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DESIGN RESOURCES

DR-07 Protective Winter Clothing

Center for Inclusive Design and Environmental Access

Protective Winter Clothing

Yue Li, PhD[1], Jennifer Hsu, PhD[1,2], Geoff Fernie, BSc, PhD, MIMechE, CEng, PEng, CCE[1,2]
[1] Toronto Rehabilitation Institute; [2] University of Toronto

Issue and Its Importance to Universal Design and to Stakeholders

Winter is associated with increased mortality rates of about 30% above those experienced the rest of the year. The two population groups who are most heavily represented in this demographic are seniors and those with chronic illnesses as a result of outdoor exposure to the cold. Proper outdoor clothing, together with adequate indoor heating, can prevent much of the excess winter mortality. Therefore, it is important to provide public health advisors with more robust evidence on the benefits of increased outdoor clothing for reducing excess winter mortality. On the other hand, winter coats pose a problem for many older adults who experience functional limitations. The dexterity, strength and flexibility requirements for putting on a winter coat are for some older adults enough of a reason to avoid going out in the winter. In establishing guidelines for universally designed winter clothing, we need to identify populations with specific requirements and to ensure that the thermal protection property and usability of the winter clothing will satisfy their needs.

Existing Research/Evidence

Indoor clothing in the winter: The World Health Organization recommends a minimal indoor temperature of 18°C (65°F) and a 2-3° C (68 - 70°F) warmer minimal temperature for rooms occupied by sedentary elderly, young children and persons with a disability (Collins, 1986). Healy and Pepter-Clinch conducted a national household survey in Ireland and found that two-thirds of fuel-poor householders demonstrate cold strain, and over half of elderly households endure inadequate ambient household temperatures during winter (Healy & Peter, 2002). An increase in blood pressure for elderly was observed when the air temperature was 15°C (59°F)(Hashiguchi et al., 2004). Webb and Parson compared responses of thermal comfort of people with physical disabilities with those of people without physical disabilities (Webb & Parsons, 1998). They found that there are few group differences between thermal comfort requirements of people with and without physical disabilities. The range of responses for people with physical disabilities is much greater than that of people without physical disabilities.

Outdoor clothing in the winter: Improvements in central indoor heating are not consistently associated with a reduction in seasonal differences in mortality from cardiovascular disease (Keatinge et al., 1989; Wilkinson et al., 2004; Barnett et al., 2005). Therefore, Keatinge and colleagues place more emphasis on personal behaviours and have argued that many excess winter mortalities are related to exposure to cold from “brief excursions outdoors rather than to low indoor temperatures” (Keatinge et al., 1989; Keatinge, 1997). Donaldson et al. found that regional variations in thermal insulation and number of items worn, after allowance for differences in climate and behaviour, were associated with geographical differences in excess winter mortality (Donaldson et al., 2001). The authors therefore concluded that there is a potential to increase clothing, particularly by wearing long underpants or tights with trousers, underskirts with skirts, jackets with overcoats, or all three of hat, scarf or gloves. The use of extra clothing would, however, have to be balanced against the practicalities of removing excess clothing when indoors.

Insulation requirements for winter clothing: Although investigations on effects of occupational protective clothing on the wearer have been undertaken for decades, studies of clothing specifically for daily outdoor activities are much less common (Holmer, 1988; Rissanen & Rintamaki, 2007). For occupational cold protective clothing, ISO 11079 presents a method for evaluation of whole body heat balance. On the basis of climate and activity, a required clothing insulation (IREQ) for heat balance is determined. For clothing with known insulation value an exposure time limit is calculated (Holmer, 1988). Several investigators have highlighted that the outdoor clothing choice and human comfort level depends not only on air temperature and wind speed but also on other meteorological parameters such as relative humidity and solar radiation as well as individual characteristics such as activity levels, age, gender, origin and acclimatization etc. (Stathopoulos et al., 2004; Nikolopoulou & Lykoudis, 2006; Nagara et al., 1996; Givoni et al., 2003; Metje et al., 2008). Furthermore, insulation provided by clothing is a dynamic property which varies due to body posture, intensity and type of activity, moisture content, and wind (Holmer, 1988; Nielsen et al. 1985). During the course of a day, people can experience considerable temperature change and the type and intensity of their activities change also. There is no guideline to inform the general public about the level of cold stress that they might experience based on their clothing and activities under defined weather conditions.

Effect of aging: It is generally believed that older persons are less able to maintain core temperature during a cold challenge than younger persons (Smolander, 2002). The greater drop in core temperature in the older persons seems to be partly due to lower heat production and partly due to higher heat loss. When at rest in the cold, older persons have a lower metabolic rate and a higher skin thermal conductance (index of skin blood flow) (Falk et al., 1994).

- **Increased heat loss:** Under thermoneutral ambient conditions the skin temperature at the extremities is lower in older people, which is indicative of enhanced baseline vasoconstriction (Rasmussen et al., 2001). However, during cold exposure both in laboratory and outdoor situations, elderly show an attenuated efficiency in diverting blood from the skin to help conserve body heat and consequently the skin remains relatively warm (Collins et al., 1977; Khan et al., 1992; Ohnaka et al., 1994; Ballester & Harchelroad, 1999; Kaji et al., 2000; Tochihara, 2000). This age-related change is likely to be the most important factor involved in poor cold defence (Florez-Duquet & McDonald, 1998). The mechanism underlying the decreased cold-induced vasoconstriction is most likely increased arterial wall stiffness (Van Somerrn et al., 2002). In summary, the delayed and slower evolving vasoconstrictive response to a cool environment will contribute to a lower and more variable body temperature.

- **Decreased heat production:** Most of the available studies indicate that cold stress produces a smaller rise in metabolic rate in older than in younger persons (Bernstein et al., 1956; Falk et al., 1994; Horvath et al., 1955; Krag & Kountz, 1950; Wagner et al., 1974). Some studies have found no difference, and some studies even a greater increase in metabolic rate in older individuals (O'Hanlon & Horvath, 1970; Wagner & Horvath, 1985; Inoue et al., 1992; Mathew et al., 1986). The lower cold-induced increase in metabolic rate in older persons may be related to the age-related decrease in muscle mass, which reduces basal and resting metabolic rates by 20% from the age 30 to 70 (Poehlman et al., 1994). These changes may also reduce shivering thermogenesis Kenney & Buskirk, 1995).

- **Attenuated thermal perception:** Neurophysiological studies, utilizing local heating and cooling of small skin areas, indicate that aging is associated with a decreased cutaneous thermal sensitivity (Stevens & Choo, 1998; Merchut & Cone, 1990; Lautenbacher & Strain, 1991; Heft et al., 1996). During daytime, older people regulate their indoor ambient temperature less precisely and tolerate larger deviations from the comfortable average before action is undertaken, indicating a decreased subjective thermal perception (Van Someren et al., 2002). There is the high risk of decrease in deep body temperature and rapid increase in blood pressure in older people, without the consciousness of cold (Yochihara et al., 1993). Therefore, it is necessary to pay a special attention to the elderly in cold as they may not be able to adjust their thermal conditions against the cold by wearing thick clothes or heating the room.

Usability issue: Many older individuals have trouble putting on winter coats because the garments are typically heavy and require flexibility, dexterity and strength levels that exceed their own. These difficulties are so problematic for some that they are often enough to keep them from going outside (Row, Paul, McKeever and Fernie, 2005; Row, Paul & Fernie, 2004). The few technological winter apparel items that offer active heating components or safety additions have been designed for the sporting and military markets, and are therefore out of scope and price range for functionally limited older adults and are not universal solutions.

Design Guidelines

Determining the needs of indoor clothing: Whereas healthy older people compensate for feeling cold by turning up the thermostat and adding extra clothing, frailer older people with impaired environmental awareness, physical abilities, and communication may be dependent on caregivers or intelligent environmental controls. There is a need for the inclusion of information on the physiologic response to cold in universal design guidelines in order to inform policy, educational program content and designers of intelligent environmental control systems.

Determining the thermal protection property of winter clothing: The required clothing insulation can be calculated for particular outdoor activities and environmental conditions (O'Leary & Parsons, 1994). However, there are no universal guidelines that can be used by the consumers or by designers of winter clothing. International standards exist for evaluation of cold workplaces (see Table 1). The thermal insulation value of clothing ensembles is measured according to ISO 15831. In practice, the thermal insulation is estimated using tables in ISO 11079 or using any of the methods proposed in ISO 9920. ISO 11079 recommends withdrawing from cold exposure when there is a drop in mean skin temperature by about 3°C (5°F) starting from "comfort" level (about 34°C, or 93°F). ISO 11079 also recommends frequent control of finger temperatures in the workplace and suggest that finger temperatures should be higher than 24°C (75°F) for preservation of good hand function. Occasionally, finger temperatures down to 15°C (50°F) may be acceptable, but dexterity, strength and coordination suffer and persons may complain about pain sensations. Inhalation of cold air may provoke respiratory distress symptoms, in particular in persons with asthma or other diseases. Also healthy persons may develop adverse effects on lung tissues when a large volume of very cold air is inhaled, for example during heavy work or athletic events at temperatures below –15 to –20°C (5° to -4°F). It is recommended to protect the airways by reducing work rate or exposure or by pre warming air by a breathing mask or similar (Holmer, 2009).

Determining the usability of winter clothing: At present there exists no specific guidance on the usability of winter clothing. We recommend that the design of winter clothing for older adults should compensate for changes in body shape and physiology as well as increased functional limitations.

Summary of Related New Research Accomplished by RERC-UD

Li et al. investigated the effect of outdoor clothing and repeated cold exposure on blood pressure, heart rate, skin temperature, and thermal sensation in normotensive participants (Li et al., 2009). Four winter clothing ensembles were used: regular winter clothing without a hat, with a hat, with an extra pair of pants, and with a hat and an extra pair of pants. The participants were exposed four times to -5°C (23°F) for 15 minutes wearing different clothing ensembles in counterbalanced order and each cold exposure was followed by 25 minutes of rewarming at 25°C (77°F). The results showed that systolic and diastolic blood pressure increased in cold and increased more when a hat was not used. Wearing hats not only reduced the blood pressure response during cold exposure but also promoted faster recovery of forehead skin temperature and blood pressure. These findings are encouraging and warrant further investigations to better understand the benefits of wearing appropriate clothing in the winter, especially among older people and people with cardiovascular diseases.

Research needs (What still needs to be done)

Indoor clothing for people with impairment in cognition or mobility: It is unknown whether the preference for seemingly uncomfortable conditions stems from physiological changes associated with dementia, or stems from the inability to control the environment and the passive acceptance thereof (Van Hoof et al., 2010). An intelligent body temperature monitoring and environment temperature controlling system could be integrated into indoor clothing for people with impairment in cognition or mobility.

Outdoor clothing: More studies of thermal comfort in cold environments are needed in order to reveal the complex interaction of perception and heat exchange (Holmer, 2004). Data on baseline metabolic rate and other physiological responses at different temperatures wearing regular winter clothing for all age groups are still very limited and scattered. A collaborative effort should be put together to establish a database in this area.

Transition between indoor and outdoor environments: It is suggested that the steady-state models for thermal comfort such as the Predicted Mean Vote (PMV) index may not be appropriate for the assessment of short-term outdoor thermal comfort, mainly because they are unable to analyse transient exposure (Thorsson et al. 2004). A previous study discovered that lower forehead temperatures resulted in lower comfort values nearly independent of the meteorological parameters (Metje et al., 2008). Therefore, the skin temperature may be used as an objective parameter to determine human outdoor-indoor transient stress levels and further tests will be needed.

Cold stress during different daily activities: Cold stress and clothing insulation are static parameters in ISO7730. In reality they are dynamic variables that change according to prevailing air velocities and type of activity (Holmer, 2004). Therefore, there is a need for studies that document the cold stress and cloth insulation values while young, older and people with disabilities participating in different daily activities (Figure 1).

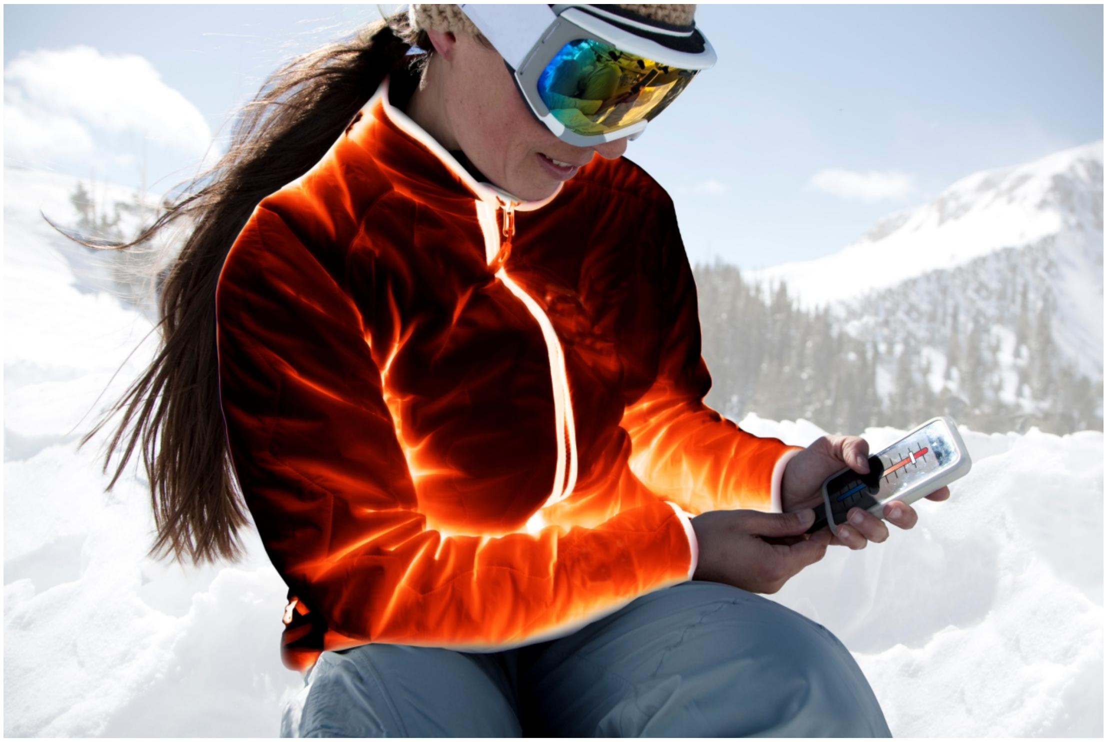

Figure 1 Illustration of a conceptual winter jacket that can monitor and control the micro environment under the clothing. (Illustration by Steven Pong, M.Des)

Impact of cold exposure duration: According to ISO 11079, required clothing insulation (IREQ) is calculated for the given climatic conditions and activity at workplaces. The insulation value of the given clothing ensemble is determined and compared with IREQ. If the insulation value is less than IREQ then body cooling may result and a supplementary method calculates a recommended exposure time (DLE = duration limited exposure) based on a small drop in body heat content. However, the insulation values provided by most of the regular winter ensembles are less than IREQ even for a young healthy person. For the general public, especially frail older people, a recommended exposure time should be established based on their thermo-physiological responses during outdoor cold exposure wearing their regular winter clothing and more research is needed to establish this universal guideline.

Usability and safety: More efforts are needed to develop winter coats that can be used by everyone including older adults with functional limitations. These designs will: 1) reduce the physical challenge of donning the coat, 2) reduce the restrictions on movement and safe ambulation, and 3) reduce the likelihood of injury from a fall.

Table 1: International Standards for Evaluation of Cold Workplaces

ISO Standard/ ASTM/ ANSI/ASHRAE/ EN
ISO Thermal comfort and thermal environment standards
ISO 15743:2008: Ergonomics of the thermal environment -- Cold workplaces -- Risk assessment and management
ISO 15831:2004 Clothing -- Physiological effects -- Measurement of thermal insulation by means of a thermal manikin
ISO 11079:2007 Ergonomics of the thermal environment-Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects.
ISO 9920:2007 Ergonomics of the thermal environment-Estimation of thermal insulation and water vapour resistance of a clothing ensemble.
ISO/TS 14415:2005 Ergonomics of the thermal environment -- Application of International Standards to people with special requirements
ISO 8996:2004 Ergonomics of the thermal environment-Determination of metabolic rate.
ISO 7726:1998 Ergonomics of the thermal environment-Instruments for measuring physical quantities.
ISO 13732-3:2005 Ergonomics of the thermal environment -- Methods for the assessment of human responses to contact with surfaces -- Part 3: Cold surfaces
ISO 9886:2004 Ergonomics-Evaluation of thermal strain by physiological measurements.
ISO 7730:2005. 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.
ISO 10551:1995 Ergonomics of the thermal environment-Assessment of the influence of the thermal environment using subjective judgement scales.
ASTM F2732 - 09 Standard Practice for Determining the Temperature Ratings for Cold Weather Protective Clothing
ANSI/ASHRAE 55-2004 Thermal environmental conditions for human occupancy.
EN 342 – Protective clothing Ensembles and Garments for protection against cold.
EN 511 – Protective gloves against cold

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University at Buffalo
School of Architecture and Planning

378 Hayes Hall
3435 Main Street
Buffalo, NY 14214-3087

Phone: (716) 829.3485 x329 | TTY (716) 829.3758

Email: ap-idea@buffalo.edu

Fax: +1 (716) 829.3861