RESEARCH SUMMARY

A GENDER PERSPECTIVE ON INDOOR ENVIRONMENTAL QUALITY

Research summary

Swegon

Introduction

Building standards and guidelines are based on the needs of a standardised person, so there is an evident risk that even in buildings where the indoor climate formally meet the set requirements, we do not take aspects such as gender or age into consideration. This may result in an indoor climate which is systematically biased to suit a certain group of people, while being less suitable for other groups.

This paper summarises available research on how humans react to the surrounding indoor climate, with a focus on gender aspects. The aim is to raise awareness of this topic, and to serve as a basis for further discussion.

Indoor climate and comfort

The development of building technology towards low-energy passive or positive energy buildings have made the standards and regulation of the indoor climate a central aspect of energy-efficient construction, with efficient heating, ventilation, and air conditioning (HVAC) as a key component. In this context, comfort criteria and standards have been established and implemented with a focus mainly on energy efficiency, while differences in the perceptions of different groups of people have been less talked about.

Reducing HVAC energy consumption and ensuring optimised comfort is difficult to accomplish because buildings are typically designed and operated to provide homogeneous conditions, and individual occupants need different temperatures and conditions to be comfortable.

The indoor climate is perceived individually

The indoor climate – typically provided by the building's HVAC system is perceived individually, and the requirements are subjectively shaped.

Also, measuring the indoor environmental quality (IEQ) factors separately – such as temperature and air quality – according to standardised parameters, neglects possible interactions or differences in the perception of different people, e.g. with respect to gender.

People spend more than 90% of their time indoors. The indoor environment quality is therefore decisive for the physical and mental health of people. (Edeltraud Haselsteiner, 2021)

> The most important thing – although not given enough attention yet – is the adaptation of indoor environmental quality to people's individual preferences.
> (Edeltraud Haselsteiner, 2021)

Differences between men and women

It is naturally hard to generalise regarding demographic groups as wide as 'men' and 'women', but there are distinct differences between the average man and the average woman in terms of physical and physiological factors. These differences affect peoples' thermal comfort and well-being. This is why men and women may tend to feel differently when exposed to the same conditions, i.e. there is a differentiated reaction and differences in perceptions of the indoor climate by gender.

Note that this research summary focuses mainly on two gender stereotypes – men and women – which are two categories of gender defined by biological differences. However, there are more types of gender.

Body types and sizes

Physical factors that may influence a person's preferred indoor climate include body type (amount of fat and muscle mass) and size (stature, weight).

In general, smaller and thinner people lose heat faster than larger and heavier types, and using muscles generates heat. Men have more muscle cells and less fat cells than women, resulting in more active cells, which produce more heat.

Women may tend to feel colder than men

Women's skin temperature is lower than that of men; women have lower blood circulation in their hands when it is cold and sweat less in the presence of high temperatures than men.

Women have slightly higher core temperatures than men (36.5°C vs 36.3°C), but their hands are colder by almost 1.5°C.

On average, women have 20% less body mass, 14% more body fat and 18% less body surface than men.
(R. L. Burse, 1979)

Other factors

Physical factors, such as proximity to cool air registers, drafts, and clothing, obviously, will affect thermal comfort for both men and women. If, for instance, the inhabitants of an office follow a conservative dress code, with men wearing formal shirts with ties and suit jackets of thicker materials, and women wearing lighter skirts and blouses with bare necks and ankles, women will naturally feel colder.

Other factors that could be considered may include behaviour and cultural aspects, etc.

Buildings, occupants and conditions are also different

Seasonal variations of temperatures – summer versus winter

Ranges of comfortable indoor temperatures are shaped by the prevailing outdoor weather and vary across seasons and climates. This means that comfort temperatures generally increase in summer and decrease in winter. For example, the dominant standard for thermal comfort suggests a summer comfort temperature range that is approximately 1.5°C warmer than the winter range.

Paradoxically, it turned out that indoor temperatures in buildings are lower in summer than in winter, especially in US offices, tropical climates throughout Asia and the Middle East, etc. This is supported by the fact that most offices are overcooled by design

Overcooling and comfort

The cause of overcooling, especially in offices, is often attributed to two broad issues. First, office buildings may have suboptimal HVAC design and control strategies for their local climates. Second, the most popular model of human comfort for designing HVAC systems — the predicted mean vote (PMV) model — tends to overestimate discomfort in warm temperatures. Advocates for cooler-than-comfortable offices point to expected performance improvements, but empirical evidence supporting this relationship is questionable.

Office temperatures are designed with men in mind

A study published in the scientific journal Nature Climate Change stated that most office buildings use temperature levels that were set with men in mind, levels which were only revised many decades ago. The thermal comfort model – which sets the ideal temperature for air conditioning and central heating systems – was developed back in the 1960s and provoked many arguments already at the time.

The Fanger's thermal comfort model uses the resting weight of a 69 kg, 40-year-old male for analysis – which was believed to be perfect for the average person at the time. The equations used to calculate air temperature, humidity, airflow, radiant temperature and metabolism of people likely to be in a building are by now outdated. (Fanger, P. O., 1970)

In the 1960s, most people in offices would have been men, but nowadays, this is far from the case, as there is mostly a more even gender balance. So the metabolic rate used to calculate the office temperatures may not be at all representative. In fact, the difference in metabolic rate of the genders is striking – research shows that the current model could overestimate women's resting heat production by as much as 35%.

The thermal comfort model – which sets the ideal temperature for air conditioning and central heating systems – was developed in the 1960s

Indoor environmental quality factors

The thermal comfort and individual perception are essential for assessing people's satisfaction, especially in offices, educational buildings and homes. Gender is also found to be an influencing factor of satisfaction with not only temperature but also humidity, acoustic conditions, visual comfort, air quality, light preferences, brightness perception, etc. We also need to take into consideration factors such as productivity, well-being and health, building design and ventilation system, and behavioural and cultural aspects

Temperature, air quality, sound and light

Studies conducted in this area show:

- Men were more sensitive to higher temperatures, and preferring colder working environments, while women preferred a slightly warmer environment. (Karjalainen, S., 2012).
- In a fully air conditioned building, the comfort temperature was 24.0°C for women and 23.2°C for men. (Maykot, J. K., et al, 2018). Other studies conducted in offices shows an even more significant divergence, with up to 3°C difference between the genders. (Kingma, B., Lichtenbelt, W.M., 2015)
- Thermal perceptions of women were shown to be colder than men; despite a similar comfort temperature for both genders (~23°C), heavier clothing insulation optimum acceptable worn by women (~0.92 clo) than men (~0.83 clo) and the higher optimum acceptable temperature of females (23.5°C) than males (22.0°C) support higher thermal requirements of women compared to men. (Jowkar, M., et al, 2020)
- Females' measured overall skin temperatures were lower than those of their male counterparts (particularly hands, feet, and lower body parts). (Liu, H., et al, 2018)
- Men and women react differently to lighting. Men performed better than women with memory and problem-solving tasks in the 'warm' (3 000 K) and 'cool' (4 000 K) lighting, and poorest in the artificial 'white daylight' (5 500 K). Conversely, women performed better in artificial white daylight lighting and perceived the room light as more expressive across all light settings than men. (Knez, I., 2001)
- The sources of dissatisfaction show some patterns, as the following overview, based on the summary of 38,851 responses to the CBE Occupant Survey about office temperatures (Graham, L., et al, 2021) illustrates:
    - Breakdown of satisfaction with temperature in office buildings by gender. Office temperatures were more satisfactory for men than women, who comprise the majority of occupants reporting feeling too cold in winter and summer.
    - Three most frequent reasons for the source of dissatisfaction with temperature for men and women as the percentages of dissatisfied respondents. The first two are the same between genders, but the third — air movement — is in opposition.
    - Dissatisfaction with the six lowest-scoring workspace items from the CBE Occupant Survey. Temperature and air quality had the largest divide between women and men; most other items resembled the gender proportions of survey respondents.

Productivity, well-being and health

- Women show a better cognitive performance in a warmer environment, while men do better in colder temperatures. (Haselsteiner, E., 2021)
- The office temperature effects differ between men and women. Within a temperature range of 16°C to 33°C, they found that men perform better at lower temperatures, while women perform better at higher temperatures. (Chang, T. Y., Kajackaite, A., 2019)
    - A 1°C increase improves women's math performance by 1.76%, and verbal performance by 1.03%.
    - A 1°C increase decrease men's math performance by 0.63%, and verbal performance by 0.6%.
- Gender was found to be a significant driver of satisfaction with air quality, reported happiness, reported productivity, and measured productivity; gender shows a significant relationship with the reported levels of difficulty concentrating and cognitive performance. (Andargie, M.S., Azar, E., 2019)
- Symptoms of sick building syndrome is more commonly felt among women. (Bakke, J. V., et al, 2007)
- The fact that women are more dissatisfied with air quality than men is particularly evident in studies of productivity in offices and schools. (Indraganti, M., et al, 2015)

A new study shows women tend to perform better on certain skills when the temperature is a little warmer, making them more productive; while men tend to perform better when the temperature is a bit cooler.
(Tom Chang, 2019)

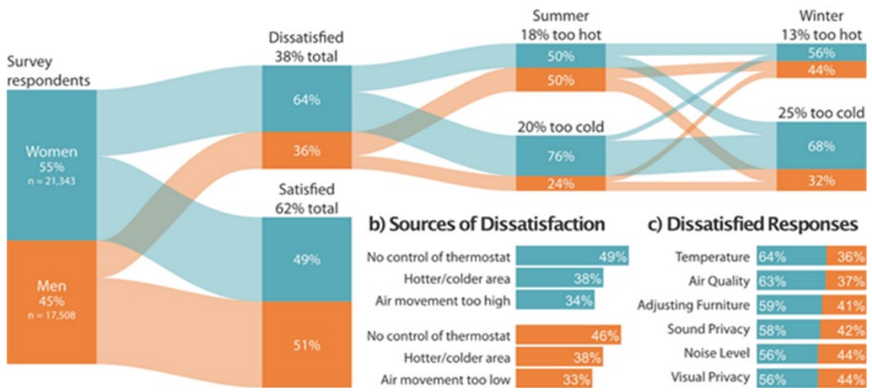

Figure 1: Overview from the CBE Occupant Survey (2021)

The male norm – influencing how we define the problem

Often the guidelines are written by men and women were neglected because these symptoms have been classified as 'atypical' and not 'according to the standards'. With the established male norm shaping how buildings are designed, we need to be aware when interpreting research results regarding dissatisfaction, complaints etc, in order not to confuse causes and symptoms:

The fact that the buildings are designed for males, means male occupants have a greater tendency to be satisfied with thermal conditions, acoustic conditions, electric lighting and privacy than female occupants. The biggest gaps between men's and women's satisfaction scores were found to be related to the adjustability of the thermal conditions, privacy, temperature and thermal conditions. (Bae, S., et al, 2020)

In situations when larger groups of people share a single thermostat, men have been observed to have a tendency to be less compromising than women, affecting the conditions. (Bae, S., et al, 2020)

Gender was relevant to physical health symptoms associated with indoor environment factors; women reported more often symptoms (fatigue, feeling heavy-headed, difficulty concentrating, itching, burning, or irritation of the eyes, dry throat and cough). In addition, women had more frequent complaints about the physical work environment (i.e., temperature too low, stuffy air, dry air) than did men. Men and women perceived physical indoor environment factors differently. (Bakke, J. V., et al, 2007)

Typical explanations found in the thermal comfort literature – lower metabolic rate or lighter clothing – inadvertently position women as the source of the problem. Rather than stating that the problem is in the thermal environments of offices. (Thomas Parkinson, et al., 2021)

Women adapt much more their clothing in the summer to outdoor temperatures more than men. But the air conditioning is operated, so the men in the business suit feel comfortable. (Bjarne Olesen, 2015)

Conclusion

In conclusion, there is clear research evidence to confirm that essential indoor environmental quality (IEQ) parameters vary significantly between men and women and should be taken more into account in the practice of building technology, including ventilation. By being aware of these aspects we can advance equality orientation and make it an integral part of the planning and design of energy-efficient buildings.

The associated impacts of pervasive overcooling on well-being and performance are borne predominantly by women. And to make matters worse, the problem may increase in the future due to the growing demand for cooling in increasingly extreme climates. There is a need to rethink the approach to air conditioning in buildings in light of gender inequity.

What can we do?

There are many ways to create more comfortable and productive indoor climate for all, by taking gender differences into account. Here are some concrete examples:

- In building design, it is now recommended, even with central control, always to allow an individual adjustment of the room temperatures of ±2 °C.
- Perception of comfort varies when people are allowed to have control over the air conditioning and ventilation. The negative effects of higher temperatures can also be mitigated when personally controlled air movement is used.
- Offices can also be designed with intentional temperature variations or different temperature zones to boost people's productivity. And combined with an open and semi-open design where workers can choose where to sit.
- Many buildings are designed with oversized air-conditioning systems, therefore, the designers must design the right-sized HVAC systems for buildings.
- Where applicable, consider loosening office clothing policies during the warmer months, i.e. men to dress in lighter clothes (no suites and dress shirts), thus lowering the need to cool the buildings – which would also mean significant energy savings.
- In smart buildings, devices such as watches could accurately measure an occupant's metabolic rate and thermostats could automatically adjust indoor temperatures.

Gender – one of many important aspects

This research summary is focused on gender, but it's important to bear in mind gender aspects intersect with other aspects, which highlights the intersectionality and shows the necessity of understanding (and acting upon) gender in connection with various diversity dimensions, such as age, origin, disability, economic conditions, etc. As an example, the voices of older people, especially with regard to age-related problems, e.g. thermal self-regulation, have until now largely been missing from the discourse. (New, K., et al, 2021)

Also, people cannot be categorized according to homogeneous groups, as they are confronted with different role expectations, attributes, and different opportunities. Therefore, thermal comfort and indoor environmental quality should not only focus on two genders but also address 'building occupants' or 'users' while trying to understand different needs while taking diversity into account.

By taking gender differences into account, there are many ways to create a more comfortable and productive indoor climate for all.

References

Andargie, M. S., & Azar, E. (2019). An applied framework to evaluate the impact of indoor office environmental factors on occupants' comfort and working conditions https://doi.org/10.1016/j.scs.2019.101447

Bae, S., et al, (2020). Impact of occupants' demographics on indoor environmental quality satisfaction in the workplace https://doi.org/10.1080/09613218.2019.1627857

Bakke, J. V., et al, (2007). Gender and the physical and psychosocial work environments are related to indoor air symptoms. https://doi.org/10.1097/JOM.0b013e31806e5fa0

Burse, R. L. (1979). Sex differences in human thermoregulatory response to heat and cold stress https://doi.org/10.1177/001872087912210606

CBE (2021). Occupant Indoor Environmental Quality Survey and Building Benchmarking

Chang, T. Y., Kajackaite, A. (2019). Battle for the thermostat: Gender and the effect of temperature on cognitive performance https://doi.org/10.1371/journal.pone.0216362

EPA (2014). Indoor Air Facts No. 4. Sick building syndrome. Revised. https://www.epa.gov/sites/default/files/2014-08/documents/sick_building_factsheet.pdf

Fanger, P.O. (1970). Thermal Comfort https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1120088

Graham, L., et al, (2021). Where do we go now? Lessons learned from 20 years of CBE's occupant survey http://doi.org/10.5334/bc.76

Haselsteiner, E. (2021). Gender matters! Thermal comfort and individual perception of indoor environmental quality: A literature review https://link.springer.com/chapter/10.1007/978-3-030-71819-0_9

Indraganti, M., et al, (2015). Thermal comfort in offices in India: Behavioral adaptation and the effect of age and gender https://doi.org/10.1016/j.enbuild.2015.05.042

Jowkar, M., et al (2020). The influence of acclimatization, age and gender-related differences on thermal perception in university buildings: Case studies in Scotland and England https://doi.org/10.1016/j.buildenv.2020.106933

Karjalainen, S. (2012). Thermal comfort and gender: A literature review. https://doi.org/10.1111/j.1600-0668.2011.00747.x

Kingma, B., Lichtenbelt, W.M. (2015). Energy consumption in buildings and female thermal demand https://www.nature.com/articles/nclimate2741

Knez, I. (2001). Effects of colour of light on nonvisual psychological processes https://doi.org/10.1006/jevp.2000.0198

Liu, H., et al, (2018). Gender differences in physiological and psychological responses to the thermal environment with varying clothing ensembles. https://doi.org/10.1016/j.buildenv.2018.05.040

Maykot, J. K., et al (2018). A field study about gender and thermal comfort temperatures in office buildings. https://doi.org/10.1016/j.enbuild.2018.08.033

National Public Radio (2015). Women, There's a reason why you're shivering in the office https://www.npr.org/sections/health-shots/2015/08/04/429005094/women-theres-a-reason-why-youre-shivering-in-the-office

New, K., et al, (2021). 'We can send a man to the moon but we can't control the temperature in our office'; A considerate approach to workplace thermal comfort by older women https://eprints.lancs.ac.uk/id/eprint/155761/1/accessible_chi21_88.pdf

Parkinson, T., et al. (2021). Overcooling of offices reveals gender inequity in thermal comfort https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8655064/

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