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Sex differences in age-related changes on peripheral warm and cold innocuous thermal sensitivity

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HIGHLIGHTS

- Forehead thermal sensitivity is persevered with ageing.
- Regional cold sensitivity is homogenous for the young and elderly.
- Regional warm sensitivity is heterogeneous especially in the young.
- Females are more sensitive to innocuous warm and cold thermal stimulation than males.
- Ageing does not change the sex related differences in thermal sensitivity.

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ABSTRACT

Cutaneous thermal sensitivity to a warm and cold stimulus was compared amongst 12 older (OF, 65.2 ± 1.0 year) and 29 younger (YF, 21.6 ± 0.2 years) female participants, and 17 older (OM, 66.2 ± 1.5 years) and 13 younger (YM, 21.2 ± 0.4 years) male participants to examine the effects of ageing and sex. In a neutral condition (27.5 °C, 50% RH) during rest, warm and cold thermal sensitivity was measured on eight body regions (forehead, chest, back, forearm, hand, thigh, calf, and foot). Using the method of limits, a thermal stimulator was applied to the skin at an adapting temperature and either increased or decreased at a constant rate (0.3 °C/s) until the participants detected the temperature with a push button. Thermal sensitivity declined with ageing to both a cold (older: 1468.6 ± 744.7 W/m^2, younger: 869.8 ± 654.7 W/m^2, $p < 0.001$) and warm (older: 2127.0 ± 1208.3 W/m^2, younger: 1301.7 ± 1055.2 W/m^2, $p < 0.001$) innocuous stimulus. YF and OF were more sensitive than YM and OM to both a warm and cold stimulus ($p < 0.05$). There was no interaction between age and sex suggesting that whilst thermal sensitivity decreases with age the decrease is similar between the sexes ($p > 0.05$). There was an interaction between temperatures, age and location and it seemed that cold thermal sensitivity was more homogenous for young and older participants however warm thermal sensitivity was more heterogeneous especially in the younger participants ($p < 0.05$). Although the pattern was not similar between ages or sexes it was evident that the forehead was the most sensitive region to a warm and cold stimulus. Interestingly the decline in sensitivity observed with ageing occurred for all locations but was attenuated at the forehead in both males and females ($p > 0.05$).

1. Introduction

Behavioral and autonomic temperature regulation is mediated by inputs from afferent signals located both centrally and peripherally. Deterioration in the afferent nerves, such as a decrease in number and density of myelinated and unmyelinated fibres, reductions in neurotransmitters and their host cells are typical age-related declines in

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neurological functioning [1]. Age-dependent neural degeneration observed in thermoreceptors can reduce both physiological and perceptual thermal sensitivity. Impaired cutaneous vascular function and delays in the sweating and shivering thresholds have been reported in age comparison studies [2–6]. Likewise, reduced thermal sensations in older adults have been reported, alongside a number of other tactile responses (touch, pressure and noxious thermal sensitivity) [7–11]. With an increasing ageing population and increased reports of climate change, understanding the age related changes in our ability to thermoregulate is vitally important. Perceptual thermal sensitivity provides immediate feedback about the thermal state of the body and initiates a set of desired actions to correct the thermal imbalance. As a result, the ability to sense temperature acts as our first line of defence against thermal imbalance yet relatively little is known about this in comparison to our physiological responses.

It has been suggested that thermal sensitivity declines with age although the findings have been contradictory. Kenshalo [12] assessed the thermal threshold of the thenar eminence and sole of the foot to either an increasing or decreasing temperature. He noted an age related decrement only at the foot to an increasing temperature. Harju et al. [13] reported no effect of age on cold or warm threshold detection at the thernar eminence; lateral upper arm, lateral knee or sole of the foot. However, Haung et al. [8] reported age related decrements to warm and cold thresholds on the dorsal hand and foot using the same technique as Kenshalo [12]. Experimental data on the age-related changes to thermal stimulation have been contradictory but recently there is evidence to suggest that the age-related decline in thermal sensitivity is site specific. Tochihara et al. [7] reported age related decrements in warm threshold detection at the hand, foot and shin but not at the chest, abdomen, upper arm, forearm or thigh. This non-uniform decline may have contributed to the lack of clarity over thermal sensitivity especially when studies investigated a limited number of locations. Typically, thermal sensitivity is limited to one or two locations across the body despite seminal research indicating regional distribution of thermoreceptors across the body [14,15]. Whilst most studies investigate a limited number of body sites, recently extensive body maps to a warm and cold innocuous stimulus have recently been reported in males and females (~20 years) [16–18]. However, more information about regional thermal sensitivity in older individuals in comparison to younger adults is required.

There is substantial evidence supporting sex differences in noxious and innocuous thermal sensitivity with females being more sensitive than males [17–21]. However this information is currently limited to relatively young adults (~20–30 years). Overall, the literature suggests that thermal sensitivity may decline with age and females are more sensitive than males but whether the decline in thermal sensitivity with ageing is similar between males and females is unknown. Therefore the aim of the present study was to assess the effect of ageing and sex on regional thermal sensitivity to a warm and cold stimulus. To address this we measured the threshold detection to an increasing and decreasing thermal stimulator on 8 locations across the body in older and younger males and females.

2. Methods

2.1. Participants

Seventy-one participants volunteered for this study, of which 12 were older female (OF), 29 younger female (YF), 17 older male (OM) and 13 younger male (YM). The physiological characteristics of the participants are shown in Table 1. The young females were not taking oral contraceptives and were tested during the early- or mid-follicular phase (4–10 days after menstruation onset). Older female participants were all post-menopausal and were not undergoing hormonal replacement therapy. Participants completed health screen questionnaires and informed consent prior to taking part. Osaka International University institutional ethics committee for human investigations approved this study, which was carried out in accordance with the Declaration of Helsinki.

2.2. Experimental design

The aim of the investigation was to compare regional sensitivity to a hot and a cold stimulus in young and elderly males and females during rest. To achieve these aims an independent design was opted for, during which, regional thermal sensitivities to an increasing and decreasing thermal probe was investigated. A total of 8 regional body segments were chosen representing major anatomical landmarks (anterior and posterior torso and extremities). The testing sequence of the locations was randomized to reduce order effect. However, cold sensitivity test always preceded the warm sensitivity test. After completing both tests a 5 min rest period was taken and the process repeated an additional 2 times to reduce unsystematic errors and order effects. Participants were familiarised with the test prior to the main experiment. The experiments were conducted between early August and late October in Japan.

2.3. Experimental protocol

Each participant completed a pre-test session for anthropometric measurements; including stature, weight and skin fold thickness. Body surface area (AD) was calculated using the following equation [22]:

$$AD(m^2) = Mass(kg)^{0.444} \times Height(m)^{0.663} \times 88.83$$

Skinfold thickness was measured using skinfold calipers over the chest, subscapular, suprailiac, triceps, anterior forearm, anterior thigh, and posterior calf and the sum of 7 skin folds calculated (Σ7SF). They then completed a submaximal incremental exercise test on a cycle ergometer (Aerobike 75 XLII, Combi Corporation, Tokyo, Japan) for the estimation of maximal O_2 uptake (VO_2max) based on the Åstrand Rhyming method. The test consisted of four progressive exercise stages each lasting 5 min. Heart rate (Polar Electro Oy, Kemple, Finland) was recorded during the last minute of each stage. Estimation of VO_2max was then calculated from the ACSM metabolic equation for cycling [23]. Participants were asked to wear a pedometer (JM-200, Yamasa,

Table 1
Physical characteristics of each group.

	n	Age (year)	Height# (cm)	Mass# (kg)	AD/mass# (cm^2/kg)	Σ7SF# (mm)	VO_2max (ml/kg/min)	PA (steps/day)
Older female	12	65.2 ± 1.0*	152.8 ± 1.8*,†	51.5 ± 2.5†	281.1 ± 6.4	148 ± 10*,†	33.8 ± 1.9*	11,650 ± 1112
Younger female	29	21.6 ± 0.2	161.0 ± 1.1†	53.2 ± 1.1†	284.5 ± 2.7	122 ± 6†	41.7 ± 1.4	12,128 ± 787†
Older male	17	66.2 ± 1.5*	163.2 ± 1.8*	59.0 ± 2.1	271.8 ± 4.3	69 ± 5	38.5 ± 1.6	11,977 ± 1177
Younger male	13	21.2 ± 0.4	171.2 ± 1.2	58.5 ± 1.8	281.0 ± 4.3	56 ± 7	43.3 ± 3.1	15,801 ± 1693

Values are means ± SEM. AD: body surface area, Σ7SF: sum of 7 skinfolds, VO_2max: maximal oxygen uptake, PR: physical activity level.
* Significantly different between older and younger participants for each sex, $p < 0.05$.
† Significantly different between female and male participants for each age, $p < 0.05$.
\# Significantly different between female and males inclusive of all ages, $p < 0.05$.