Thermal comfort and older adults

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J. van Hoof, J.L.M. Hensen, Thermal comfort and older adults, Gerontechnology 2006; 4(4):223-228. The majority of the increasing number of older adults wishes to age-in-place. Appropriate and comfortable housing is of great importance to facilitate this desire. One of the aspects of concern is thermal comfort. This is normally assessed using the model of Fanger, however, one might ask if this model is sufficiently accurate to be used for older adults. This paper provides a short overview of the model, its applicability and implementation, and discusses aspects of the living environment that offer older adults the best possible indoor climate.

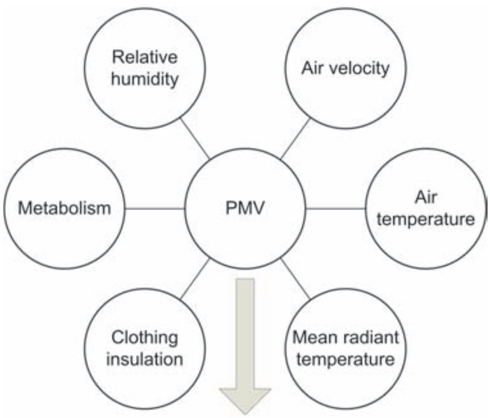
Keywords: thermal comfort, older adults, PMV/PPD-model, HVAC

In 2025, there will be 360 million people aged 60 or over in the Industrialised World[1]. The vast majority of older adults that live independently wish to continue their current life style, and therefore ask for extra support and guidance at home, as well as assistive technologies[2]. Some of these technologies can be found in the domain of the building service engineer. One of the aspects of the home environment that is directly related to this profession is thermal comfort, which contributes to well-being and overall health. The current method for assessing thermal comfort in indoor environments is the PMV/PPD-model (Predicted Mean Vote, Predicted Percentage of Dissatisfied) by Fanger[3], which is adopted by the (inter)national standards ISO 7730[4] and ANSI/ASHRAE 55[5]. These standards that are used in the design of buildings and heating, ventilation and air-conditioning (HVAC) systems, aim to specify conditions that provide comfort to all healthy adults, including older adults[6], while in practice, a selection of an acceptable percentage of dissatisfied is often made depending on economy and technical feasibility[7].

Fanger[3] created his predictive model through climate chamber research involving approximately 1300 college-age students, followed by much smaller experiments involving 128 elderly subjects to study the influence of age and ageing. The question arises if the PMV/PPD-model is valid for application to the healthy older population, which has different physical characteristics compared to younger groups. Therefore, the PMV/PPD-model and its validity, the impact of age(ing) on the perception of thermal comfort, as well as a correct implementation in relation to modern architectural solutions and heating, ventilation and air-conditioning (HVAC) technologies, will be discussed based on literature study and the latest technological developments.

The PMV/PPD-model

In order to perceive thermal comfort, the heat gains and losses of the human body must be in balance, the mean skin temperature and sweat rate must be within certain limits, and the body should not experience any local discomfort[3]. Fangers Predicted Mean Vote (PMV) model is based on these assumptions, and predicts the hypothetical vote on the standard 7-point ASHRAE scale of thermal sensation for an average person; i.e., the mean response of a large number of people with equal clothing and activity levels who are exposed to identical and uniform environmental conditions. The model includes six major personal and environmental thermal variables[3] (*Figure 1*). To ensure a comfortable indoor environment, the ideal PMV is zero (i.e. thermal neutrality) with a tolerance of 0.5[4,5]. Fanger established a relation between PMV and the Predicted Percentage of Dissatisfied (PPD)[3]. PPD is a statistical measure, which applies to a large group of people with identical personal and environmental thermal conditions. In practice, however, clothing insulation, metabolic rate, and the environmental thermal conditions may vary considerably between the individuals in a group in a given space.



3	Hot
2	Warm
1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

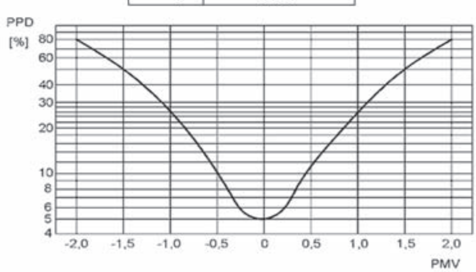


Figure 1. The Predicted Mean Vote (PMV) with its six input parameters, the relation to the 7-point ASHRAE scale of thermal sensation (inserted table) and the graphed relation between PMV and PPD (Predicted Percentage of Dissatisfied)

Since the introduction of the PMV/PPD-model in 1970, numerous studies on thermal comfort in real life situations have been conducted. Fountain et al.[8] state that individual differences between people are frequently greater than one ASHRAE scale value (*Figure 1*) when exposed to the same environment. Moreover, the individual day-to-day perception of a certain environment can also vary in the order of one scale value, which corresponds to a temperature difference of 3°C or about the full width of the comfort zone (Winter 20-24°C, Summer 23-26°C). That is the reason why it is unreasonable to expect everyone to be satisfied within a centrally controlled environment, even when thermal conditions meet current standards[8]. Humphreys and Nicol[9] showed that PMV often does not match the actual sensation of warmth, is only reliable in the comfort range, i.e., between -0.5 and 0.5, and is unable to predict comfort of large groups in realistic conditions. Because PMV is particularly sensitive to air velocity, metabolism and clothing insulation, inaccurate assumptions regarding these parameters can lead to serious misinterpretations[9]. Moreover, the bandwidths of parameters matching correct PMV are narrower than stated in ISO 7730. In addition, its validity range is too narrow for application in tropical areas[9].

De Dear et al.[10] found that the PMV/PPD-model is too restrictive for naturally ventilated (office) buildings, and therefore created an adaptive comfort model[5,10] that relates indoor to outdoor air temperature. Unfortunately, this model has a limited applicability as well. Fanger and Toftum[11] acknowledge the importance of expectancy accounted for by the adaptive model.

Ageing and thermal comfort

In principle, older adults do not perceive thermal comfort differently from younger college-age adults[2,12]. The effects of gender and age can be accounted for by model parameters such as activity and clothing level[12]. On average, older adults have a lower activity level, and thus metabolic rate, than younger persons which is the main reason that they require higher ambient temperatures[12,13]. The ability to regulate body temperature tends to decrease with age[12]. Although 20% of older adults show no vasoconstriction of cutaneous blood vessels, not all of the remaining 80% have diminished control of body temperature[14]. Foster et al.[15] found a reduction in the sweating activity of aged men compared to younger age groups. The body temperature threshold for the onset of sweating was increased as well. These differences were even more pronounced in aged women. Tsuzuki and Iwata[13] found that the evaporative water loss does not significantly increase with metabolic rate in older adults taking light exercise.

In general, older adults have reduced (i) muscle strength, (ii) work capacity, (iii) sweating capacity, (iv) ability to transport heat from body core to skin, (v) hydration levels, (vi) vascular reactivity, and (vii) lower cardiovascular stability[12].

A number of studies have been conducted on older adults and their preferences of, and responses to, the thermal environment. Some studies found differences in heat balance, or preferences for higher or even lower temperatures between the old and the young, while others have given support to the PMV/PPD-model that supposes the same thermal preference for all age groups.

Climate chamber research by Tsuzuki et al.[16] showed that the heat balance of older adults was, or appeared to be, less than that of college-age people. Tsuzuki and Ohfuku[17] found that older adults have reduced warmth sensitivity in cold seasons, and similarly reduced cold sensitivity in hot seasons.

Enomoto-Koshimizu et al.[18] showed through climate chamber research that older adults were thermally neutral at 23°C operative temperature without heater, and 20°C with heater, in contrast to 21°C for young people in both situations. Operative temperature is the uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. PPD was the lowest at 24°C operative temperature. Physiologically older adults preferred a warmer environment (+ 2°C) than younger people. It is suggested that, also psychologically, the 20-24°C comfort zone was not warm enough for older adults.

Collins and Hoinville[19] showed that older adults on average preferred a lower temperature than young people, which was explained in terms of higher clothing insulation. Field research by Cena et al.[20] found that elderly in Canada were comfortable at temperatures considered to be too low according to the PMV/PPD-model. This could be explained by an inability to heat the home adequately, a pattern also found in over half of elderly households in Ireland[21]. Tsuzuki and Iwata[13] found that elderly in general experienced experimental conditions to be warmer than PMV. Rohles and Johnson[22] found that older women felt warmer than younger at the same temperature. No age-dependent difference was found among men. These results contradict expectations that older adults would prefer a higher temperature at same clothing and activity levels, due to lower basal metabolism. Collins and Hoinville[19] explain that older adults may have higher percentages of cutaneous fat decreasing the conductive heat loss. This makes it easier for the body to maintain a certain core temperature at lower ambient temperatures, and will also lead to lower skin temperature, which influences thermal comfort negatively. Moreover, elderly may have a decreased perception of (particularly low) temperature[19].

Turnquist and Volmer[23] found an optimum temperature of 25.3°C for sedentary older adults, which is within the current comfort range. However, the clothing insulation was found to be lower than that of young adults. A study by Collins et al.[24] showed that when given control over their environment, older adults preferred the same mean comfort temperature (22-23°C) but manipulated ambient temperature much less precisely than the young. According to Cena et al.[25], studies give support to PMV, even in non-standard groups such as older adults.

In general, elderly seem to perceive thermal comfort differently from the young due to a combination of physical ageing and behavioural differences. Individual differences are too large to draw an unequivocal conclusion on the requirements of older adults regarding their preferred thermal environment. Although there is evidence that the PMV/PPD model does not completely accurate predict thermal comfort for elderly, currently there exists no better model. It may be concluded that more research is needed on thermal preferences of older adults, for example through field studies in which older adults are given personal control options over their thermal environment.

Technological home environment

Thermal comfort in the home environment can be achieved through: (i) passive, architectural solutions, e.g. thermal mass, blinds, orientation etc, and (ii) more active technological solutions, such as HVAC-systems and home automation[26]. Architectural solutions often form an integral part of vernacular and modern buildings, and in most cases require minimal user interaction to guarantee a comfortable indoor climate. Moreover, most of these solutions do not use extra energy and do not put a strain on the environment. Home automation technology includes all in-home devices and infrastructures that use electronic information for measuring, programming, and control of functions to the benefit of the residents. Through the intelligent combination of non-invasive biological and environmental sensors and actuators (*Figure 2*), automatic tuning of the indoor climate to individual needs is likely to become possible in the homes of older adults in the Industrialised World in the future[2], even though no well-evaluated and working systems can be purchased on the market-place yet. Bottlenecks of current home technologies are inadequate control options for people with decreased muscular, visual and auditory functioning, the limited compatibility of various systems, and financial aspects. Future dwellings could respond autonomously to changing weather conditions and at the same time optimise energy use, for instance, by automatically closing windows when outdoor temperature drops or turning off heating when windows are opened. HVAC-systems, which can supplement architectural solutions in

Figure 2. MyHeart (Royal Philips Electronics) allows for real-time monitoring of a persons body signals, such as activity level, which could be used as input parameter for HVAC-control. MyHeart can be integrated into wearable garment, while a mirror contains a display for user interaction. Source: http://www.research.philips.com/newscenter/pictures/downloads/health_pershealth_06_h.jpg

weather extremes, could be controlled in compliance with personal preferences. Rooms could have individual temperature profiles. Impairment of thermoregulatory functions due to diminished or absent sweating[15] is thought to be one of the factors responsible for increased mortality among older adults during hot summers[12,27]. This is even more critical for bedridden (institutionalised) older adults, whose clothing insulation is strongly increased by the bed and bedding[28], and therefore need lower ambient temperatures (22.5-25.5°C) as compared to mobile people[27]. Adequate HVAC-systems at home of the frail are of great importance in periods of extreme weather conditions. Depending on the size, effectiveness and controls of the cooling system, this reduces or eliminates the number of hours with too high indoor air temperature[27].

There is no need for prescriptive standards if individual control is provided in order to optimise the indoor environment to personal needs[8]. Although passive architectural solutions are preferred to guarantee thermal comfort, rooms of frail older adults may be actively controlled for the average occupant[12] based on a PMV/PPD-algorithm using real-time measured input data. Additionally individuals should be given direct control for fine tuning environmental parameters, in time supported by intelligent technology substituting frequent user intervention. Easily operable technology, characterising the future housing of older adults, is expected to increase user autonomy, and provide optimum thermal comfort for everyone.

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