

## REVIEW

**A systematic review of body temperature variations in older people**

Shu-Hua Lu, Angela-Renee Leasure and Yu-Tzu Dai

**Aim.** The purpose of this systematic review was to determine the extent to which the research literature indicates body temperature norms in the geriatric population.

**Objectives.** The specific questions addressed were to examine normal body temperature values in persons 60 years of age and older; determine differences in temperature values depending on non-invasive measurement site and measurement device used; and, examine the degree and extent of temperature variability according to time of day and time of year.

**Background.** The traditional 'normal' temperature of 98.6 °F/37 °C may in fact be lower in older people due to the ageing process. Age-associated changes in vasomotor sweating function, skeletal muscle response, temperature perception and physical behaviours may influence the ability to maintain optimum temperature.

**Design.** A systematic literature review.

**Methods.** A search of multiple databases yielded 22 papers which met inclusion criteria. Studies were included which focused on temperature measurement, sampled persons 60 years of age and older, collected data from non-invasive temperature measurement sites and which used a prospective study design. Studies were independently appraised using a structured appraisal format.

**Results.** Temperature normal values by site were rectal 98.8 °F/37.1 °C, ear-based 98.3 °F/36.8 °C, urine 97.6 °F/36.5 °C, oral 97.4 °F/36.3 °C and axillary 97.1 °F/36.2 °C. Temperature exhibited a 0.7 °F/0.4 °C diurnal and 0.2 °F/0.1 °C circannual variation.

**Conclusions.** Synthesis of data indicated that normal body temperature values in older people by sites were rectal 0.7 °F/0.4 °C, ear-based 0.3 °F/0.2 °C, oral 1.2 °F/0.7 °C, axillary 0.6 °F/0.3 °C lower than adults' acceptable value from those traditionally found in nursing textbooks.

**Relevance to clinical practice.** Given the fact that normal body temperature values were consistently lower than values reported in the literature, clinicians may need to re-evaluate the point at which interventions for abnormal temperatures are initiated.

**Key words:** axillary temperature, body temperature, ear-based temperature, oral temperature, rectal temperature, urine temperature

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**Introduction**

To intervene accurately in the care of older people, nurses should be armed with the knowledge of normal temperature range and mean, predictable variations as well as potential

sources of measurement error. An accurate measurement of body temperature depends upon three factors: an accurate thermometer; a valid measurement site; and, the skills of the individual measuring the temperature. Measurement error can arise from any one of the three factors and result in either

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unnecessary or delayed treatment for conditions ranging from infection to hypothermia. As well as external sources of measurement error can result from both systematic and random sources of temperature variability, albeit within a narrow range, within each person.

Wunderlich (1869) is credited with establishing the ranges of normal body temperature in 1869. He supervised the collection of axillary temperatures of 25,000 healthy subjects and then defined normal body temperature as being 98.6 °F/37 °C and the normal temperature range as 97.2 °F/36.2 °C to 99.4 °F/37.5 °C. Wunderlich found temperature values reached their nadir period in the mornings between two and eight and zenith in the evenings between four and nine. He also reported a 0.9 °F/0.5 °C lower reading in older people as compared to adults of a younger age. Wunderlich's values have been widely adopted since that time although we now know that temperature values differ across measurement sites, modern thermometry has improved accuracy; and we now know that temperature has predictable variability. Also, the thermometer Wunderlich used was later found to read 1.4–2.2 °C higher than the thermometry in use today (Mackowiak & Worden 1994).

### Aim

The aims of this systematic review was to evaluate existing evidence to (i) determine a normal body temperature value and range for persons 60 years of age and older; (ii) determine differences in temperature ranges according to non-invasive measurement site and device in older people and (iii) examine the degree and extent of temperature variability according to time of day and time of year.

### Background knowledge

Temperature monitoring sites and devices are evaluated against their ability to estimate core body temperature (Cereda & Maccioli 2004). In this section, the literature on the sites and temperature measurement devices will be reviewed to examine their theoretical base, strengths and limitations.

### Noninvasive temperature measurement sites

Several non-invasive and more accessible sites including rectum, oral cavity, urinary bladder, axilla and ear canal have been widely used to measure body temperature. A site receiving afferent blood supply and airless space is presumed to be more likely to reflect core body temperature, the temperature of the hypothalamus. The gold standard of core

temperature obtained with a pulmonary artery catheter is not used in daily clinical practice due to the invasiveness of catheterization.

### Rectal site measurement

Among non-invasive sites, temperatures measured using the rectal site is considered to most closely reflect core body temperature (Smith 2003a). However, rectal temperatures are not commonly used in the home and ambulatory care settings because it is often considered to be intrusive and thus less acceptable to patients. Sources of error can result from excess faecal matter in the rectum, faecal incontinence, as well as inadequate depth of thermometer insertion. Also rectal temperature is thought to lag behind core temperature changes during times of rapid temperature changes.

### Oral site measurement

The oral cavity is a popular site for temperature measurement, because the thermometer probe is placed in a sublingual pocket near deep tongue arteries that are supplied by the carotid artery (Fulbrook 1993). Hot and cold beverages, smoking of cigarettes and chewing gum should be avoided for a minimum of 30 minutes before temperature measurement (Sugarek 1986, Quatrara *et al.* 2007) to avoid false high or low readings. In older people, dentures may impair the accuracy of readings due to the difficulty keeping the probe in place and the lips sealed (Marion *et al.* 1991). Also, persons with dementia or experiencing confusion may have inaccurate readings due to the inability of the individual to keep the temperature probe in the sublingual pocket and the lips sealed. Neither use of supplemental oxygen therapy being delivered at <6 l/minute nor the presence of an endotracheal tube have been consistently shown to significantly alter oral temperature readings (Hasler & Cohen 1982, Yonkman 1982).

### Urine temperature measurement

Urinary bladder temperatures can be measured using an indwelling urinary bladder thermistor catheter which provides a continuous digital display of temperature readings (Lilly *et al.* 1980). Although considered to be one type of core temperature measurement, this type of temperature measurement is considered to be intrusive and is used almost exclusively with critically ill patients. A more popular way to measure urine temperature is to void urine into a container through a funnel containing a thermometer. The resulting urine temperature, an indirect measure of bladder

temperature, has been shown to be highly correlated with both rectal (Brooke *et al.* 1973, Ehrenkranz 1986) and vaginal temperatures (Samples & Abrams 1984).

### Axillary site measurement

In contrast to oral, urinary bladder and rectal sites; the axillary site does not carry the same exposure to body fluid contact. The axillary site is an area that is protected from radiant heat loss. The asymmetrical location of chest organs may suggest a predictable difference between right and left axilla (Giuffre *et al.* 1990, Heidenreich & Giuffre 1990); vasodilatation and vasoconstriction may increase and decrease axillary temperatures respectively; and, during times of rapid temperature changes, axillary temperatures are thought to lag behind core temperatures. Today, axillary temperatures are considered to be less accurate, reflecting skin rather than core temperature.

### Ear-based temperature measurement

Ear-based or tympanic membrane temperature measurement is used popularly in the clinical setting, because it is non-invasive and convenient. The blood supply to the tympanic membrane arises from the same branch of the carotid arteries as the hypothalamus (Boulant 1998). However, it is still controversial whether ear-based temperature represents the core body temperature.

### Temperature measurement devices

The search for an ideal measurement device which reflects core temperature change accurately, safely, quickly and with easy access continues (Erickson & Yount 1991, Varney *et al.* 2002). Each of the temperature measurement devices available today has strengths and limitations. An acceptable difference between measurement devices was set *a priori* at 0.4 °F/0.2 °C (Hanneman 2008).

### Mercury-in-glass thermometers

Mercury-in-glass thermometers have been considered to be a highly reliable tool for years and as such were used as the temperature measurement device in many of the studies included in this systematic review. However, due to concerns about mercury poisoning and environmental protection, mercury-in-glass thermometers have all but disappeared from clinical practice although they may still be found in many homes. These bulb thermometers contain mercury which responds to heat by rising in a standardised

manner. Temperatures are read based upon marks on the glass of the thermometer which corresponds to the height of the mercury column. A temperature is taken in a 'shake and take' manner where the mercury is 'shaken down' into the bulb of the thermometer prior to use. The mercury then rises within the glass thermometer column to the highest temperature and remains there until 'shaken down'. The National Institute of Standards and Technology (NIST) is responsible for maintenance and dissemination of the International Temperature Scale of 1990 (ITS-90) for the United States. Thermometers are evaluated for accuracy using a water bath and comparing at three different temperature points. Thermometer readings are compared against an NIST calibrated and certified thermometer. Thermometers which differ more than  $\pm 0.2$  °F/0.1 °C from the calibrated reference thermometer at the three temperature points are not considered to be accurate (Wise 1991, 1994).

### Electronic thermometers

Electronic thermometers are comprised of a metal thermoprobe coupled with an electronic display unit. The metal probe is covered with a single use plastic cover. Electronic thermometers use internal circuitry to predict body temperature based upon initial heat curves in typically 30–50 seconds (Erickson & Meyer 1994, Prentice & Moreland 1999).

### Ear-based thermometry

Infrared ear thermometers (IET) include a speculum like probe which when inserted into the aural canal samples radiant heat coming from the tympanic membrane and surrounding structures. Readings can be set to display as actual mode, core equivalent, oral equivalent, or rectal equivalent through use of an internal conversion utility. As different IET use different algorithms, the actual mode was considered to be desirable when using this type of thermometer for data collection in the studies (Terndrup & Rajk 1992, Christensen & Boysen 2002). IET was initially derived from the direct contact tympanic membrane thermometer. Tympanic membrane thermometers consisted of a thin wire which was advanced until making contact with the tympanic membrane and either left at that point or withdrawn a short distance.

There are many factors that may result in an inaccurate measurement when taking ear-based temperature including; cerumen or hair follicles in the auditory canal; the natural curvature of the aural canal or its size which result in inaccurate positioning of the thermometer probe; and a chipped or dirty

infrared detector may each impede unobstructed access to the tympanic membrane. Ear-based temperature readings in these situations tend to be inaccurate and show a falsely low body temperature. Some sources recommend tugging the ear down and back to straighten the external auditory canal. As use of an ear tug is not universal included studies were reviewed regarding inclusion of this measurement method. Stability of measurement can be negatively impacted by errors introduced when the opposite, rather than near ear, is used. Also, values can be falsely elevated if the ear used has been occluded by a pillow (Erickson & Meyer 1994, Hasel & Erickson 1995, Petersen & Hauge 1997, Braun *et al.* 1998, Heusch & McCarthy 2005).

### Urine thermometry

Urine temperatures are collected using a device which has a thermometer placed below a funnel. Although designs vary depending on the specific device used, urine is voided into a collecting jar through a funnel which contains a thermometer. The thermometer tip partially occludes the funnel mouth which allows a longer immersion time with the urine. Accuracy of urine temperatures is decreased when <100 ml of urine is collected, in cold ambient environments and in situations where the urine stream is passed from a great height (Ellenbogen & Nord 1972, Brooke *et al.* 1973, Judson *et al.* 1979, Samples & Abrams 1984).

### Galinstan<sup>TM</sup>-in-glass thermometers

Galinstan<sup>TM</sup>-in-glass thermometers an alloy of gallium, indium and tin, are being used as nontoxic replacements for mercury-in-glass thermometers. These devices have not yet been widely used in temperature research but have garnered interest among clinicians in an effort to reduce possible cross-contamination of patients with communicable illnesses. Evidence to date has indicated clinical agreement between mercury-in-glass and Galinstan-in-glass thermometers (oral .203 °F; axillary .253 °F and rectal -.05 °F bias across site). Both mercury-in-glass and Galinstan-in-glass thermometers are checked for accuracy using a swirling water bath and checking against a NIST calibrated thermometer (Smith 2003b).

## Methods

### Study inclusion criteria

Original studies were included in this review if they focused on normal body temperature of older people and

met the following inclusion criteria: (i) study samples which included human subjects ages 60 and older; (ii) measured body temperature at least one time and used at least one non-invasive method of temperature measurement and (iii) used a prospective design.

### Search strategy

A systematic literature review was performed, using both Chinese and Western scientific databases including: MEDLINE (1966–2008), CINAHL (1982–2008), Ageline (1978–2008), EMBASE (1988–2008), Current Contents, Cochrane and the Electronic Theses and Dissertations System. Terms searched were: axillary temperature, basal body temperature, body temperature, body temperature measurement, core temperature, mouth temperature, normal body temperature, oral temperature, rectal temperature, skin temperature, temperature, temperature measurement, ear temperature, tympanic temperature, temperature measurement, temperature monitoring, temperature recording, elderly, aged, ageing and geriatric. The results were then merged and cross-searched. Studies were limited to human and to adults (middle-aged and aged) when these limits were available. Additionally, the references of retrieved studies were examined for additional studies which met inclusion criteria.

From this search 290 studies were retrieved. From this initial number, abstracts were reviewed for inclusion. From the abstracts reviewed 23 full text articles were evaluated for inclusion. Studies were excluded which: grouped afebrile and febrile subjects: reported correlations and measures of agreement rather than group means; collected data through chart review; and combined those 60 and over with other age groups. Twenty-two articles were selected for inclusion in this systematic review.

### Definitions

Older people were defined as persons 60 years of age and older to be as inclusive of as many studies as possible. Studies were included in this systematic review which sampled a larger age range if those 60 years or older could be identified for subgroup analysis. Definitions of non-invasive temperature vary widely. For the purposes of this review non-invasive sites of temperature were considered to be oral, rectal, ear-based, urine and axillary. Hand, groyne and cutaneous sites were excluded due to the infrequent use of these sites for temperature measurement in the clinical practice environment.

## Results

### Summary of papers selected for inclusion in the review

Studies included in the review were independently appraised by two different reviewers using a structured appraisal sheet. Discrepancies in ratings were resolved through discussion and when necessary consultation with a third person. Some studies only indicated mean temperatures, making it impossible to identify the distribution of temperature highs, lows and extremes. If the primary data did not specifically include range values, the temperature range was indicated with the mean ( $\chi$ ) value  $\pm$  2 standard deviations (SD) provided in the study report and the results were labelled with an asterisk (\*). If the primary data did not include body temperature means and SD, they were indicated by a dash (-).

Among the 22 sampled studies, ten of the studies reviewed sampled community dwelling elders, five sampled nursing home residents and eight recruited older subjects from hospital inpatients. Two studies (Fox *et al.* 1973b, Primrose & Smith 1982) used a systematic random sampling procedure while the other studies used non-random sampling procedures. Sample size for the included studies ranged from 18–1020 subjects. The measurement site and device most frequently reported was the oral temperature using a mercury thermometer. Few studies reported information assuring inter-rater reliability testing and training of data collectors, number of data collectors used and methods of assuring stability and consistency of measurement. Finally, in studies which compared values obtained from different temperature measurement sites, statistical analyses were primarily correlational rather than graphed as Bland and Altman plots (Bland & Altman 1995). Table 1 provides a synthesis of study findings.

The methods described by Sund-Levander *et al.* (2002) guided the meta-analysis of temperature data across studies. When data was reported by differing age groups, time of day, time of year, sites, devices, or setting; new mean values were calculated by using the formula  $[(\chi_1 n_1 + \chi_2 n_2 \dots) / (n_1 + n_2 \dots)]$ . For comparison °C was converted to °F using the formula  $(^{\circ}\text{C} \times \frac{9}{5}) + 32 = ^{\circ}\text{F}$ .

### Normal body temperature values across measurement sites

The data of body temperature from five measurement sites in 22 studies were examined. Three studies measured a total of 547 rectal temperatures for  $\chi = 98.76$  (SD 0.08). Using these values the normal rectal temperature would be 98.8 °F/37.1 °C and the normal temperature range would be 98.6 to

99.0 °F/37.0 to 37.2 °C. Five studies collected 1118 ear-based temperatures  $\chi = 98.3$  (SD 0.81). Using these values the normal ear-based temperature would be 98.3 °F/36.8 °C with a normal temperature range of 97.5 to 99.1 °F/36.4 to 37.3 °C. Four studies collected 1282 urine temperatures with a  $\chi = 97.59$  (SD 0.28). Thus, the normal urine temperature would be 97.6 °F/36.5 °C with a urine temperature range of 97.3 to 97.9 °F/36.3 to 36.7 °C.

Among the 16 studies which sampled oral temperatures, the overall lowest value registered was 85.99 °F/30 °C which was considered to be an outlying data point (Howell 1975). The primary study author calculated temperature midpoints with and without the next lowest value, 95 °F/32.6 °C. Thus the study mean based upon the second lowest temperature value of temperature of 95 °F/32.6 °C, rather than 85.99 °F/30 °C, was used in calculations. Also, temperature values from two publications (Marion *et al.* 1991, McGann *et al.* 1993) which described findings from the same group of subjects were included only once in the analysis. Across 2265 oral temperature measurements a  $\chi = 97.41$  (SD 0.17) was obtained. The mean temperature difference between electronic and mercury thermometry was compared to determine differences based upon type of thermometry used. The mercury to electronic thermometer difference was 0.16 °F/0.1 °C which falls within an acceptable range of difference. Thus a normal oral temperature would be 97.4 °F/36.3 °C and the oral temperature range would be 97.0 to 97.8 °F/36.1 to 36.6 °C. Across 395 axillary temperatures measurements from four studies the mean was  $\chi = 97.06$  (SD 0.87) with a resulting normal axillary temperature would be 97.10 °F/36.2 °C and the axillary temperature range would be 96.2 to 97.9 °F/35.7 to 36.6 °C. Figure 1 is a schematic representation of temperature ranges across studies grouped by site of temperature measurement. In summary, when rectal temperatures were used as the standard of comparison, the rectal site yielded body temperatures 0.5 °F/0.3 °C higher than the ear-based site; 1.2 °F/0.6 °C higher than urine temperatures; 1.4 °F/0.7 °C higher than the oral site; and 1.7 °F/0.9 °C higher than the axillary site (Table 2).

### Temperature variability

Diurnal variation was examined comparing 1344 oral temperature readings. Morning mean temperatures were  $\chi = 96.9$  (SD 0.20) and afternoon  $\chi = 97.6$  (SD 0.17) resulting in a 0.7 °F/0.4 °C diurnal variation. Circannual variation was based upon 237 oral temperature measurements. Mean body temperatures in the summer were  $\chi = 97.53$  (SD 0.44) and in the winter were slightly lower at  $\chi = 97.3$  (SD 0.60) which resulted in a 0.2 °F/0.1 °C variation.

Table 1 Summary and review of included studies

No.	Authors	Case Number/setting	Age	Season/time of day	Site (Device)	Mean (°F/°C)	Range/mean $\pm$ 2 SD (°F/°C)	Notes
1	Collins <i>et al.</i> (1981)	17 Elderly 13 Young Research centre	70–80 18–39	Not specified	Oral (E)	98.1/36.7 97.9/36.6	96.4–99.7/35.8–37.6* 96.8–99.0/36.0–37.2*	No exclusion criterion was specified
2	Chamberlain <i>et al.</i> (1995)	497 Hospital	66–75 76–85 > 85	Not specified	Ear (IET)	97.6/36.5 97.5/36.4 97.5/36.4	96.1–99.2/35.6–37.3 95.8–99.3/35.5–37.4 95.9–99.2/35.5–37.3	Exclusion criteria were reported. Infrared ear thermometer (Thermoscan® Pro-1) was used. Mode was reported in the actual mode and were collected from the right ear
3	Darowski <i>et al.</i> (1991)	50 Hospital	$\geq 70$	10 a.m. 6 p.m.	Rectal (M) Oral (E) Axillary (M) Ear (ACT) £	98.9/37.2 97.9/36.6 97.3/36.3 98.2/36.8	98.2–99.7/36.8–37.6 96.7–99.0/36.1–37.2 95.9–98.6/35.5–37.0 97.7–98.8/36.5–37.1	Rectal thermometers were inserted a depth of 5 cm from the anus. Auditory canal thermometer was used
4	Fox <i>et al.</i> (1973a)	72 Community	65–91	Winter	Oral (M) Urine	97.0/36.1 97.5/36.4	94.8–99.1/34.9–37.3* 94.3–100.7/34.6–38.2*	Exclusion criteria not specified. Reliability of data collection instruments not reported
5	Fox <i>et al.</i> (1973b)	1020 Community	$\geq 65$	Winter	Oral (M) Urine	96.8/36.0 97.3/36.3	94.3–99.4/34.6–37.4* 95.5–99.1/35.3–37.3*	Exclusion criteria were specified. The investigators did not report how reliability was established
6	Giantin <i>et al.</i> (2008)	107 Hospital	65–104	8–10 a.m. 4–6 p.m. June–August	Oral (M) Urine Axillary (G) Axillary (E) Axillary £ Ear (IET)	97.6/36.5 98.0/36.6 98.4/36.9 98.4/36.9 97.7/36.5 98.8/37.1	95.8–99.5/35.4–37.5* 95.8–100.1/35.5–37.8* 96.2–100.6/35.7–38.1* 96.2–100.6/35.7–38.1* 95.5–99.8/35.3–37.7* 96.2–101.3/35.7–38.5*	Room temperature was constantly maintained at 23 °C. Infrared ear thermometer (First Temp® Genius® Model 3000A) was used and the mode was not reported. Reliability of the temperature measurement devices was reported
7	Gomolin <i>et al.</i> (2005)	100 Nursing Home	65–98	6 a.m. 4 p.m.	Oral (E)	97.3/36.3 97.4/36.3	94.0–98.8/34.4–37.1 95.5–99.6/35.2–37.6	Calibration of thermometers was not reported
8	Gomolin <i>et al.</i> (2007)	50 Community 167 Nursing home 21 Teenagers	65–102	10 p.m. Midday 6–8 a.m. 4–5 p.m. 6–8 a.m.	Oral (E)	97.8/36.6 97.7/36.5 97.3/36.3 97.4/36.3	96.1–99.6/35.6–37.6 95.7–99.1/35.4–37.3 94.0–99.0/34.4–37.2 95.1–99.6/35.1–37.6 95.5–98.7/35.3–37.1	There was no description of verification of thermometer accuracy
9	Gunes and Zaybak (2008)	133 Nursing home	14–17.8 65–90	4–5 p.m. 8 a.m. 2 p.m. 6 p.m.	Axillary (M)	97.8/36.6 96.2/35.6 96.3/35.7 96.8/36.0	96.0–99.2/35.6–37.3 95.0–97.7/35.0–36.5 94.1–97.7/34.5–36.5 95.5–97.7/35.3–36.5	The method of establishing accuracy of thermometers was reported
10	Higgins (1983)	60 Community	65–90	9–12 a.m.	Oral (M)	97.9/36.6	–	Exclusion criteria were specified. The thermometer used for data collection was calibrated

Table 1 (Continued)

No.	Authors	Case Number/setting	Age	Season/time of day	Site (Device)	Mean (°F/°C)	Range/mean $\pm$ 2 SD (°F/°C)	Notes
11	Howell (1972)	105 Hospital	60–100	11 a.m.	Axillary (E)	96.4/35.8	93.2–99.3/34.0–37.4	Exclusion criteria were not specified. The electric thermometer was calibrated
12	Howell (1975)	105 Hospital	61–100	11 a.m.	Oral (E)	–	85.9–99.0/30.0–37.2	Inclusion and exclusion criteria were not specified
13	Keilson et al. (1985)	97 Elderly 20 Adult Community	65–90 22–43	November–April	Oral (E) Urine Oral (E) Urine	97.2/36.2 97.5/36.4 97.5/36.4 97.7/36.5	95.7–98.7/35.4–37.0* 96.3–98.8/35.7–37.1* 96.0–99.1/35.6–37.2* 96.4–99.1/35.8–37.3*	The only exclusion criteria specified was no known acute illness
14	Marion et al. (1991)	93 Hospital & Community	62–96	November	Oral (M) Oral (E) Urine	98.3/36.8 98.5/36.9 98.6/37.0	97.5–99.1/36.4–37.3* 97.5–99.4/36.4–37.5* 97.7–99.4/36.5–37.5*	Exclusion criteria were clearly identified. Thermometers were calibrated in a water bath before and after each measurement
15	McGann et al. (1993)	92 Community	64–96	November	Oral (M)	98.4/36.9	97.5–99.2/36.4–37.3*	Exclusion criteria clearly specified. Mercury in glass thermometers were calibrated
16	Nakamura et al. (1997)	57 Nursing home	75.7 (SD 6.3)	Morning Summer Winter Afternoon Summer Winter	Oral (E)	97.5/36.4 98.4/36.1	96.2–98.7/35.7–37.1* 94.8–99.2/34.9–37.3*	Inclusion criteria were specified. The procedure for establishing and monitoring the accuracy of thermometers was not specified
17	Prentice and Moreland (1999)	18 Hospital	Not specified	Not specified	Oral (M) Oral (E) Ear (IET)	99.7/36.5 97.8/36.5 97.5/36.4	– – –	Exclusion criteria were not specified. Infrared ear thermometer (Thermoscan® Pro-1) was used and the mode was not reported.
18	Primrose and Smith (1982)	220 Community	65–94	November–December 9 a.m. & 1 p.m.	Oral (E)	97.0/36.0	95.9–99.1/35.5–37.3	Intra-rater and inter-rater differences were clearly described. Exclusion criteria were not specified. The procedure for establishing intra- and inter-rater reliability among data collectors described
19	Salvosa et al. (1971)	40 Community	69–93	Winter Morning Afternoon Summer Morning Afternoon	Oral (M)	96.4/35.8 97.0/36.1 96.7/35.9 97.3/36.3	94.0–98.7/34.5–37.1* 94.8–99.2/35.0–37.4* 95.1–98.3/35.1–36.9* 95.3–99.4/35.2–37.4*	Ambient room temperatures were reported for each group of subjects. Measures of body mass index and skin fold thickness body fat were reported

Table 1 (Continued)

No.	Authors	Case Number/setting	Age	Season/time of day	Site (Device)	Mean (°F/°C)	Range/mean $\pm$ 2 SD (°F/°C)	Notes
20	Sund-Levander and Wahren (2002)	237 Nursing home	71–98	7–9 a.m. 6–8 p.m. 7–9 a.m. 6–8 p.m.	Rectal (E) Ear (IET)	98.2/36.8 99.1/37.3 98.4/36.9 99.1/37.3	96.8–99.7/36.0–37.6* 97.7–100.6/36.5–38.1* 96.2–100.6/35.7–38.1* 97.3–100.9/36.3–38.3*	Exclusion criteria were specified. Accuracy of the temperature measurement devices was established and reported. Infrared ear thermometer (First Temp® Genius® Model 3000A) and the unadjusted mode were used. The author did not report depth of insertion of rectal thermometers
21	Thatcher (1983)	100 Community	60–94	Summer Winter	Oral (E)	98.3/36.9 97.4/36.4	97.4–99.2/36.3–37.4 96.3–98.7/35.7–37.1	Exclusion criteria were reported. The accuracy of the thermometer was verified
22	Vaux <i>et al.</i> (2000)	260 Hospital	$\geq 75$	Winter	Rectal (M) Ear (IET)	98.8/37.1 98.8/37.1	97.7–99.7/36.5–37.6 97.5–100.2/36.4–37.9	Infrared ear thermometer (First Temp® Genius® Model 3000A) was used and mode was not reported. Rectal thermometers were inserted 3 cm from the anal margin and read after three minutes.

Note: 1. \* $\pm$  indicates that range was calculated with/mean  $\pm$  2 SD; \* $\pm$  indicates that primary data do not include Mean or/mean  $\pm$  2 SD; £, Temperature site/device excluded from analysis. 2. Device of thermometer used: M, Mercury-in-glass; E, Electronic thermometer; U, Urine temperature device; G, Galinstan-in-glass; IET, Infrared ear thermometer; ACT, auditory canal thermometer.

## Discussion

### Normal body temperature values in older people

This systematic review demonstrated a mean rectal temperature of 98.8 °F/37.1 °C, range 98.6 to 99.0 °F/37.0 to 37.2 °C; ear-based temperature of 98.3 °F/36.8 °C, range 97.5 to 99.1 °F/36.4 to 37.3 °C, urine temperature of 97.6 °F/36.5 °C, range 97.3 to 97.9 °F/36.3 to 36.7 °C; oral temperature of 97.4 °F/36.3 °C, range 97.0 to 97.8 °F/36.1 to 36.6 °C; and axillary temperature of 97.1 °F/36.2 °C, range 96.2 to 97.9 °F/35.7 to 36.6 °C. The commonly reported temperatures in adults (Potter & Perry 2009) were compared to the values obtained in this review (Table 3). Body temperatures from all sites demonstrated lower values in older people group than in the adult group, suggesting the findings of this study confirm the theory of 'the older are colder.'

### Temperature variation by measurement site

The literature adds evidence to the generally held belief that rectal temperatures are usually 1.0 °F/0.5 °C higher than oral and ear-based temperature and axillary temperatures are usually 1.0 °F/0.5 °C lower than oral temperatures (Potter & Perry 2009). In this study rectal temperatures, the noninvasive gold standard, were 0.5 °F/0.3 °C higher than ear-based; 1.2 °F/0.6 °C higher than urine; 1.4 °F/0.8 °C higher than oral; and 1.7 °F/0.9 °C higher than axillary temperatures.

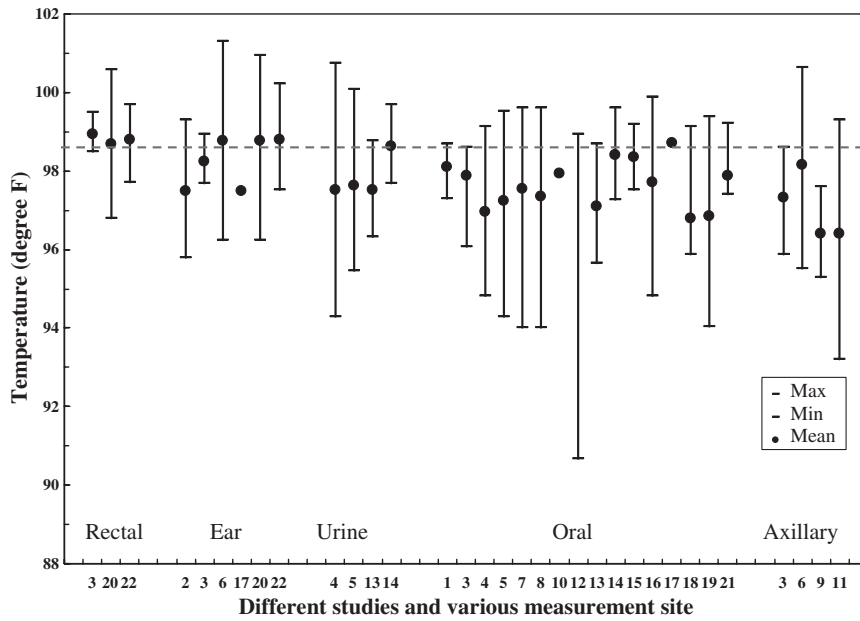
The results of temperature variations across sites must be interpreted with caution. Due to the small numbers of comparisons across several sites these findings represent a preliminary estimate. Many of the oral temperatures were collected with mercury thermometers which are no longer widely used. Also, no studies made comprehensive comparisons of body temperature across each of the measurements sites. Studies using thermometry found in today's health care setting and comparing body temperature across measurement sites are needed to validate these findings.

### Diurnal and circannual temperature variation

Body temperature exhibited a 0.7 °F/0.4 °C diurnal variation which is less than half of the 1.8° F/1.0 °C diurnal variation reported in adults (Kelly 2006). This finding is congruent with the report of other investigators who have found that circadian rhythms of older people are different from those of young adults (Campbell & Murphy 1998, Gubin *et al.* 2006).

A circannual oral temperature variation of 0.2 °F/0.1 °C lower in the winter season than summer was demonstrated





**Figure 1** The specific mean and range of body temperatures in the elderly arranged by measurement sites represented from 22 studies. Note: ‘1,2,3...’ corresponds to study numbers listed in Table 1.

**Table 2** Comparison of overall statistics of body temperature in the elderly collected from different measurement sites and times 22 studies

	Mean	Range	Difference
<b>Sites</b>			
Rectal	98.8 °F/37.1 °C	98.6–99.0 °F/37.0–37.2° C	
Ear-based	98.3 °F/36.8 °C	97.5–99.1 °F/36.4–37.3 °C	0.5 °F/0.3 °C lower than the rectal site
Urine	97.6 °F/36.5 °C	97.3–97.9 °F/36.3–36.7 °C	1.2 °F/0.6 °C lower than the rectal site
Oral	97.4 °F/36.3 °C	97.0–97.8 °F/36.1–36.6 °C	1.4 °F/0.7 °C lower than the rectal site
Axillary	97.1 °F/36.2 °C	96.2–97.9 °F/35.7–36.6 °C	1.7 °F/0.9 °C lower than the rectal site
<b>Diurnal variations</b>			
Morning	96.9 °F/36.0 °C		0.7 °F/0.4 °C
Afternoon	97.6 °F/36.4 °C		
<b>Circannual variations</b>			
Summer	97.5 °F/36.4 °C		0.2 °F/0.1 °C
Winter	97.3 °F/36.3 °C		

**Table 3** Comparison of mean temperature value of adult group and older group by measurement sites

Sites	Mean body temperature in adult*	Mean body temperature in the elderly†	Difference
Rectal	99.5 °F/37.5 °C	98.8 °F/37.1 °C	0.7 °F/0.4 °C lower than adult
Ear-based	98.6 °F/37.0 °C	98.3 °F/36.8 °C	0.3 °F/0.2 °C lower than adult
Oral	98.6 °F/37.0 °C	97.4 °F/36.3 °C	1.2 °F/0.7 °C lower than adult
Axillary	97.7 °F/36.5 °C	97.1 °F/36.2 °C	0.6 °F/0.3 °C lower than adult

\*Source from: Potter and Perry (2009). Vital signs. In Potter PA & Perry AG (eds.), *Fundamentals of nursing* (7th edn, pp. 503). St. Louis: Mosby Elsevier.

†Source from: the findings of this study.

across comparisons. However, the small circannual temperature variation may have been influenced by the ambient temperatures of the rooms where temperatures were collected

as well as the small number of comparisons. So although the studies included in this review do show a decrease in body temperature during the winter as compared to summer

months, the magnitude of difference cannot be estimated at this time due to the small number of studies and several potentially confounding variables. To increase confidence in synthesising results across studies, it would be helpful if as well as reporting season of the year; future studies consistently report ambient temperatures. This would allow comparison of results of studies which originate from different parts of the globe and which have different seasonal climates.

## Conclusion

### Body temperature in older people

Present evidence indicates a lower temperature mean in persons 60 years of age and older than the widely accepted normal value of 98.6 °F/37 °C. Tal *et al.* (2002) stated that normal physiologic changes associated with the ageing process may result in a lower body temperature which coupled with less temperature variability may result in a 'blunted fever response'. It has been suggested that a temperature above 100 °F/37.8 °C and two or more readings above 99 °F/37.2 °C or an increase of 2 °F/1.1 °C represents an index of suspicion for infection (Castle *et al.* 1991, Bentley *et al.* 2000).

Temperature findings may in fact be high or low secondary to cognitive impairment which may result in loss of the behavioural response to body signals (Culp & Cacchione 2008). Preliminary evidence indicates a modest increase in core body temperature in patients with Alzheimer's disease (Klegeris *et al.* 2007). Alternately, differences in readings may be due to age related physiologic changes such as alterations in cutaneous blood flow (Grassi *et al.* 2003, Thompson-Torgerson *et al.* 2008).

### Differences in temperature ranges in older people according to measurement site

The temperature difference across sites was greater than the 1 °F/0.5 °C degree difference traditionally discussed in the literature (Potter & Perry 2009). The evidence at this time does not support a conversion factor for comparison of temperature values across sites. Rather the evidence supports the importance of following and treating temperature abnormalities based upon the readings from one consistent site and using one consistent form of thermometry (Sund-Levander *et al.* 2004).

### Temperature variability in older people

Temperature did reflect a diurnal variation with temperature peaking in the evening. Due to concerns regarding hypother-

mia in older people, perhaps it is time to question the traditional nursing practice of giving baths in the morning when body temperatures are at their nadir rather than considering evening baths when temperatures are at their zenith. Circannual variation was very modest. However this finding may have been influenced by ambient conditions during data collection.

### Relevance to clinical practice

The findings of this systematic review show that the normal body temperature values of older people from all sites were consistently lower than values reported in the literature, clinicians may need to re-evaluate the point at which interventions for abnormal temperatures are initiated.

### Limitations

Many of the studies included in this review were published 10 years ago or longer; had relatively small samples (<100); did not measure temperatures at a consistent time of day; only measured temperatures one time; and, only used one method of temperature measurement. Mercury-in-glass thermometers, which are no longer available in many countries, were most frequently used to measure body temperature. Also, few studies reported the method by which reliability of the measuring thermometer was monitored throughout the study. Although intra-rater and inter-rater reliability of the data collectors may have been established and monitored, it was not routinely reported in the studies reviewed. Participants who were taking medications such as medication that causes vasodilatation which may promote heat loss or thyroid replacement which may increase heat production were not routinely excluded from participation.

### Recommendations for future research

Studies which employ a longitudinal study design are needed to examine diurnal and circannual variation in older people. A cross sectional study design could be used to determine accurate sites for temperature measurement, in addition to the reliable methods of thermometry in those ages 60 and older. Internal validity of future studies could be enhanced through controlling for the consistency of measurement procedures and also through evaluation and reporting of the accuracy and sensitivity of the thermometer used in the study.

To control for potentially confounding variables such as nutrition, activity and cognitive impairment (Ferro-Luzzi 2005, Culp & Cacchione 2008) a metabolic cart could be

used to determine basal metabolic rate. A metabolic cart measures heat production and hence energy expenditure. Thus, the impact of basal metabolic rate on temperature in older people could be examined. There is evidence that basal metabolic rate may in fact increase in some individuals as they age (Henry 2000). Use of a metabolic cart would also address the role of nutritional status as a potentially confounding variable in the young-old as compared to the old-old. It may well be that basal metabolic rate is a more sensitive measure of temperature variation than is age.

Because temperature has nonlinear variability, techniques similar to those being used to measure heart rate variability could be employed to examine temperature variability in older people (Kelly 2006). Differences in variability, as well as baseline ranges may differ between the old and oldest-old age groups.

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## Contributions

Study design: SHL, ARL, YTD, data collection and analysis: SHL, ARL, YTD and manuscript preparation: SHL, ARL, YTD.

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