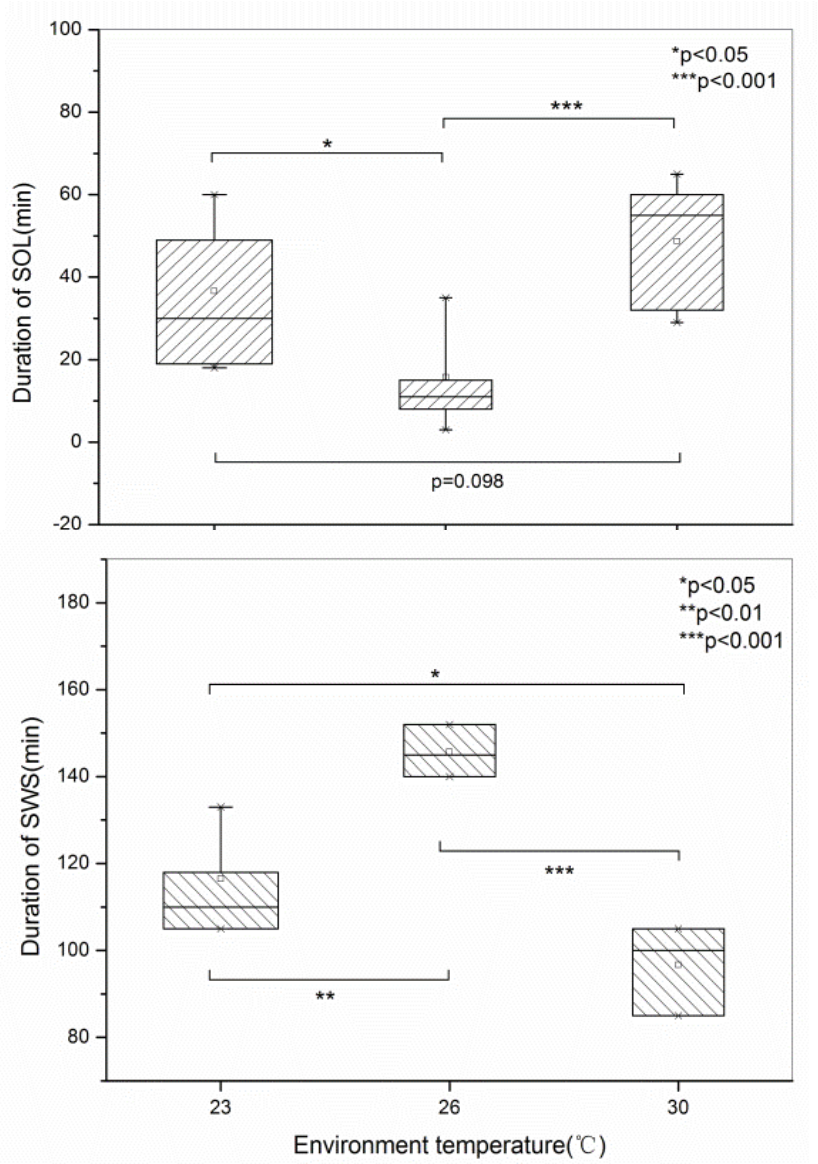

Kilde: Pan et al. (2014); Lan et al. (2016)

Building and Environment 73 (2014) 24–31

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Experimental study on thermal comfort of sleeping people at different air temperatures

Li Lan [a], Li Pan [a,b], Zhiwei Lian [a,*], Hongyuan Huang [c], Yanbing Lin [c]

[a] Department of Architecture, School of Naval Architecture, Ocean & Civil Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
[b] Shanghai Research Institute of Building Sciences, Shanghai 200032, China
[c] The Third Shanghai People's Hospital, Shanghai 201900, China

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ABSTRACT

Current thermal comfort theories and standards are mainly concerned with people in waking state. The effects of air temperature on sleep quality and thermal comfort of sleeping people were investigated in this study by experimenting on human subjects. Sleep quality was evaluated by subjective questionnaires performed in the morning as well as electroencephalogram (EEG) signals, which were continuously recorded during the all-night sleep period. Subjective assessments on thermal comfort were performed both before and after sleep. Analysis on EEG signals indicated that the subjects took longer time to fall asleep and experienced shorter period of slow wave sleep (SWS) when the room temperatures moderately deviated from neutral. Consistently, they reported poorer subjective sleep quality in such conditions. The returned subjective questionnaires on thermal comfort from subjects reflected that the thermal comfort temperature was higher in sleep compared with that in waking state. Their skin temperatures were increased with air temperature and fluctuated during the sleeping period. In view of the distinctive requirements from waking people, it makes sense to study the thermal comfort of sleeping people. The results also have practical implications on energy savings in bedrooms.

1. Introduction

1.1. Thermal environment and sleep quality

Sleep is essential for the body to recover from both physical and psychological fatigue suffered throughout the day and restore energy to maintain bodily functions [1]. Normal human sleep is comprised of two states – rapid eye movement (REM) and non-REM (NREM) sleep – that alternate cyclically across a sleep episode. Sleep begins in NREM and progresses through deeper NREM stages (stages N2 and N3) before the first episode of REM sleep occurs approximately 80–100 min later [2]. The stage N3 sleep is characterized by slow wave activity (brain waves of frequency 0.5 Hz–2 Hz), thus is referred as slow wave sleep (SWS) or deep sleep and is of vital importance to both body and mind. Studies with humans showed that poor sleep quality impaired cognitive performance in older adults [3], and impacted brain function related to reward processing, risk-taking, and cognition in adolescents [4]. Disturbed nocturnal sleep also has consequential effects on health, increasing the risk of obesity, type 2 diabetes and cardiovascular disease [5].

Thermal environment could be one of the most important factors that affect human sleep. Very high or low air temperatures decreased SWS sleep, and increased the frequency and duration of wakefulness [6,7]. Moreover, thermoregulatory systems were shown to be strongly linked to the mechanisms regulating sleep [8–10]. The thermoregulatory control center, the preoptic – anterior – hypothalamus (POAH), also regulated sleep. It had been demonstrated in kangaroo and rat that peripheral thermal stimulation was capable of stimulating warm-sensitive neurons in the POAH, which in turn could promote sleep [11]. Therefore, providing a thermally comfortable sleeping environment is important for sleep maintenance and contributes positively to human health and their daytime activities.

1.2. Thermal comfort in sleep environment

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Ten questions concerning thermal environment and sleep quality

Li Lan, Zhiwei Lian*

Department of Architecture, School of Naval Architecture, Ocean & Civil Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

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ABSTRACT

People spend about one third of their lives sleeping. Sleep is essential for the recovery of the body from both physical and psychological fatigue suffered throughout the day, the refreshment of mind, and the restoration of energy for maintenance of bodily functions. Current thermal comfort theories and standards are mainly concerned with people in waking state. However, many problems regarding thermal environment are found within a few field surveys in bedrooms, pushing out the need to investigate thermal environment and thermal comfort for sleeping people. In this paper, the questions concerning the measurement and evaluation of human sleep quality, the correlation between thermal regulation system and sleep regulation, and the characteristics of night-time space cooling load etc. are answered. The evidences illustrating the effects of thermal parameters on human sleep quality are also provided, in an attempt to shed light on the thermal comfort requirements of sleeping people.

1. Introduction

People spend about one third of their lives sleeping. Sleep is essential for the recovery of the body from both physical and psychological fatigue suffered throughout the day, the refreshment of mind, and the restoration of energy for maintenance of bodily functions [1]. Poor sleep quality impaires cognitive performance in older adults [2], and impacts brain function related to reward processing, risk-taking, and cognition in adolescents [3]. Disturbed nocturnal sleep also has consequential effects on health, increasing the risk of obesity, type 2 diabetes and cardiovascular disease [4,5].

Many factors, such as health states, emotional states, bedding conditions, and thermal environments affect sleep quality, with thermal environment being one of the most important factors [6,7]. The issues of thermal comfort in office buildings in different climates have been studied by several researchers and are well documented in the scientific literature [8]. However, the definition of sleep thermal comfort and the relationship between sleep efficiency and sleep thermal environment have not been well-established in current literature. While there are many studies on thermal environment implication to psychological and physiological responses during sleep, most are in relation to medical conditions or necessities, such as sleep deprivation thermal regulatory changes [9] or military/performance athlete needs [10]. The studies from sleep medicine could offer great help to study thermal comfort in sleeping environments, but due to their different focus they usually cover extreme temperatures which rarely occur at typical sleeping environment and they also lack information on thermal comfort and covering insulation. There have been a few researches on sleeping thermal environment and thermal comfort of sleeping people. In this paper, the questions concerning the measurement and evaluation of human sleep quality, the correlation between thermal regulation system and sleep regulation, and the characteristics of night-time space cooling load etc., are answered. The evidences illustrating the effects of thermal parameters on human sleep quality are also provided, in an attempt to shed light on the thermal comfort requirements of sleeping people.

2. Ten questions concerning thermal environment and sleep quality

2.1. What are the characteristics of normal human sleep?

Vigtiste resultater, temperatur

- Der findes ingen enkelt temperatur, der er ideel på alle stadier af søvn i løbet af natten
- Det er svært at falde i søvn og at blive i søvn, når soveværelset er for koldt eller for varmt
- Søvnkvaliteten ser ud til at blive forbedret, når soveværelsestemperaturerne er varme, når du falder i søvn, og når du vågner, men kølige imellem

Kilde: Pan et al. (2014); Lan et al. (2016)

TAK TIL FLERE...

Mizuho Akimoto
Ph.D. candidate

Mariya P. Bivolarova
Asst. Prof.

Xiaojun Fan
Ph.D. candidate

Chao Guo
Ph.D. candidate

Negin Hosseinpour
M.Sc. student

Kazuki Kuga
Asst. Prof.

Mengyuan Kang
M.Sc. student

Li Lan
Prof.

Zhiwei Lian
Prof.

Jelle Laverge
Assoc. Prof.

Chenxi Liao
Postdoc.

Kazuya Matsuo
M.Sc. student

Anna Mainka
Asst. Prof.

Chandra Sekhar
Prof.

Huiqi Shao
Ph.D.

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M.Sc. student

Mitsuharu Sakamoto
M.Sc. student

Haodong Zhang
M.Sc. student

Pawel Wargocki
Assoc. Prof.

Xinbo Xu
Ph.D. candidate

Yan Yan
Ph.D. candidate

SPØRGSMÅL.....


Sleep
Quality
Bedroom
REM
Air Quality
Deep sleep
Light sleep
Temperature
Sleep onset
Next-day performance
Sleep efficiency