The effects of the thermal environment on occupants' responses in health care facilities: A literature review

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ABSTRACT
Understanding the environmental characteristics that affect health and well-being is a requirement for good indoor environment design. The thermal environment is one of the factors that may affect patients, staff, family, and visitors in health care facilities (HCFs), and perceptions of general thermal comfort and local thermal discomfort are affected by air temperature, radiant temperature, relative humidity, air velocity, turbulence intensity, activity, and clothing. This study reviewed the effects of the thermal environment on patient and staff responses in HCFs, especially in patient and operating rooms. The material in this literature review consists of peer-reviewed journal articles searched by using Google Scholar and PubMed. According to the literature, thermal environment is one of the fundamental characteristics of the indoor environment and the effects of temperature on the comfort, well-being, safety, and health of both the patients and the health care personnel are broadly recognized. Thermal comfort affects sleep quality and quantity in a patient room, and thermal comfort or discomfort during surgery has an effect on the patient's overall satisfaction with surgical care. It also affects the comfort and performance of the health care personnel who work in these environments. In the future, finding adequate solutions to reconcile the different thermal comfort conditions required by different occupants in hospitals will be important. Both the needs of patients and the attending hospital workers in different hospital spaces should be taken into account. Possible solutions could be, for example, different thermal micro environments based on different temperature and air velocity for different thermal comfort requirements, appropriate clothing for patients and staff, or active warming devices above patients.

KEYWORDS
Thermal environment, Whole body thermal sensation, Local thermal discomfort, Health care facility, Hospital

INTRODUCTION
Thermal environment is one of the factors that affect perceived indoor conditions and may affect the healing process of patients as well as the hospital staff's productivity (Djongyang, Tchinda and Njomo 2010, Khodakarami and Nasrollahi 2012). However, it is evident that published standards for these kinds of buildings are still missing the concept of thermal environment and comfort as a part of the healing process and the productivity. Currently, hygiene and safety are the main parameters for establishing building codes and standards for health care facilities (Khodakarami and Nasrollahi 2012). For example, codes and guidelines

for temperature and humidity range criteria in some areas of health care buildings are influenced by the measure of infection control more than comfort (ASHRAE 2003).

Criteria for the thermal environment in heated and/or mechanically cooled buildings are based on the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) thermal comfort indices with assumed typical levels of activity and the typical values of thermal insulation for clothing (winter and summer) as described in detail in EN ISO 7730 (2005). Criteria for local thermal discomfort, such as drafts, radiant temperature asymmetry, vertical air temperature differences, and floor surface temperatures, shall also be taken into account when designing buildings and heating, ventilation and air conditioning systems (HVAC systems).

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), thermal comfort can be defined as "the condition of the mind in which satisfaction is expressed with the thermal environment" (ANSI/ASHRAE 2004). Hensen (1991) defined thermal comfort as "a state in which there are no driving impulses to correct the environment by the behaviour." When a person is satisfied with the thermal environment (ANSI/ASHRAE 2004, ISO 7730 2005) and does not need to use an thermoregulator (Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different) mechanism, he or she is in thermal comfort.

Factors that determine general thermal comfort and local thermal discomfort include: 1) personal factors (individual sensitivity, insulative clothing (clo value), and activity levels (met rate)); 2) general factors (air temperature, mean radiant temperature, relative humidity, and drifts and ramps in operative temperature); and 3) localized factors (turbulence/velocity, radiant asymmetry, floor surface temperatures, and air temperature stratification) (ISO 7730 2005). In addition, thermal comfort is influenced by personal differences in mood and culture, and other individual, organizational, and social factors (Djongyang et al. 2010). Dissatisfaction may be caused by cool or warm discomfort of the body as a whole (general thermal comfort) as expressed by the PMV and PPD indices or may be caused by the unwanted cooling (or heating) of one particular part of the body (local thermal discomfort).

Thermal discomfort is one of the contributory factors of sick building syndrome (SBS). Other suggested contributory factors include physical aspects, such as inadequate ventilation, low humidity, and air pollution (including airborne organic matter), and other factors, such as low morale and general dissatisfaction with working conditions (Health and Safety Executive OC 311/2 2004).

So far, a wide range of literature covers the area of thermal comfort, but a focused literature review on the effects of the thermal environment on patient and staff perception in different types of HCF spaces has not been published. Thus, the aim of our study was to critically review the studies on the effects of the thermal environment on the patients and staff of the HCFs, especially in the patient and operating rooms, and to provide a background on and an input to a future guideline in this subject.

METHODS

The literature review was conducted by searching the scientific research related to the thermal environment in health care facilities, using Google Scholar and PubMed. The material in this literature review consists of peer-reviewed journal articles, reports, and standards. The search terms were based on individual words and combinations, such as thermal environment, thermal comfort, temperature, radiant temperature, humidity, air velocity, activity, clothing, health care facilities, hospitals, patient room, operating room, indoor environment, environmental characteristics, health, occupant, responses, well-being, and perceived indoor air quality.

Altogether, 90 abstracts were selected (based on the eligibility of their titles), and 60 full publications were then read based on the eligibility of their abstracts. A search limitation was set for publications that were electronically available through Aalto University library subscriptions or as free downloads from the Internet. After reading the articles, 48 publications were selected to include in for the redaction of this review paper.

RESULTS AND DISCUSSION

The effects of the thermal environment on occupants' perceptions of comfort in health care facilities (HCFs)

For patients, a comfortable thermal environment in an HCF helps to stabilize their moods, assists their healing (Hwang et al. 2007, Khodakarami and Nasrollahi 2012), and affects their overall satisfaction with surgical care (Fossum, Hays and Henson 2001). For staff, thermal comfort affects their working conditions, well-being, safety, and health (Balaras, Dascalaki and Gaglia 2007).

According to the international standards (drafted for healthy people), the desirable indoor air temperature is 20-24 °C, but lower or higher temperatures are acceptable when patient comfort and/or medical conditions require those conditions (Balaras et al. 2007). Generally, air temperatures over 24 °C are associated with problems caused by overheating during the summer, and might cause discomfort and even morbidity and mortality. Population-based studies have reported that a wide range of chronic conditions can increase the risk of heat-related morbidity and mortality (Hajat, Kovats and Lachowycz 2007). People who are older, very young, have chronic diseases (particularly cardiovascular, respiratory, diabetes, and musculoskeletal conditions), take particular medications that impair thermoregulation (Department of Health 2012a), or have mental health conditions (Department of Health 2012b) are at increased risk of heat-related injury or death.

Among staff, people who are physically active in high temperatures are at increased risk of heat injury (Carmichael et al. 2013). Kjellstrom et al. (2009) reported that at high ambient temperatures, workers experience reduced cognitive abilities and an increased risk of accidents.

In a patient room, the current thermal comfort theories and standards, which are mainly concerned with people in a waking state (during steady state conditions), are not appropriate for sleeping people (Lan and Lian 2016). Concerning thermal comfort, the entire covering insulation of the bedding system (the mattress, bedding, sleep wear, and percentage of coverage) is an important factor that affects the indoor thermal temperature for sleeping people (Lan and Lian 2016, Lin and Deng 2008). To accommodate individual and gender differences, a patient may need to use coverings of different insulation levels to achieve a comfortable thermal sleeping environment.

Uncomfortable thermal conditions in a patient room affect sleep quality and quantity. In cold environments, sleep was characterized by difficulty falling asleep, difficulty staying asleep, increased movements, and reductions in rapid eye movement (REM) sleep (Kaplow and Hardin 2007). Low temperatures can cause occupant discomfort, including shivering, inattentiveness, and muscular and joint tension (Kameel and Khalil 2003). Johnston and Hunter (1984) reported that to prevent patient thermal risk, the temperature must not drop below 21 °C.

In warm environments, total sleep (including REM and non-REM sleep) was reduced due to increased wakefulness (Kaplow and Hardin 2007). It has been reported that total sleep time, along with all stages of sleep, were maximum when the ambient temperature was thermally neutral (about 80 °F = 26-27 °C) (Kaplow and Hardin 2007) and subjective sleep sensation was better when the room temperature was first reduced 1.5 °C from 27 °C over 4 h and then increased back up to 27 °C over 4 h (Teramoto et al. 1998). High temperatures may cause an increased out-gassing of toxins from building materials (Kameel and Khalil 2003).

Women prefer a higher ambient temperature during sleep than men. The finger skin temperature and finger blood flow of women were not only lower, but also more sensitive to air temperature than those of men (Pan, Lian and Lan 2012). According to Okamoto-Mizuno et al. (2004), for older men, even mild heat exposure during nighttime may increase the thermal load, suppress the decrease of rectal temperature, decrease REM, and increase sleep. The percentage of REM and the sleep efficiency index (SEI) declined, while the number of sleep disruptions and the overall percentage of wakefulness increased at 32 °C, indicating inefficient and fragmented sleep.

Increased wakefulness and decline of the SEI index are the typical effects observed under heavy thermal load and a humid climate (Okamoto-Mizuno et al. 1999, Okamoto-Mizuno et al. 2004, Okamoto-Mizuno, Tsuzuki and Mizuno 2005, Parmeggiani 1987). Okamoto-Mizuno et al. (2005) reported that a hot and humid climate (32 °C, 80%) increases the total time that people are awake and that the use of air conditioning during the initial sleep hours can improve sleep and thermoregulation. Intense heat (with an electric blanket at 39.8 °C) decreases total sleep time, causes more frequent and longer disruptions, and causes greater shifting between sleep stages and a delayed onset of deep sleep (Karacan, Thornby and Anch 1978). Mora et al. (2001) reported that higher levels of humidity cause the growth and transfer of bacteria and thermal discomfort, whereas lower levels of humidity favor blood coagulation, skin drying, and thermal comfort. It has also been reported that low humidity can increase susceptibility to respiratory disease, affect comfort, and contribute to irritation (Berglund 1998, Liviana, Rohles and Bulloc 1988).

According to ASHRAE (2003), the following design temperature and relative humidity should be used: 24 °C ± 1 °C, 30% (Winter), and 50% (Summer) for the patient room; 22-26 °C and 30-60% for the newborn nursery; 24 °C ± 1 °C, 30% (Winter), and 50% (Summer) for labor, delivery, and recovery rooms; and ≤ 24 °C and 30-60% for general inpatient areas. The minimum suggested air changes for the outside air per hour for all these spaces is 2 and the minimum total air changes per hour for patient room and newborn nursery is 6 and 4 for the patient corridor and other areas (ASHRAE 2003). To satisfy patient comfort, in patient rooms the total air changes per hour (ACH) must be ≥ 6, but in rooms with supplemental heating and/or cooling this rate may be reduced to 4 ACH (Ninomura and Bartley 2001).

When designing the wards, it should be noted that medicine taken by patients may affect their metabolism and patients with different thermal requirements may be located in the same ward (Skoog, Fransson and Jagemaar 2005, Parsons 2002, Buskirk and Loomis 1997, Wang and Peterson 1995). Medication or drug use may have an effect on part of a patient's thermophysiology or thermoregulatory system and thus affect thermal comfort (Verheyen 2012).

Although the main concerns **in the operating room** are guarding the room against infection and achieving good indoor air quality, there is very little research about patient and staff thermal comfort in these spaces. In operating rooms, environmental factors (temperature and air velocity) related to thermal comfort can change in accordance with the type of surgery (Melhado, Hensen and Loomans 2006a). Each surgery can present different levels and types of staff activities, different patient requirements, different types and numbers of equipment and lights, different numbers of people, and sometimes the type of surgery and functions of the staff in the operating room also define the clothing (Melhado et al. 2006a, Melhado, Hensen and Loomans 2006b). Thus, it is difficult to create thermal condition guidelines for all the different occupants in an operating room.

Although heavier gown requirements used by the surgical team to protect them (i.e., because of AIDS) may require an indoor temperature of 18 °C or even lower (Mora et al. 2001), it has been reported that a temperature between 24 ºC and 26 ºC in an operating room is suitable for patients with lower levels of activity, while temperatures below 21 ºC put the patient at risk of becoming hypothermic (Johnston and Hunter 1984). In addition, cold as an uncomfortable sensation can increase restlessness; aggravate pain shivering, inattentiveness, and muscular and joint tension; and decrease overall patient satisfaction with the surgery (Fossum et al. 2001, Wagner, Byrne and K. 2006, Wagner 2003, Sessler et al. 1995, D'Angelo Vanni et al. 2003).

One possible solution can be active warming devices, which prevent hypothermia more efficiently than passive coverings (Moysés et al. 2014). However, the issue of the "thermal risks" of the patient is difficult to resolve, because the patient is anesthetized and, therefore, his or her thermoregulatory mechanisms are not active. In addition, sometimes the type of surgery does not permit heating through blankets or other systems. The patient's temperature must be controlled to prevent it, for example, from dropping enough to cause perioperative hypothermia (Leslie and Sessler 2003). Some researchers rated a low ambient temperature in the operating room as a critical risk factor for hypothermia (Marcario and Dexter 2002). It has been noted that memories of thermal comfort or discomfort during surgery have an effect on a patient's overall satisfaction with surgical care (Fossum et al. 2001).

For the surgical staff, a temperature over 23 ºC is usually intolerable (Leslie and Sessler 2003, Wildt 1996). In addition, it has been noted that the surgical lights have a significant influence on the thermal comfort of the staff (Janicki et al. 2001). Although occupants can generally adapt themselves to the environment by increasing or decreasing clothing levels (Skoog 2006), managing the thermal discomfort of the staff is complex, because it is usually not possible to reduce the amount of clothing, to alter the activity being performed, or to reduce the various heat sources used during the surgery. Sometimes the staff must use alternative types of protection (e.g., additional special clothing or a helmet aspirator system) that can change their thermal sensations (Melhado et al. 2006a).

The recommended levels of relative humidity range from 30-60%, but because of the possible use of flammable anesthetic gases and the frequent use of volatile liquids, and to prevent the accumulation of static electricity, the relative humidity should sometimes be > 60% in operating rooms (Balaras et al. 2007).

CONCLUSIONS

This paper presents a literature review on occupants' responses to the thermal environment in health care facilities, especially in the patient and operating rooms. We have reported the available evidence on temperature and relative humidity-related aspects that should be considered for common tasks and micro environments, which are important for researchers, building designers, building owners and operators, and future investigations. From the review, we can say that the thermal environment is a parameter of the indoor environmental conditions in health care facilities that affects the well-being, safety, and health of both the patients and health care personnel. It also affects the working conditions of the health care personnel who work in these environments and the sleep quality and quantity as well as the overall satisfaction of the patients.

A limitation of this overview is that most of the studies in this literature review were undertaken in just a single hospital, and generally for one type of occupant. No study in the literature tried to reconcile the different thermal comfort requirements of different types of occupants (patient groups and health care personnel) who must stay in one room at the same time.

It is important to get more information about the thermal environment conditions required by different spaces in hospitals, and find some solutions that take all these requirements into account. These solutions are important, for example, when patients and the attending caregivers have to stay in one room for a long time. It would be useful to focus on research and solutions that include the staff's thermal comfort and its relation to their performance while at the same time preventing hypothermia and ensuring comfort among different patient groups. One possible option for solving this problem is to prepare different thermal micro climates based on different air and radiant temperatures and air velocity for different thermal comfort requirements. Solutions might also include suitable clothing for the staff and patients or active warming devices above patients.

In order to design buildings and systems that reconcile the many conflicting factors for the people occupying the buildings, interaction and co-operation between the occupants and the system and architectural designers are needed.

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REFERENCES

ANSI/ASHRAE. 2004. ANSI/ASHRAE Standard 55-2004. Thermal environmental conditions for human occupancy. 30. Atlanta, GA.: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE. 2003. Chapter 7, Health Care Facilities. In *Handbook 2003 Applications –HVAC Applications*. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Balaras, C. A., E. Dascalaki & A. Gaglia (2007) HVAC and indoor thermal comfort conditions in hospital operating rooms. *Energy and Buildings,* 39**,** 454–70.

Berglund, L. G. (1998) Comfort and humidity. *ASHRAE Journal* 35-40.

Buskirk, E. R. & J. L. Loomis. 1997. Aspects of indoor environments: tolerable vs. comfortable thermal environments. In *Thermal analysis – human comfort – indoor environments* Gaithersburg, MD, United States of America:: U.S. Department of Commerce/National Bureau of Standards.

Carmichael, C., G. Bickler, S. Kovats, D. Pencheon, V. Murray, C. West & Y. Doyle (2013) Overheating and hospitals – what do we know? *Journal of Hospital Administration,* 2**,** 1-7.

D'Angelo Vanni, S. M., J. R. C. Braz, N. S. P. Módolo, R. B. Amorim & G. R. Rodrigues (2003) Preoperative combined with intraoperative skin–surface warming avoids hypothermia caused by general anesthesia and surgery. *Journal of Clinical Anesthesia,* 15**,** 119-25.

Department of Health. 2012a. Department of Health National Heatwave Plan for England: Making the Case: The impact of heat on health: now and in the future. London: Department of Health.

Department of Health. 2012b. National Heatwave Plan for England: Protecting Health and reducing harm from severe heat and heatwaves. London: Department of Health.

Djongyang, N., R. Tchinda & D. Njomo (2010) Thermal comfort: A review paper. *Renewable and Sustainable Energy Reviews,* 14**,** 2626-2640.

Fossum, S., J. Hays & M. M. Henson (2001) A comparison study on the effects of prewarming patients in the outpatient surgery setting. *Journal of PeriAnesthesia Nursing,* 17**,** 102-14.

Hajat, S., R. S. Kovats & K. Lachowycz (2007) Heat-related and cold-related deaths in England and Wales: who is at risk? . *Occupational and Environmental Medicine* 64**,** 93-100.

Health and Safety Executive OC 311/2. 2004. Sick building syndrome. Guidance for specialist inspectors. 5.

Hensen, J. L. M. 1991. On the thermal interaction of building structure and heating and ventilating system. PhD thesis. Technische Universiteit Eindhoven.

Hwang, R. L., T. P. Lin, M. J. Cheng & J. H. Chien (2007) Patient thermal comfort requirement for hospital environments in Taiwan. *Building and Environment,* 42**,** 2980–7.

ISO 7730. 2005. ISO 7730. Ergonomics of the thermal environment, Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. Available online at: http://www.buildingreen.net/assets/cms/File/ISO_7730-2005.PDF (Accessed 3th March 2016) Switzerland.

Janicki, P. K., M. S. Higgins, J. Janssen, R. F. Johnson & C. Beattie (2001) Comparison of two different temperature maintenance strategies during open abdominal surgery: upper body forced-air warming versus whole body water garment. *Anesthesiology,* 95**,** 868-74.

Johnston, I. D. A. & A. R. Hunter. 1984. The design and utilization of operating theatres. The Royal College of Surgeons of England.

Kameel, R. & E. Khalil. 2003. Thermal comfort VS air quality in air-conditioned healthcare applications. Available online at: http://arc.aiaa.org/doi/abs/10.2514/6.2003-4199. In *36th AIAA thermophysics conference 2003*. Orlando, Florida: Aerospace research central (ARC).

Kaplow, R. & S. R. Hardin. 2007. *Critical care nursing:synergy for optimal outcomes*. Sundbury, MA: Jones and Bartlett Publishers.

Karacan, I., J. I. Thornby & A. M. Anch (1978) Effects of high ambient temperature on sleep in young men. *Aviation, Space, and Environmental Medicine* 49**,** 855-860.

Khodakarami, J. & N. Nasrollahi (2012) Thermal comfort in hospitals – A literature review. *Renewable and Sustainable Energy Reviews,* 16**,** 4071-4077.

Kjellstrom T, I. Holmer & B. Lemke (2009) Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change *Glob Health Action,* 2**,** 2047.

Lan, L. & Z. Lian (2016) Ten questions concerning thermal environment and sleep quality. Available at: http://dx.doi.org/10.1016/j.buildenv.2016.01.017. *Building and Environment*.

Leslie, K. & D. I. Sessler (2003) Perioperative hypothermia in the high-risk surgical patient. *Best Practice & Research: Clinical Anaesthesiology,* 17**,** 485–98.

Lin, Z. & S. Deng (2008) A study on the thermal comfort in sleeping environments in the subtropics—developing a thermal comfort model for sleeping environments. *Building and Environment,* 43**,** 70–80.

Liviana, J. E., F. H. Rohles & k. P. E. Bulloc (1988) Humidity comfort and contact lenses. *ASHRAE Transactions,* 94**,** 3-11.

Marcario, A. & F. Dexter (2002) What are the Most Important Risk Factors for a Patient's Developing Intraoperative Hypothermia? *Anesthesia & Analgesia,* 94**,** 215-220.

Melhado, M., J. L. M. Hensen & M. Loomans. 2006a. Literature review of staff thermal comfort and patient thermal risks in operating rooms. In *8th International healthy buildings conference*, 11–14.

Melhado, M. A., J. L. M. Hensen & M. Loomans. 2006b. Review of ventilation systems in operating rooms in view of infection control. In *Proceedings of the 6th Int. Postgraduate Research Conference in the Built and Human environment*. Technische Universitet Delft, BuHu, University of Salford.

Mora, R., M. J. M. English & A. K. Athienitis (2001) Assessment of thermal comfort during surgical operations. *ASHRAE Transactions,* 1**,** 52-62.

Moysés, A. M., A. Trettene, L. H. C. Navarro & J. A. Ayres (2014) Hypothermia Prevention During Surgery: Comparison Between Thermal Mattress And Thermal Blanket. *Revista da Escola de Enfermagen da USP. Journal of Sao Paulo University School of Nursing*.

Ninomura, P. E. & J. Bartley (2001) New ventilation guidelines for health-care facilities. *ASHRAE Journal***,** 29-33.

Okamoto-Mizuno, K., K. Mizuno, S. Michie, A. Maeda & S. Lizuka (1999) Effects of humid heat exposure on human sleep stages and body temperature. *Sleep* 22**,** 767–773.

Okamoto-Mizuno, K., K. Tsuzuki & K. Mizuno (2004) Effects of mild heat exposure on sleep stages and body temperature in older men. *International Journal of Biometeorology,* 49**,** 32-36.

Okamoto-Mizuno, K., K. Tsuzuki & K. Mizuno (2005) Effects of humid heat exposure in later segments on sleep stages and body temperature in humans. *International Journal of Biometeorology,* 49**,** 232–237.

Pan, L., Z. W. Lian & L. Lan (2012) Investigation of gender differences in sleeping comfort at different environmental temperatures. *Indoor and Built Environment,* 21**,** 811-820.

Parmeggiani, P. L. (1987) Interaction between sleep and thermoregulation: an aspect of the control of behavioural states. *Sleep* 10**,** 426-435.

Parsons, K. C. (2002) The effects of gender, acclimation state, the opportunity to adjust clothing and physical disability on requirements for thermal comfort. *Energy and Buildings* 34**,** 593-9.

Sessler, D. I., M. Schroeder, B. Merrifield, T. Matsukawa & C. Cheng (1995) Optimal duration and temperature of pre-warming. *Anesthesiology,* 82**,** 674–81.

Skoog, J. (2006) Relative air humidity in hospital wards – user perception and technical consequences. *Indoor and Built Environment* 15**,** 93–7.

Skoog, J., N. Fransson & L. Jagemaar (2005) Thermal environment in Swedish hospitals. Summer and winter measurements. *Energy and Buildings,* 37**,** 872-7.

Teramoto, Y., H. Tokura, I. Ioki, S. Suho, R. Inoshiri & M. Masuda (1998) The effect of room temperature on rectal temperature during night sleep. *Journal of Thermal Biology* 23**,** 15-21.

Wagner, D., M. Byrne & K. K. (2006) Effects of comfort warming on preoperative patients. *ARON Journal* 84**,** 427–47.

Wagner, V. D. (2003) Impact of perioperative temperature management on patient safety. *Surgical Services Management* 9**,** 38–43.

Wang, X. & F. Peterson (1995) To stay in warm and damped environment – how you perceive the heat. *Energi & Miljö,* 66**,** 46–8.

Verheyen, J. 2012. Thermal comfort of patients in healthcare facilities [Dissertation]. In *Faculty of engineering sciences, Department of architectural engineering*, 353. Vrije Universiteit Brussel.

Wildt, M. 1996. Pressure hierarchy and indoor climate of hospital rooms. In *Ventilation and indoor air quality in hospitals,* ed. M. Maroni, et al., 219–225. Kluwer Academic.