HEALTHY INDOOR ENVIRONMENT RESULTS IN ENERGY SAVINGS

Wouter D. van Marken Lichtenbelt
Department of Nutrition and Movement Sciences, NUTRIM School, Maastricht University Medical Center, Maastricht, the Netherlands

ABSTRACT

Traditionally the indoor conditions in the built environment are designed to accommodate thermal comfort criteria based on the PMV model. Secondly, in the built environment much emphasis has been on the reduction of energy use. Nowadays important changes in insight occur: more focus on the occupant and more focus on the adaptive comfort model. However, health aspects are underappreciated. Our results show that implementing healthy environmental conditions may go hand in hand with energy reductions.
The concepts of comfort and health may be related but are not synonyms. We have gained important new knowledge regarding metabolic health effects of temperature exposure outside the human thermal comfort zone. Mild cold and warm environments increase metabolism, thereby targeting obesity by counterbalancing excess energy intake. Furthermore, mild cold positively influences glucose metabolism, which is very important in the face of the huge increase in the occurrence of diabetes type 2. Lastly, there are indications that cardiovascular parameters may be positively affected by regular exposure to heat and cold.
What does this mean for the practical implementation in the built environment? We show that during acclimation to cold thermal comfort increases, and low or high temperatures in a dynamic thermal environment may be perceived as acceptable or even pleasant (evoking thermal alliesthesia). Such dynamic conditions may result in significant reductions in building energy consumption. Finally, we should acknowledge that a human has many senses. By focusing on human thermal comfort and thermal behavior, we may forget what we see and hear. Recently we showed significant interactions between light quality and quantity on thermal physiology and comfort.
The time is ripe to put the current laboratory derived knowledge into practice under living lab conditions.

KEY WORDS: European Union (EU), Horizon 2020, hybridGEOTABS, Metabolic health, thermal comfort, dynamic indoor environment

1. HUMAN EVOLUTION

Nowadays we spend on average more that 87% of our time in enclosed buildings and about 6% of our time in vehicles [1]. Indoor environmental conditions are tightly regulated. However, these were not the conditions in which we evolved and to which we are adapted. Few studies from the 1950's were dedicated to human adaptation in their natural environment. Famous are the studies by on Kalahari bushman of Africa and the aborigines of Australia [2, 3]. These studies clearly showed that these people were well able to cope with heat and cold, even though they were (semi) nude. Apart from some behavioral adjustments, it was shown that they were physiologically adapted to heat and cold. Western controls were much less adapted to those dynamic climatological conditions. For instance, in the cold desert night in Australia with hardly any clothing and only a small fire place aborigines slept well, while their western control subjects were shivering like hell, very uncomfortable and had a bad night sleep. In those days and under these circumstances aborigines and Kalahari bushmen were lean and did not show any sign of our nowadays common metabolic syndrome (obesitas/type 2 diabetes/cardiovascular diseases).
The lesson of this writing will not be that we have to go back to nature in order to get rid of our prosperity diseases. But we can learn from biology in order to create healthy indoor environments. From an evolutionary viewpoint we are prehistoric creatures living in dwellings and offices with tightly controlled environments.
Generally, lifestyle programs focus on diet and physical activity. These may be most important factors causing metabolic diseases such as obesity, type 2 diabetes and cardiovascular diseases. The point I want to

make here that other lifestyle factors, such as the indoor climate and light conditions, also can play a significant role in our long-term health.

2. OUR INDOOR ENVIRONMENT

Current guidelines in buildings concerning the indoor temperature are largely based on a model from the 1970s and focus on the thermal comfort of an average person [4]. The use of this model has led to a uniform indoor climate: a temperature for everyone, throughout the day, during all seasons, in various climate zones from the tropics to the arctic regions. This often leads to complaints from the users about the temperature, but also to high energy costs by the buildings. Moreover, with central regulation of fixed indoor conditions, the users become very critical. Even relatively small deviations from expected conditions may result in dissatisfaction.

More recently, the so-called adaptive comfort model has been introduced. This model takes into account the fact that individuals differ and that people adapt to a cool and warm environment and accept that environmental conditions vary during the year and during the day [5] [6]. Application of this adaptive model results in a more dynamic indoor climate. This also leads to lower heating and cooling costs.
However, physiological and health aspects are still not included in the adaptive model. New, initiated by our research group in Maastricht, is precisely that link between indoor climate and health.

The ambient temperature is traditionally associated with comfort. However, comfort and health are not synonymous by definition. Therefore we studied mild cold and warm conditions that we may encounter in our daily living situations.

3. COLD AND WARM ENVIRONMENTS

Most thermo-physiological studies on cold exposure used to concentrate on adaptation to extreme cold, with a few exceptions (for instance: [7]). Following up the few preceding studies we showed that mild cold increases our energy metabolism without the uncomfortable shivering. This is advantageous with respect to overweight and obesity, because this may affect our energy balance. It should be noted that this non-shivering response was subject to a large individual variation [8]. We also found a tissue that may be responsible for this increase in metabolism the so-called brown fat [9]. Activating brown fat is known to increase metabolism, but until then this was only known in animals and babies. Next we showed that regular exposure to mild cold increases our capacity of increasing energy metabolism in the cold without shivering [10]. Interestingly, in a follow up cold acclimation study it also appeared that a cool environment greatly improved insulin sensitivity in people with diabetes type 2 [11]. Importantly, these studies also showed that people can adapt very well to a variation in indoor climate including mild cold, provided they have the opportunity to get used to it. In addition it was shown that a metabolic effective variation of temperature throughout the day (drifting or dynamic temperature) is acceptable to users, both young lean adults as well in elderly [12].

Comparable to the lack of mild cold research, few studies have been carried out on the effect of mild heat (warmth) exposure and acclimation on comfort, behavior, thermophysiology and health. Most studies combined more extreme heat and exercise for for instance sports and military purposes [13]. These so-called active heat-acclimation studies showed physiological adaptations such as a decrease of body core temperature, and heat loss by sweating. However, the results of those very intense heat-acclimation studies may not be applicable to daily living situations. Therefore recently we performed mild passive (without exercise) warmth acclimation. We showed that thermophysiological and behavioral parameters such as body temperatures and temperature perception can be significantly affected by prolonged (7-9 days) passive exposure to warmth [14, 15]. The results indicate that higher indoor temperatures are more easily accepted after regular exposure to warmer conditions.

In conclusion, being exposed to both mild cold and warm conditions result in physiological adaptation and in improved comfort and resilience to those conditions.

4. INTERACTION LIGHT AND AMBIENT TEMPERATURE

Light is the zeitgeber for our body: it puts our biological clock on time every day [16]. Light affects the activity in the brain and hormone production that prepare our body and metabolism for sleep and recovery processes at night and for activity and alertness during the day. Due to the modern patterns of light exposure in our buildings, the natural sleep/wake rhythm is no longer adapted to the natural day-night rhythm: people are exposed to light up to the late hours, which is relatively low during the day and high during the evening [17]. The spectral composition of light also plays an important role in this process. Disruption of the internal biological clock leads to lower vitality and alertness and a decrease in the duration and quality of sleep that are crucial for health [18]. After all, correct lighting conditions have vitalizing, and alertness and performance-enhancing effects [19].

It is interesting to note that light and environmental temperature interact with each other influencing our physiology and psychology (in [20]. Both luminance and room temperature have an acute influence on body temperatures and alertness [21]. The spectral distribution of light can also influence the body temperature and the comfort experience [22]. The steering effects of light on our circadian rhythm also influence body energy metabolism. Finally, these studies also indicate that thermal discomfort can be partly compensated by lighting conditions, thereby increasing the window of acceptable indoor temperatures. Resuming, the right timing of the light conditions together with the indoor climate may positively affect visual comfort, thermal comfort, and alertness.

All in all, laboratory experiments have shown significant effects of temperature and light (and the interactions of these) on our metabolic health. This, however, does not mean that certain fixed conditions prevail over others. With respect to lighting conditions, its effect depends to a large extent to the time of the day and preceding light conditions. With respect to temperature both warm and mild cold conditions seem advantageous for metabolic health and for resilience to heat and cold. Long term fixed cool or hot environments may be uncomfortable, but the results so far show that dynamic conditions (drifting temperatures) are more generally accepted. It also should be noted that there are significant differences in thermophysiology, comfort and acceptance between individual users and groups (young adult, elderly, overweight, males versus females, see for instance [23]).
Modern climate systems and light technology (LED) make it possible to create a dynamic indoor environment that also can be attuned to individual needs (Figure 1). This not only positively affects the human energy balance and metabolic health, but allowing temperatures to drift also results in significant reductions in building energy consumption.

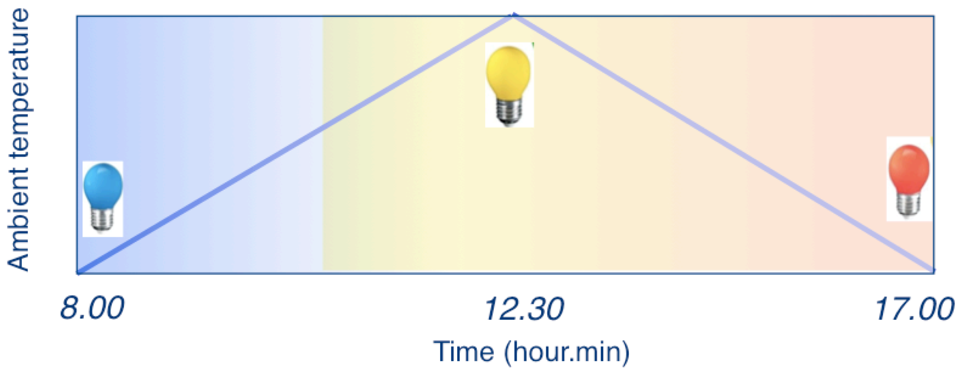

Fig. 1. Schematic impression of potential dynamic light and temperature conditions.

5. APPLICATION

Currently there is a need to test the laboratory findings in actual living conditions, in real life living labs. The project ‘hybridGeotabs’ (Horizon 2020: 723649 - MPC-. GT) studies in several demo cases in Europe the optimal design strategy for model based predicted control in buildings with geothermal heat pumps (GEO-HP) combined with thermally activated building systems (TABS) – GEOTABS. The advantage from the health perspective of this climate control is that it uses two controls systems, i.e. the primary system for base load control, which is characterized by a high efficiency with little personal control, and a secondary system. The secondary system is for the unpredictable conditions with respect to for instance whether conditions. The latter can ideally also be used for individual control and dynamic temperature conditions. In the project the more variable conditions will be tested with respect to comfort, acceptance and health parameters. In addition a just started Dutch project (DYNKA, TKI Urban Energy-TEUE117001) focuses on the interaction between dynamic light and indoor climate in a real life office environment.
It is expected that this concept of a dynamic indoor environment will result in both a healthy environment and in energy efficient buildings. The information from these studies can therefore provide input and be relevant for both certified BREEAM rating and WELL Certification.

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