Investigating the correlation between body temperature and body mass index: a meta-analysis

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Type of article: Meta-analysis

Abstract

Background: The relationship between body temperature and body mass index is controversial.

Objective: The purpose of this study was to determine the relationship between these two variables in various studies.

Methods: A systematic review was conducted in Google Scholar, PubMed, Scopus, ProQuest, Web of Science, and Elsevier databases. Studies were searched and collected from May 9, 1980 to April 19, 2019. The preliminary steps before data extraction included the selection of the study and the qualitative evaluation of the studies. Mesh database was used for all search keywords. The quality of studies was assessed according to 'Cochrane’s’ checklist, related articles and literature. This led to the inclusion of five articles. Next, all the effect sizes were converted into correlations; then, the relationship between temperature and Body Mass Index was estimated. An appropriate model was selected according to 'Cochran’s’ Q Test. Sensitivity analysis was used to assess the stability and heterogeneity of the findings. All analyses were performed through Comprehensive CMA software, version 3.

Results: Overall, the analysis showed a positive correlation between body temperature and body mass index at a 95% confidence interval (r=0.58 95% CI: 0.05-0.85). The effect of the age variable was significant in explaining inter-group variance (p<0.05, R² =0.43). For men, a positive and significant relationship was found between changes in body temperature and body mass index (r=0.158 95% CI: 0.11-0.19, p≤0.05). However, there was no significant relationship for women (r=0.32, 95% CI: -0.1-0.64, p=0.13).

Conclusion: A relationship between body temperature and BMI was found in the total population and men. The lack of a significant relationship in women may be due to sudden and severe secretion of luteinizing hormone (LH) in the menstrual cycle.

Keywords: Meta-analysis, Body Temperature, Body Mass Index, Correlation

Abbreviations / Acronyms:
BMI: Body Mass Index; LH: luteinizing Hormone; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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Note:
This study has followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement (http://www.prisma-statement.org). PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses. PRISMA focuses on the reporting of reviews evaluating randomized trials, but can also be used as a basis for reporting systematic reviews of other types of research, particularly evaluations of interventions.

1. Introduction
The relationship between body temperature changes and its effects on health has gained increasing attention in recent years (1, 2). Body temperature is controlled by the thermoregulation centre in the anterior hypothalamus and is the result of a complex balance between metabolic processes, muscle activities, and possibly microbiome (3, 4). To maintain a proper function of the body, body temperature must be kept in a specific range (5, 6) to maintain a suitable metabolic range. Various factors can affect body temperature based on physiology (gender, age, and menstruation) and pathology (infection, inflammation, and neoplasia) (7, 8).

Several studies have revealed a contradictory association between body mass index (BMI) and obesity. Some studies have demonstrated a positive relationship between BMI and body temperature (9-11); in others, however, this was not the case (12-14). Most of these studies had a smaller sample size because they measured body temperature using pill-sized sensors. This method is not readily applicable to large samples (10, 12). Because of the so-called contradiction, it is necessary to collect all these contradictory effects. Hence, this study set to determine the relationship between body temperature and BMI in various studies. In this regard, the meta-analysis method was employed to balance and adjust the weight of studies in determining the average effect size.

2. Material and Methods
2.1. Search strategy and study criteria
The present study is a meta-analysis. A systematic search was performed across Google Scholar, PubMed, Scopus, ProQuest, Web of Science, and Elsevier. The data were updated on April 19, 2019. Mesh database was used for all search keywords. In the case of PubMed, for example, the search strategy was "body temperature « [mesh] AND “obesity” [mesh] OR” body mass index” [mesh]. To cover all the related studies, we also considered search-related references. Some studies have shown that the temperature measurement method is not significant in the outcome (15-17). This led to the entry of different methods of temperature measurement to the study. Animal studies, repetitive studies, and studies that measured other relationships were also excluded. Since the aim of the study was to find a relationship between temperature changes and metabolic effects, articles emphasizing long-term effects were omitted.

2.2. Study selection
The title and abstract of the articles were entered into Endnote software, and duplicates were removed. All titles and abstracts were reviewed by the researcher to eliminate unrelated items. The full text of qualified studies was downloaded and read. The researchers compared the results and reached a consensus to enter the qualified articles into a systematic review (Figure 1).

2.3. Quality Assessment
The quality of studies was assessed according to ‘Cochrane’s checklist (18), related articles and literature (19, 20), and based on the following criteria including study design, sample size, statistical methods, temperature measurement, intervening variables, and environmental factors. However, the studies in this field were significantly different in terms of common indices.

2.4. Study extraction and publication bias
The authors independently extracted the data using a standard checklist. After quality assessment, the articles that met the inclusion criteria were included in the study. The collected data comprised of the title, author, publication year, conclusion, study design, and place of study. The effect sizes estimate was expressed as a correlation. Finally, the Egger test was employed to determine publication bias.
2.5. Statistical analysis
In the next step, statistical analysis was performed. For this purpose, all selected studies were analyzed. The statistical analysis consisted of two steps. First, all the estimated effect sizes were converted to correlations. Second, the mean of the estimated effect sizes was approximated using meta-analysis.

2.5.1. Step one
The correlation was considered a common index. Then, mean, frequency, and other indices were converted to correlations. For example, to convert \( d \) index to \( r \) (correlation), equations 1, 2, and 3 were adopted (21) as follows:

\[
\text{Equation 1) } \quad r = \frac{d}{\sqrt{d^2 + \alpha}}
\]

\[
\text{Equation 2) } \quad \alpha = \frac{(n_1 + n_2)^2}{n_1 n_2}
\]

Variance \( r \) in this method is calculated according to Eq. 3:

\[
\text{Equation 3) } \quad V_r = \frac{a^2 V_d}{d^2 + a^3}
\]

2.5.2. Step two
The average effect size of five selected studies was estimated. Then, the appropriate model was selected according to 'Cochran’s Q Test, from the two models (the fixed and random effects models). Sensitivity analysis was employed to assess the stability and heterogeneity of the findings. All analyses were performed using Microsoft Excel 2017 and Comprehensive Meta-Analysis (CMA) software, version 3.

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**Figure 1.** Flowchart of information in different phases of the systematic review (PRISMA 2009 Flow Diagram)
3. Results

3.1. General findings

According to Figure 1, 400 articles were included in the initial search. After reviewing the article titles, 329 studies were found not eligible, and 64 were excluded after reviewing their abstracts. Finally, seven studies were included in the meta-analysis. Among the seven studies, only five studies had the inclusion criteria for meta-analysis. Figure 1 shows the flowchart of information at different steps of the meta-analysis. The characteristics of the selected articles are given in Table 1. Figure 2 shows the Forest Plot for a general analysis of the relationship between body temperature and BMI. Due to the rejection of the null hypothesis of the Cochran’s Q Test, the random-effects model was adopted for analysis (p<0.05, Q-VALUE = 312.98, DF (Q) = 4). A positive relationship was observed between body temperature changes and BMI (p=0.033) (0.58, 95% CI: 0.05 to 0.85) (Figure 2). The gender-disaggregated forest plot for men and women are presented in Figures 3 and 4, respectively. After calculating the average effect size for men, a positive and significant relationship was observed between body temperature changes and BMI (p<0.05) (0.158, 95% CI: 0.11 to 0.19). However, no significant relationship was observed between body temperature changes and BMI for women (p=0.137) (0.32, 95% CI: -0.10 to 0.64).

3.2. The review results of publication bias and other biases

Egger regression test was used to evaluate the publication bias. Based on p-value>0.05, the hypothesis of the Egger regression test is accepted (Table 2).

Table 1. The characteristics of articles in the meta-analysis

<table>
<thead>
<tr>
<th>Code</th>
<th>Publication year</th>
<th>Author</th>
<th>Country</th>
<th>Sample size</th>
<th>Type of study</th>
<th>Gender</th>
<th>Temperature measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2019</td>
<td>Vollenweider (22)</td>
<td>Switzerland</td>
<td>4224</td>
<td>Prospective</td>
<td>Male (2032), Premenstrual women (631), Postmenopausal women (1561)</td>
<td>Tympanic membrane</td>
</tr>
<tr>
<td>2</td>
<td>2012</td>
<td>Linsenmeier (23)</td>
<td>USA</td>
<td>24</td>
<td>Cross-sectional</td>
<td>Male (12), Female (12)</td>
<td>Core Temperature</td>
</tr>
<tr>
<td>3</td>
<td>2011</td>
<td>Yanovski (24)</td>
<td>USA</td>
<td>Non-obese (35), Obese (46)</td>
<td>Cross-sectional</td>
<td>Non-obese (Female: 19, Male 16); Obese (Female: 34, Male 12)</td>
<td>Temperature-sensing capsule</td>
</tr>
<tr>
<td>4</td>
<td>1998</td>
<td>Kim (25)</td>
<td>USA</td>
<td>219</td>
<td>Cross-sectional</td>
<td>Male (78), Female (141)</td>
<td>Infrared tympanic thermometry (ITT), Tympanic membrane</td>
</tr>
<tr>
<td>5</td>
<td>1989</td>
<td>Adam (14)</td>
<td>University of California, Los Angeles (USA)</td>
<td>60</td>
<td>Cross-sectional</td>
<td>Female (42), Male (18)</td>
<td>Oral temperature</td>
</tr>
</tbody>
</table>

Table 2. The results of Egger regression in meta-analysis

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Standard error</th>
<th>95% lower limit</th>
<th>95% upper limit</th>
<th>t-value</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.66</td>
<td>5.86</td>
<td>12.06</td>
<td>25.38</td>
<td>1.1</td>
<td>3</td>
<td>0.33</td>
</tr>
</tbody>
</table>
3.3. Calculation of I-SQUARE and R-SQUARE
The results of the Cochran’s Q Test showed that the between-study variance was about 98% (98.98 = I-SQUARE). An analysis was performed to explain the between-study variance regarding the age variable. The results of the meta-regression test are shown in Figure 5. The results of the moderator variable (age) in explaining intergroup variance are presented in Tables 3 and 4. In the slope line, the effect of the age variable is significant in explaining the intergroup variance (p<0.001), and the extent of this effect is $R^2=0.43$.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point estimate</th>
<th>Standard error</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>-0.0037</td>
<td>0.0028</td>
<td>-0.049</td>
<td>0.031</td>
<td>13.03</td>
<td>0</td>
</tr>
<tr>
<td>Intercept</td>
<td>2.32</td>
<td>0.16</td>
<td>1.99</td>
<td>2.64</td>
<td>13.93</td>
<td>0</td>
</tr>
<tr>
<td>Tau_squared</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Explanatory variable results (age) for intergroup variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Q</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>169.88</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Residual</td>
<td>223.0049</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>392.88</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 5. Meta-regression test results about between-study variance explanation

4. Discussion
The present study is the first meta-analysis research to examine the correlation between body temperature and BMI. The findings showed that the correlation between these two indices was positive and significant. The relationship between body temperature and BMI has been reported in various studies. Some researchers have reported a positive relationship between these two factors (9-11) and others have reported conflicting reports (12-14). This meta-analysis has been designed to answer conflicting evidence. As there have not been many studies in this area, the researchers were obliged to include studies with a smaller sample size in the meta-analysis to compensate for the relatively low power of these studies in explaining the average effect size. Hence, in the first stage, all the estimated effects were converted into correlation. In the second step, the estimated average effects were assessed through meta-analysis. Then, the average effect size was calculated according to the described methods. The results showed a positive and significant relationship between these two indices. In explaining the causality of this issue, there is a direct and significant relationship between body fat percentage and core body temperature. Thicker subcutaneous fat acts as an insulating layer between the skin surface and deep tissues, especially in the extremities, abdomen, and trunk. This fat layer theoretically reduces heat transfer through conduction from the muscles to the surface of the skin. However, an increase in body surface area, compared to weight gain due to increased body fat, can be effective in reducing the cold tolerance because the area from which heat transfer takes place has expanded. On the other hand, subcutaneous fat may reduce the surface temperature of the body because it restricts heat transfer from the body depth to the surface (22-24).

The correlation was further examined by gender. The results showed that the correlation in men was positive and significantly associated with BMI. No significant relationship was observed between body temperature and BMI in women. Lack of correlation in women may be due to the sudden and intense secretion of Luteinizing Hormone (LH) since it can change body temperature to some extent. This process continues until menstruation and is somewhat dependent on pregnancy. Studies have proven that women’s temperature during the menstrual cycle changes due to hormonal changes. After ovulation, their body temperature rises 0.6 degrees compared to the first two weeks of menstruation (25). Since this factor was not taken into account in all the studies, it was excluded from the meta-analysis. Two other factors, i.e., lower muscle volume and higher body surface in women, can be somewhat effective in the so-called lack of significance and indicate the fact that women are more sensitive to the cold than men (26, 27).
After evaluating various studies (11, 26, 28), it was found that the age variable is one of the factors influencing the correlation between BMI and body temperature. It was initially thought that this factor could partially justify the cause of heterogeneity (difference in the effect size) among studies. Accordingly, the age variable was analyzed as a moderator variable. The results showed that an increase in the age variable reduces the effect size logarithm. According to the slope presented in Table 3, there was a logical relationship between these variables as the age variable could account for 43% of changes in variance (the difference between studies). Waalen et al. demonstrated that age has a negative effect on body temperature (11). In contrast, Vollenweider et al. revealed a positive relationship between age and body temperature (26). Research has shown that in both men and women, the temperature decreases with age. In women, the results can be enhanced by the onset of menopause (28). Various studies have assessed the relationship between BMI and age, which established that physical activity decreases with an increase in age. Also, the inability in controlling food intake and lack of exercise may increase BMI. Some studies have manifested that mood disorders occur on a daily, monthly, and even seasonal basis in higher ages and pave the way for eating foods rich in carbohydrate, which subsequently increases the BMI. In such situations, an individual resists physical activity, which results in increased obesity (29-31). One of the reasons for the increase in BMI at a higher age in women is possibly the hormonal effects of menopause, which affects not only body temperature but also BMI indices through physiological changes (29, 32).

The present study has several limitations. Some of the studies had a small sample size and did not represent all the individuals in their population. As in meta-analyses, body temperature was measured using a variety of methods. These methods included temperature sensor capsule, oral temperature, and tympanic temperature. Unlike tympanic temperature, which is a non-invasive method, in studies that used sensor devices to measure core body temperature, the participants’ contribution was relatively low since these pill-sized devices entered the ‘patient’s stomach and intestines. Therefore, such studies, because of their invasive nature, face difficulties in selecting a large (appropriate and sufficient) sample size. Another limitation of meta-analysis is the lack of inclusion of some variables, which can be attributed to the lack of similarity among studies. For example, some studies did not classify women as premenopausal and post-menopausal, which prevented the effects of menstruation from entering the analyses. Factors such as paracetamol, nonsteroidal anti-inflammatory drugs, and corticosteroids were studied in only one study, so the meta-analyst was restricted in analyzing the so-called relationships.

5. Conclusions
In this study, body temperature was found in correlation with BMI in the male population. Lack of correlation in women may be due to the sudden and intense secretion of LH because this factor can change the body temperature to some extent. Due to the dissimilarities between studies in evaluating the effective variables, further studies are recommended to assess more and similar variables such as menstruation and the effect of different drugs, which could assist the researchers in examining the studies based on further evidence and similarities.

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Conflict of Interest:
There is no conflict of interest to be declared.

Authors' contributions:
All authors contributed to this project and article equally. All authors read and approved the final manuscript.

References:


