Investigation of whether elderly people can benefit from local cooling devices in warm environments

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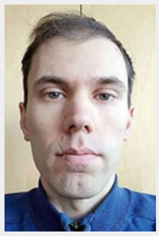

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The benefits of local cooling devices are being cheap, energy-efficient, user-friendly, portable, and personalized. The study conducted confirmed the positive effects of three local cooling devices, including normal table fan, evaporative cooling devices, and air-cooled jacket, on the physiology and psychology of the elderly. The three local cooling devices depicted to be capability to reduce thermal discomfort for the elderly. Using devices in a 28°C/60% and 29°C/40% environment can return the elderly's thermal sensation to a neutral state, making them feel comfortable.

Keywords: Thermal comfort; elderly people; local cooling devices; warm environment

Convective local cooling devices

Global warming exacerbates the difficulties faced by aging societies. Increased cardiovascular strain caused by heat stress is an important health concern during heat waves. Compared with young adults, older adults face more difficulties, such as reduced mobility and perception, as well as fuel poverty.

This study selected three convective local cooling devices that are available on the market: the table fan (**Figure 1(a)**), evaporative cooling device (**Figure 1(b)**), and air-cooled jacket (**Figure 1(c)**). The table fan was 230 mm in diameter with an electric power range of 0–25 W. The evaporative cooling device was 180 mm × 180 mm × 182 mm. It had a medium that was humidified via capillary action using water from a small side tank (1000 mL) and a small fan with an electric power range of 0–10 W. The air-cooled jacket, designed to be worn over clothing, consisted of a spacer vest liner with an impermeable outer layer, two 97-mm wide fans placed symmetrically on the lower back, an internal pocket for a rechargeable battery,

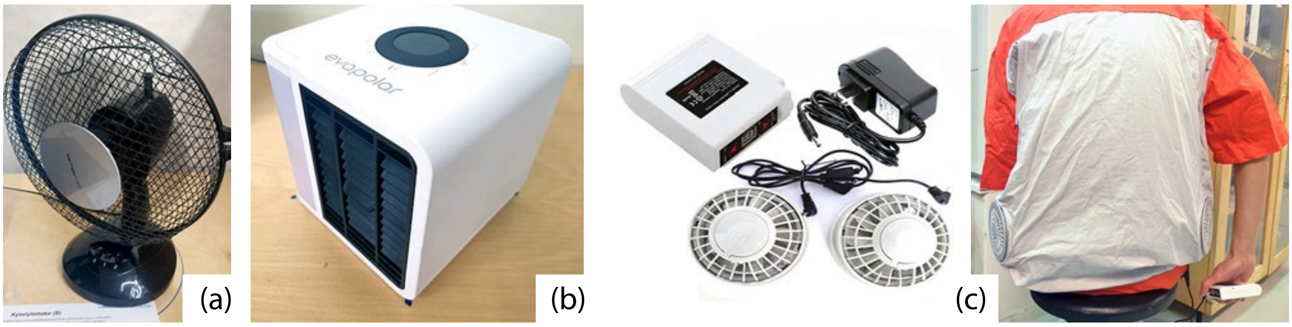

Figure 1. Convective local cooling devices: (a) table fan, (b) evaporative cooling device, and (c) air-cooled jacket.

and weighed 0.7 kg. The total electric power range is 0–20 W. The table fan and air-cooled jacket drew room air, and the evaporative cooling device produced cooler (approximately 2°C) but more humid air.

Climate chamber experiments

A previous study [1] estimated that in Finland in 2050, rooms without cooling systems will experience more hours above 32°C, whereas rooms with ventilation systems will experience more hours above 27°C. Thus, a total of five conditions, using the air temperature (T_a) and relative humidity (RH) of typical summertime and heat wave periods in Finland [2], were selected for experiments: T_a = 26°C, RH = 40%; 28°C, 60%; 29°C, 40%; 32°C, 50%; and 33°C, 40%. To control the environmental parameters to achieve the setting values, this experiment was conducted in a climate chamber, as shown in **Figure 2**. The climate chamber environment was controlled by a diffuse-ceiling ventilation system and humidifiers. The environmental parameters were detected by six TinyTag 2 plus data loggers.

The Aalto University Research Ethics Committee authorized and supported this study (D/793/03.04/2021, approved on September 23, 2021). We recruited 26 healthy Finnish elderly people to participate in the experiment. The experimental process is shown in **Table 1**. During the experiment, the participates' physiological and psychological parameters were collected. By filling questionnaires, we obtained the thermal sensation and thermal comfort state (psychological parameters) of the elderly. The questionnaire including thermal sensation vote (–3 to +3: cold to hot) and thermal comfort vote (–3 to +3: very cold uncomfortable to very hot uncomfortable). The skin temperature and core temperature (physiological parameters) of the elderly were obtained through iButton sensors and an ear temperature gun, as shown in **Figure 3**.

Performance of local cooling devices

The thermal sensation vote (TSV) and thermal comfort vote (TCV) collected at the end of the rest phase and three time points in the local cooling phase are shown in **Figure 4**.

The skin temperature measured at the end of the rest phase and in the entire local cooling phase is shown in **Figure 5(a)**. The core temperature measured at the end of the rest phase and three time points in the local cooling phase are shown in **Figure 5(b)**. ▶

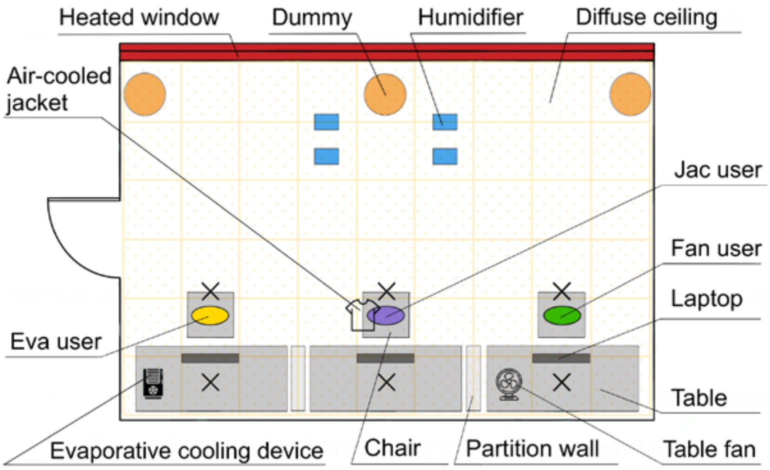

Figure 2. Climate chamber test layout. (Fan = table fan; Eva = evaporative cooling device; Jac = air-cooled jacket).

Table 1. *Schedule of the experiment.*

Step	Phase	Time	Participant activities	Data collection
1	Preparation	25 min	Change clothe and attach sensors	(Skin temperature is measured continuously with a 10s interval after attaching sensors)
2	Rest	35 min	Remain sedentary (Unable to use device)	Core temperature and questionnaire at the 35th minute
3	Local cooling	15 min	Free use of local cooling device for 40 minutes	Core temperature and questionnaire at the 15th minute
		10 min		Core temperature and questionnaire at the 10th minute
		10 min		Core temperature and questionnaire at the 10th minute

*Cycle 2 and 3 until each participant has used all three local cooling devices.

Figure 3. Measurements of skin temperature and core temperature.

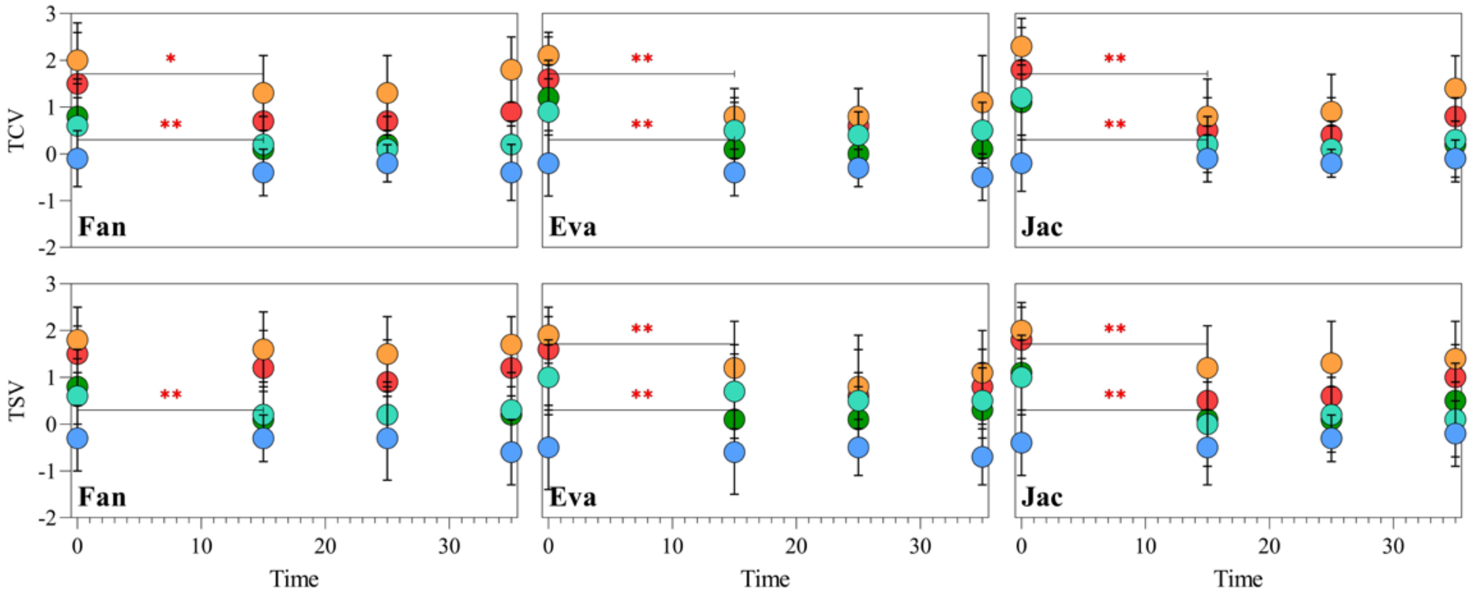

Figure 4. Elderly people's psychological parameters: (a) TCV and (b) TSV.

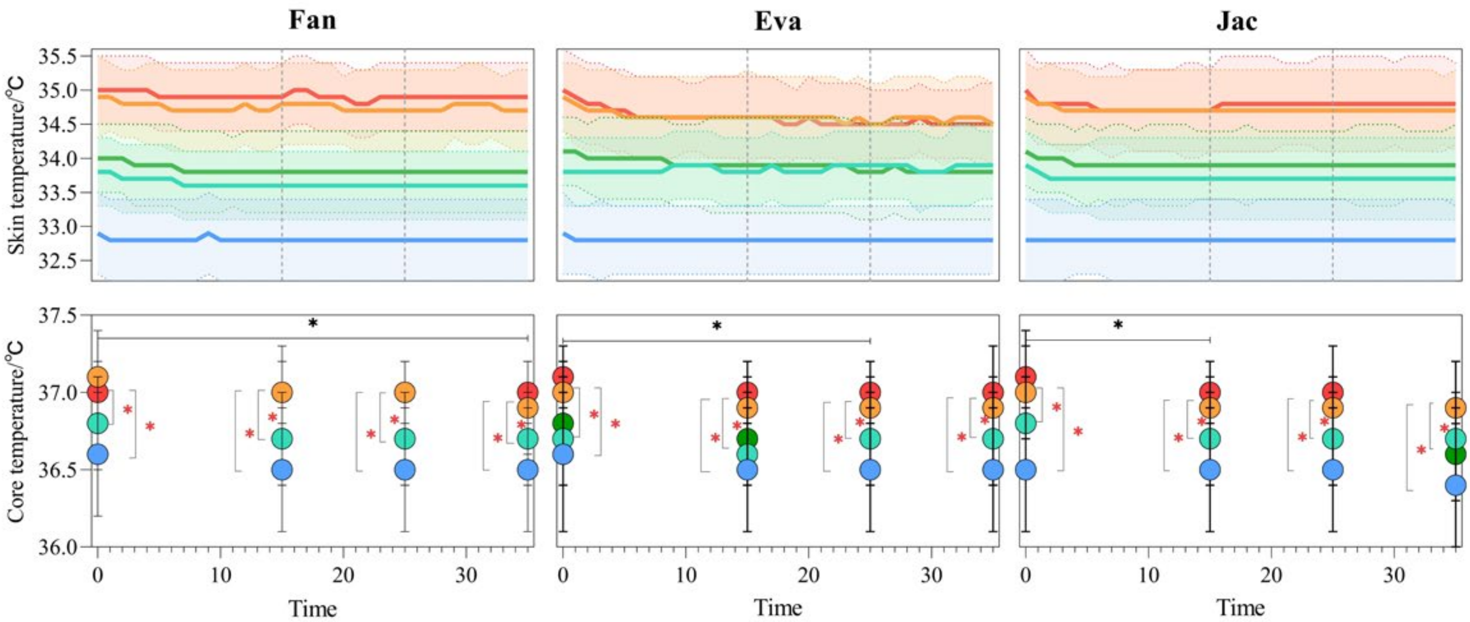

Figure 5. Elderly people's physiological parameters: (a) skin temperature and (b) core temperature.

- A statistically significant difference ($P<0.05$) was observed in the physiological and psychological parameters of elderly people before and after using local cooling devices. Compared with the thermal perception vote (TSV and TCV) in the rest phase, the first voting (at the 15th minute) in the local cooling phase decreased significantly, which means participants felt cooler and more comfortable. Using devices in a slightly warm (28°C, 60%; 29°C, 40%) environment can return the elderly's thermal sensation to a neutral state, making them feel comfortable. However, this effect cannot be achieved when using devices in a warm environment (32°C, 50%; 33°C, 40%).

During the local cooling phase, the skin temperature of the elderly dropped rapidly by about 0.5°C in 10 minutes before remaining stable. The core temperature decreased slower than the skin temperature, and decreased about 0.1°C. Among all local cooling devices, the table fan exhibited comparatively lower efficacy in alleviating thermal discomfort, particularly in warmer environments; and the evaporative cooling device performed the best, especially in lower humidity environments.

Practical applications

In contrast with typical cooling methods such as air conditioning cooling and radiant cooling systems, the convective local cooling device shows a distinct advantage in rapidly reducing skin temperature and thermal sensation. They are even able to produce a cooler sensation than what skin temperature would predict. When the environment is around 29°C, convective local cooling devices can effectively reduce thermal stress on the human body, and ensure the comfort and health of the elderly.

Although the psychological parameters decreased to levels below what was predicted based on the physiological parameters, this may not be beneficial in a warmer environment. Due to the high skin and core temperatures in the environment around 33°C, the thermal stress is not effectively removed, but only the subjective feeling is alleviated. Thus, elderly people are not suggested to rely only on convective local cooling devices under these conditions. The addition of colder air is necessary to lower skin and core temperatures and promptly reduce thermal stress in the human body. A convective local cooling device may be employed as a supplementary facility during the start-up phase of use for air conditioning and radiation cooling systems.

The three local cooling devices examined in this research exhibit a capability to reduce thermal discomfort for the elderly. Furthermore, their electrical power of around 20 W ensures that these devices will not burden the energy expenses of the elderly. These portable, low-power devices, which are commonly powered by outlets or portable power sources, can offer thermal comfort to individuals at anytime and anywhere. The thermal comfort they offer may be disregarded by current flexibility strategies for grid control [3], which classify them as minor miscellaneous plug loads. Potential consideration for future research on flexibility strategies could be given to this aspect. ■

Acknowledgments

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Reference

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