Normal Body Temperature: A Systematic Review

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PubMed was searched from 1935 to December 2017 with a variety of search phrases among article titles. The references of the identified manuscripts were then manually searched. The inclusion criteria were as follows: (1) the paper presented data on measured normal body temperature of healthy human subjects ages 18 and older, (2) a prospective design was used, and (3) the paper was written in or translated into the English language. Thirty-six articles met the inclusion criteria. This comprised 9227 measurement sites from 7636 subjects. The calculated ranges (mean ± 2 standard deviations) were 36.32–37.76 (rectal), 35.76–37.52 (tympanic), 35.61–37.61 (urine), 35.73–37.41 (oral), and 35.01–36.93 (axillary). Older adults (age ≥60) had lower temperature than younger adults (age <60) by 0.23°C, on average. There was only insignificant gender difference. Compared with the currently established reference point for normothermia of 36.8°C, our means are slightly lower but the difference likely has no physiological importance. We conclude that the most important patient factors remain site of measurement and patient’s age.

Keywords. body temperature; fever; hypothermia; normothermia.

Human body temperature is well established as one of the key vital signs. It is measured at regular intervals in the medical setting and often at home to try estimate the degree of “sickness” of an individual [1]. It had been used since antiquity [2–5], yet its interpretation had been, and still is, actively debated in the clinical setting [1, 6, 7]. The first step towards understanding the relationship between temperature and disease is to define “normal” body temperature, from where deviations can be measured. Indeed, many attempts had been made to this end, including the 1868 seminal paper by Wunderlich [8], who is believed to be the first to establish a link between fever and clinical diagnosis. He was also the first to apply a thermometer experimentally to measure human body temperature. Using a large sample size, Wunderlich [8] concluded that the average axillary temperature was 37.0°C, with the upper limit of normal defined as 38.0°C. However, newer studies challenged Wunderlich’s [8] “normothermia” [6]. Furthermore, research had shown that body temperature is a nonlinear function of several variables such as age, state of health, gender, environmental temperature, time of the diurnal cycle, among many others [9, 10]. To make the best use of the currently available literature, we reviewed and herein present an analysis of previously published human body temperature studies using healthy individuals, with the goal of better understanding the variables that determine normal body temperature.

METHODS

The peer-reviewed literature was searched using PubMed (Table 1). The time period ranged from 1935 to December 2017. The following search phrases among article titles were used: “normal body temperature”, “body temperature AND review”, “body temperature AND adult”, “body temperature AND gender”, “human body temperature”, “core body temperature”, “hypothermia AND elderly”, “body temperature AND measurement”, “tympanic body temperature AND measurement”, “rectal body temperature AND measurement”, and “oral body temperature AND measurement”. Furthermore, the references of the above-identified papers were manually searched for additional useful articles. To be included in our analysis, papers had to meet the following inclusion criteria: (1) the paper presented data on measured normal body temperature of healthy human subjects ages 18 and older, (2) a prospective design was used, and (3) the paper was written in or translated into the English language. Using the data from the articles that met our inclusion criteria, we calculated mean temperatures and ranges before and after stratifying the data by gender, age (less than 60 years old vs 60 years old or older), and site of measurement (oral, axillary, temporal, rectal, urine) or by both variables.

Pooled standard deviations were calculated using the pooled standard deviation formula:
The average temperatures per measurement site, in decreasing order, were rectal at 37.04 ± 0.36, tympanic at 36.64 ± 0.44, urine at 36.61 ± 0.5, oral at 36.57 ± 0.42, and axillary at 35.97 ± 0.48 (Figure 1B, Table 3). Overall, when using the data from all of the measurement sites, the average body temperature of younger adults (<60 years of age) was higher (36.69 ± 0.34) than the average body temperature of older adults (≥60 years of age), which was 36.5 ± 0.48. The same age-related trend held true for all individual measurement sites (Figure 1C, Table 3). When looking at gender differences, we found that when using all reported measurements, the average body temperature of females was slightly lower (36.65 ± 0.46) compared with males (36.69 ± 0.43), but this trend was not pronounced when looking at the individual measurement sites, except for the urine measurement site (Figure 1D, Table 3).

### DISCUSSION

The quest for understanding human body temperature and defining normothermia is ongoing, as is evidenced by the steady number of published prospective studies depicted in Figure 1A. To the best of our knowledge, our systematic review, where we analyzed 36 separate prospective studies, is the largest of its kind. When using the data from all measurement sites and all included studies, we calculated the overall mean body temperature to be 36.59°C, which is lower than the currently acceptable mean of 36.8, as published in one of the most respected medical reference books, Harrison's Principles of Internal Medicine [46]. However, the latter number from the reference book is not based on an all-inclusive meta-analysis, and therefore our average is likely more accurate. Of course, it should be kept in mind that there is no single number that defines normothermia; instead, there is a range for normal temperature, with corresponding standard deviation and standard error. As such, the 0.2°C difference in the mean when we compare our mean temperature with the Harrison's is likely not of much physiological relevance. In that respect, our calculated overall range (mean ± 2 standard deviations) is 36.16–37.02°C, which is narrower than the range of 33.2–38.3°C reported by Sund-Levander et al [42], which is an older systematic review comprising of only 20 studies, all of which were also part of our analysis. The tighter range is most likely due to bigger sample size used in our report, which validates our results further.

Knowing that body temperature is influenced by the measurement site, we calculated average temperatures, in decreasing order, rectal at 37.04°C, tympanic at 36.64°C, urine at 36.61°C, oral at 36.57°C, and axillary at 35.97°C. The trend is similar to the one reported by Sund-Levander et al [42]; however, the latter systematic review did not contain measurements of urine temperature. In addition, all of our site-specific calculated temperatures, except for axillary, were higher compared with the Sund-Levander et al [42] report. Furthermore, it is intriguing
| Author          | Year | Demographics                                                                 | N     | Measurement Site | Mean ± 2 SD       |
|-----------------|------|-----------------------------------------------------------------------------|-------|------------------|-------------------|
| Baker [11]      | 1984 | 24 female students                                                          | 24    | Oral             | 36.8 ± 36.058–37.542 |
| Barley [12]     | 1970 | Undescribed demographics                                                    | 38    | Oral             | 36.36 ± 35.28–37.37 |
| Basak [13]      | 2013 | Healthy Asian student volunteers, mixed gender with an average age of 19.66  | 452   | Oral             | 36.71 ± 35.91–37.51 |
| Castle [15]     | 1993 | NH residents (unknown gender) age 42–102                                    | 85    | Oral             | 36.33 ± 35.67–36.99 |
| Basak [13]      | 2013 | Healthy Asian student volunteers, mixed gender with an average age of 19.66  | 452   | Oral             | 36.71 ± 35.91–37.51 |
| Chamberlain [16]| 1995 | Age 66–75                                                                  | 180   | Tympanic         | 36.4 ± 35.6–36.46  |
| Chamberlain [16]| 1995 | Age 76–85                                                                  | 149   | Tympanic         | 36.43 ± 35.47–37.39 |
| Chamberlain [16]| 1995 | Age >85                                                                    | 168   | Tympanic         | 36.4 ± 35.48–37.32 |
| Chamberlain [16]| 1995 | All                                                                       | 1532  | Tympanic         | 36.51 ± 35.618–37.405 |
| Collins [17]    | 1977 | Age 69–90, measured during winter                                           | 47    | Oral             | 36.28 ± 35.307–37.263 |
| Collins [17]    | 1977 | Age 70–80                                                                  | 17    | Oral             | 36.6 ± 36–37.27  |
| Doyle [19]      | 1992 | Healthy healthcare worker volunteers, mixed gender                          | 41    | Rectal           | 37.7 ± 36.9–38.5  |
| Doyle [19]      | 1992 | Healthy healthcare worker volunteers, mixed gender                          | 41    | Rectal           | 37.7 ± 36.9–38.5  |
| Edwards [20]    | 1978 | Healthy volunteers, mixed gender age 20–35                                  | 12    | Tympanic         | 36.77 ± 36.21–37.33 |
| Edwards [20]    | 1978 | Healthy volunteers, mixed gender age 20–35                                  | 12    | Tympanic         | 36.77 ± 36.21–37.33 |
| Erickson [21]   | 1980 | Hospital faculty between ages 18–42                                        | 50    | Oral             | 36.69 ± 35.515–36.857 |
| Erickson [22]   | 1985 | Males age 57–75                                                            | 760   | Oral             | 36.7 ± 35.89–37.57 |
| Fox [23]        | 1971 | Males age 12–28                                                            | 12    | Rectal           | 37.24 ± 36.98–37.496 |
| Fox [23]        | 1971 | Males age 12–28                                                            | 12    | Rectal           | 37.24 ± 36.98–37.496 |
| Fox [24]        | 1973 | Mixed genders, age >65                                                      | 1020  | Oral             | 36.24 ± 34.999–37.491 |
| Fox [25]        | 1973 | Mixed gender, age ≥65                                                      | 72    | Oral             | 36.1 ± 34.9–37.3 |
| Fox [25]        | 1973 | Mixed gender, age ≥65                                                      | 72    | Oral             | 36.1 ± 34.9–37.3 |
| Gommolin [26]   | 2005 | NH residents, mixed gender with an average age of 80.7                      | 150   | Oral             | 36.40 ± 35.527–37.283 |
| Gommolin [27]   | 2007 | NH residents, mixed gender with an average age of 82.5                      | 167   | Oral             | 36.30 ± 35.332–37.228 |
| Gunes [28]      | 2008 | NH residents, age 65–90                                                    | 133   | Axillary         | 35.77 ± 34.5–36.5 |
| Hasan [29]      | 2010 | Mixed gender, average age 34                                               | 184   | Axillary         | 36.39 ± 35.61–37.5 |
| Higgins [30]    | 1983 | Healthy volunteers, mixed gender age 65–90                                  | 60    | Oral             | 36.61 ± 35.7 |
| Higgins [30]    | 1983 | Healthy volunteers, mixed gender age 65–90                                  | 60    | Oral             | 36.61 ± 35.7 |
| Horwath [31]    | 1950 | Healthy male volunteers, age 16–37                                         | 16    | Rectal           | 37.056 ± 36.428–37.684 |
| Horwath [31]    | 1950 | Healthy male volunteers, age 16–37                                         | 16    | Rectal           | 37.056 ± 36.428–37.684 |
| Ivy [32]        | 1945 | Healthy medical students                                                   | 276   | Oral             | 36.7 ± 35.8–37.4 |
| Kelison [33]    | 1985 | 11 males, 9 females age 22–43                                              | 20    | Urine            | 36.4 ± 35.72–37.08 |
| Kelison [33]    | 1985 | 30 males, 65 females age 65–90                                             | 95    | Urine            | 36.53 ± 35.81–37.25 |
|                 |      |                                                                             |       | Oral             | 36.41 ± 35.57–37.25 |
that we found such a large difference between what is considered the body core temperatures: rectal (37.04°C) and urine (urine at 36.61°C). This likely reflects a fault in the measurement in earlier studies from the 1970s and 1980s, which constitute a significant portion of the analyzed data and in which the measurements of urine temperature were not done invasively, e.g., via a monotherm system. Therefore, these urine temperatures are fundamentally different from what we should consider core body temperature, which is temperature measured inside the human body.

With regards to age, our analysis confirmed that, on average, healthy elderly people have lower body temperature (Table 3 and Figure 1B) compared with younger adults. This was true for both the total average as well as for the individual measurements sites, except for urine temperatures because there were no studies reporting such measurements among younger adults. The decrease in body temperature with age is believed to be a phenomenon arising from a slowing of the human metabolic rate coupled with a decline in the ability to regulate body temperature in response to environmental changes such as seasonal

| Author       | Study Year | Demographics                             | N    | Measurement Site | Mean   | Mean ± 2 SD |
|--------------|------------|------------------------------------------|------|------------------|--------|-------------|
| Kolanowski   | 1981       | Mixed gender, age 65–97 reported in the winter | 101  | Rectal           | 36.66  | 34.4–37.6  |
|              |            |                                          |      | Oral             | 36.02  | 33.4–37.3  |
| Linder       | 1935       | Male volunteers, medical staff, and researchers | 24   | Oral             | 36.64  | 36.564–36.708 |
|              |            |                                          |      | Rectal           | 37.14  | 37.044–37.244 |
| Lu           | 2009       | Taiwanese volunteers, temperatures measured in winter and summer | 519  | Oral             | 36.79  | 36.392–37.196 |
|              |            |                                          |      | Rectal           | 36.79  | 36.392–37.196 |
|              |            |                                          |      | Oral             | 36.80  | 36.393–37.197 |
|              |            |                                          |      | Rectal           | 36.76  | 36.358–37.162 |
|              |            |                                          |      | Rectal           | 36.84  | 36.453–37.217 |
| Mackowiack   | 1992       | Healthy volunteers, age 18–40             | 120  | Oral             | 36.8   | 35.6–38.2  |
|              |            |                                          |      | Female           | 36.9   | 35.78–38.02 |
|              |            |                                          |      | Male             | 36.7   | 35.62–37.78 |
|              |            |                                          |      | African American | 36.8   | 35.78–37.82 |
|              |            |                                          |      | White            | 36.7   | 35.48–37.92 |
| Marion       | 1991       | Healthy volunteers, mixed gender age 64–96 | 93   | Urine            | 37     | 36.5–37.5  |
|              |            |                                          |      | Oral             | 36.89  | 36.387–37.391 |
| Marui        | 2017       | Mixed gender, Japanese volunteers with an average age of 20.7 | 141  | Axillary         | 36.45  | 35.544–37.356 |
| McGann       | 1993       | Healthy African American females          | 35   | Oral             | 36.94  | 36.42–37.46 |
|              |            |                                          |      | Healthy white females | 36.81  | 36.39–37.23 |
|              |            |                                          |      | Healthy white males | 36.79  | 36.37–37.21 |
| Nakamura     | 1997       | Healthy Japanese nursing home residents, age ≥63 | 57   | Oral             | 36.49  | 35.952–37.428 |
| Salvia       | 1971       | Women, age 69–93                          | 40   | Oral             | 36.02  | 34.81–37.23 |
| Sund-Levander| 2002       | Healthy volunteers, mixed gender age ≥65   | 237  | Rectal           | 37.05  | 35.6–38.4  |
|              |            |                                          |      | Female only      | 37.1   | 33.8–38.4  |
|              |            |                                          |      | Male only        | 37.1   | 33.8–37.9  |
| Terndrup     | 1989       | Healthy volunteers, mixed gender with an average age of 33.4 | 22   | Rectal           | 36.4   | 36.9–37.3  |
| Thatcher     | 1983       | Mixed gender, age 60–94 measured in summer and winter | 100  | Rectal           | 36.6   | 35.7–37.4  |
|              |            |                                          |      | Summer subset    | 36.8   | 36.3–37.4  |
|              |            |                                          |      | Winter subset    | 36.4   | 35.7–37.3  |
| Thomas       | 2004       | Healthy females, age 21–36                | 19   | Rectal           | 37.19  | 36.38–38.8 |
|              |            |                                          |      | Axillary         | 36.01  | 34.622–37.398 |
|              |            |                                          |      | Axillary         | 34.39  | 33.11–35.67 |

Abbreviations: N, number of participants; NH, New Hampshire; SD, standard deviation.
changes, which had been previously studied [17, 19, 22, 47, 48]. These age-related changes are of particular clinical importance because elderly patients are often not capable of mounting a strong inflammatory response to infection and disease, with their temperature failing to reach the temperature range of what is traditionally considered the fever temperature range. Moreover, there is evidence to suggest that the presence of a robust fever response carries prognostic value when considering such infectious disease processes [49]. In the elderly, who may not be able to mount such a thermal response, we may similarly have to readjust our outlook on temperature-based prognostication. However, until we have research data to specifically address this question, clinicians should use lower normal temperature ranges as reference in the elderly, such as the ones presented in our systematic review.

Finally, our analysis demonstrated only a trivial difference in body temperature between the genders (Table 2 and Figure 1C), with women's temperature being slightly lower when using all measurements from all measurement sites. However, when grouping the results by measurement site, in some cases (tympanic site) females' body temperature is in fact higher compared with their male counterparts, whereas in other cases there is no difference (oral and rectal sites). There had been a disagreement in the literature as well, with some studies reporting that females have higher body temperature [6, 8, 16, 31], whereas others reported no differences among the genders [39]. Gender differences in body temperature had been suspected to relate to a difference in body fat percentage between women and men. Those studies revealed that women have a comparably larger percentage of body fat distribution subcutaneously, which in turn correlates with lower average skin temperatures [50, 51]. It had also been theorized that body temperature differences relate to female hormone levels, and yet, even in the studies that report statistically significant
differences, the actual difference is fairly small and thus not likely to be of any clinical significance. Our large sample size from 36 individual studies is expected to reflect the true temperature variable in the human population and supports the lack of clinical significance of gender-based body temperature difference even if it could be measured.

CONCLUSIONS

Human body temperature is a highly variable vital sign and known to be influenced by several variables, most prominently the person’s age and the site of measurement. Our systematic review is the largest of its kind and provides clinicians with evidence-based normal temperature ranges to guide their evaluation of patients with possible fever or hypothermia.

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Potential conflicts of interest. All authors: No reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

Table 3. Summary of Normal Body Temperature Ranges Stratified by the Modifying Factors Measurement Site, Age, and Gender

| N                  | Number of Studies | Number of Individual Measurement Sites | Mean Temperature (°C) | Standard Deviation |
|--------------------|-------------------|----------------------------------------|------------------------|--------------------|
| All measurement sites, all subjects | 36                | 9227                                   | 36.59                  | 0.43               |
| Stratification by Measurement Site |                   |                                        |                        |                    |
| Axillary           | 5                 | 551                                    | 35.97                  | 0.48               |
| Oral               | 33                | 5257                                   | 36.57                  | 0.42               |
| Rectal             | 13                | 618                                    | 37.04                  | 0.36               |
| Tympanic           | 9                 | 2462                                   | 36.64                  | 0.44               |
| Urine              | 6                 | 339                                    | 36.61                  | 0.5                |
| Stratification by Age |                 |                                        |                        |                    |
| All measurement sites, all subjects <60 years | 17                | 3114                                   | 36.69                  | 0.34               |
| All measurement sites, all subjects ≥60 years | 19               | 4249                                   | 36.5                   | 0.48               |
| Stratification by Age and Measurement Site |                     |                                        |                        |                    |
| Axillary, subjects <60 years | 4               | 418                                    | 36.04                  | 0.47               |
| Oral, subjects <60 years | 15              | 1795                                   | 36.7                   | 0.3                |
| Rectal, subjects <60 years | 8               | 217                                    | 37.1                   | 0.26               |
| Tympanic, subjects <60 years | 5               | 652                                    | 36.82                  | 0.36               |
| Axillary, subjects ≥60 years | 1              | 133                                    | 35.77                  |                    |
| Oral, subjects ≥60 years | 18              | 2715                                   | 36.42                  | 0.48               |
| Rectal, subjects ≥60 years | 3               | 360                                    | 36.94                  | 0.4                |
| Tympanic, subjects ≥60 years | 4               | 734                                    | 36.65                  | 0.49               |
| Urine, subjects ≥60 years | 4               | 307                                    | 36.6                   | 0.52               |
| Stratification by Gender |                   |                                        |                        |                    |
| All measurement sites, all female subjects | 12              | 1992                                   | 36.65                  | 0.48               |
| All measurement sites, all male subjects | 12             | 2102                                   | 36.69                  | 0.43               |
| Stratification by Gender and Measurement Site |                     |                                        |                        |                    |
| Axillary, female subjects | 2               | 93                                     | 34.72                  | 0.65               |
| Oral, female subjects | 9                | 537                                    | 36.7                   | 0.34               |
| Rectal, female subjects | 4                | 290                                    | 37.08                  | 0.36               |
| Tympanic, female subjects | 2               | 1020                                   | 36.68                  | 0.47               |
| Urine, female subjects | 1                | 52                                     | 36.4                   | 1                  |
| Oral, male subjects | 11               | 1298                                   | 36.71                  | 0.39               |
| Rectal, male subjects | 4                | 130                                    | 37.08                  | 0.3                |
| Tympanic, male subjects | 2               | 642                                    | 36.56                  | 0.51               |
| Urine, male subjects | 2                | 32                                     | 36.59                  | 0.57               |

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