JOURNAL OF NUTRITION FASTING AND HEALTH

Association of Obesity Prevalence and Ambient Temperature: A Systematic Review

Ammar Salehi-Sahlabadi[1], Aref Momeni[2], Jamal Rahmani[1], Hamed Kord[3]*

1. Student Research Committee, Department of Clinical Nutrition and Dietetics, Faculty of Nutrition and Food Technology, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2. MSc Student in Sport Nutrition, Semnan University of Medical Sciences, Semnan, Iran
3. Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran

ARTICLEINFO

Article type:
Review Article

Article History:
Received: 03 Sep 2019
Accepted: 01 Dec 2019
Published: 15 Jul 2020

Keywords:
Obesity
Ambient
Temperature

ABSTRACT

Introduction: Ambient temperature is considered to be an influential factor in metabolism, and reduced/increased ambient temperature to the thermoneutral zone (TNZ) (20.3-23°C for covered populations) lead to metabolic changes, while also affecting the prevalence of obesity. The present study aimed to review the findings on the correlation of ambient temperature with obesity in various regions with ambient temperature.
Methods: This systematic review was conducted in July 2019 via searching in databases such as PubMed and Scopus using three terms to describe the exposure and four terms for the outcome. The quality of the articles was assessed using the Newcastle-Ottawa quality assessment. Among 461 selected articles, four cross-sectional studies were systematically reviewed. The quality of these studies was graded nine based on a nine-point scale. In addition, the four cross-sectional studies reported a correlation between the prevalence of obesity and ambient temperatures in various regions in Spain, Korea, England, and the United States.
Results: An association has been reported between ambient temperature and obesity in various regions with ambient temperature, and increased ambient temperature to the TNZ has been associated with the higher prevalence of obesity, while higher temperature than the TNZ range has been reported to decrease the prevalence of obesity.
Conclusion: Evidence suggests that ambient temperature may affect the prevalence of obesity. However, further investigations are required in different countries with wider temperature ranges in order determine the correlation between ambient temperature and the prevalence of obesity.

► *Please cite this paper as*:
Salehi-Sahlabadi A, Momeni A, Rahmani J, Kord H. Association of Obesity Prevalence and Ambient Temperature: A Systematic Review. J Nutrition Fasting Health. 2020; 8(3): 145-150. DOI: 10.22038/jnfh.2019.42923.1221

Introduction

Overweightness and obesity are major public health concerns across the world [1], and weight gain is an important risk factor for chronic diseases and mortality [2]. The prevalence of obesity-related diseases has been on the rise worldwide. Obesity may be caused by the chronic imbalance between energy intake and energy expenditure [3-5]. The energy expenditure in the body is classified into three categories, including basal metabolic energy (60-80% of total expenditure), physical activity (10-30% of total expenditure), and the thermal energy for compliance (10% of total energy) [6]. Most individuals spend their time within the temperature ranges of normal metabolism, which are referred to as the thermoneutral zone (TNZ) and is within the range of 20.3-23°C for the covered populations [7, 8]. Declined environmental temperature under TNZ temperatures increases energy expenditure (105-156 kJ) per each degree of reduction in temperature [9]. On the other hand, higher environmental temperature than TNZ leads to increased energy expenditure during rest periods by 10-13% per each degree of increase in temperature [10]. This may be caused by energy expenditure and loss of appetite, which reduces energy intake and decreases body weight [6, 11]. However, some studies have proposed conflicting results in this regard.

This systematic review aimed to assess the correlation between the risk/prevalence of obesity in various regions with ambient temperature.

Materials and Methods

This meta-analysis was conducted based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement [13].

Search Strategy

* *Corresponding author:* Hamed Kord, Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Hojjat-dost Alley, Keshavarz Blvd, Tehran, Iran. Tel: 00989185427366. Email: tiyam0081@gmail.com.

All the studies reporting the association between obesity and ambient temperature were retrieved since the earliest available time up to July 2019. The literature search was performed for observational studies (cross-sectional, case-control, and cohort) by reviewing the reference lists of a relevant systematic review (Figure 1; e.g., full search strategy). In order to search for related articles in terms of the subject, we searched the PubMed and Scopus databases using keywords in two stages, as follows:

1) ambient temperature [tiab] OR air temperature [tiab] OR climate change [tiab]; 2) obesity [tiab] OR obes * [tiab] OR overweight [tiab] OR body mass index [tiab].

The literature search results were downloaded into EndNote version X7 (Windows, Thomson Reuters, Philadelphia, PA, USA; release date: 30 September 2014) in order to merge the retrieved citations, eliminate duplications, and facilitate the review process.

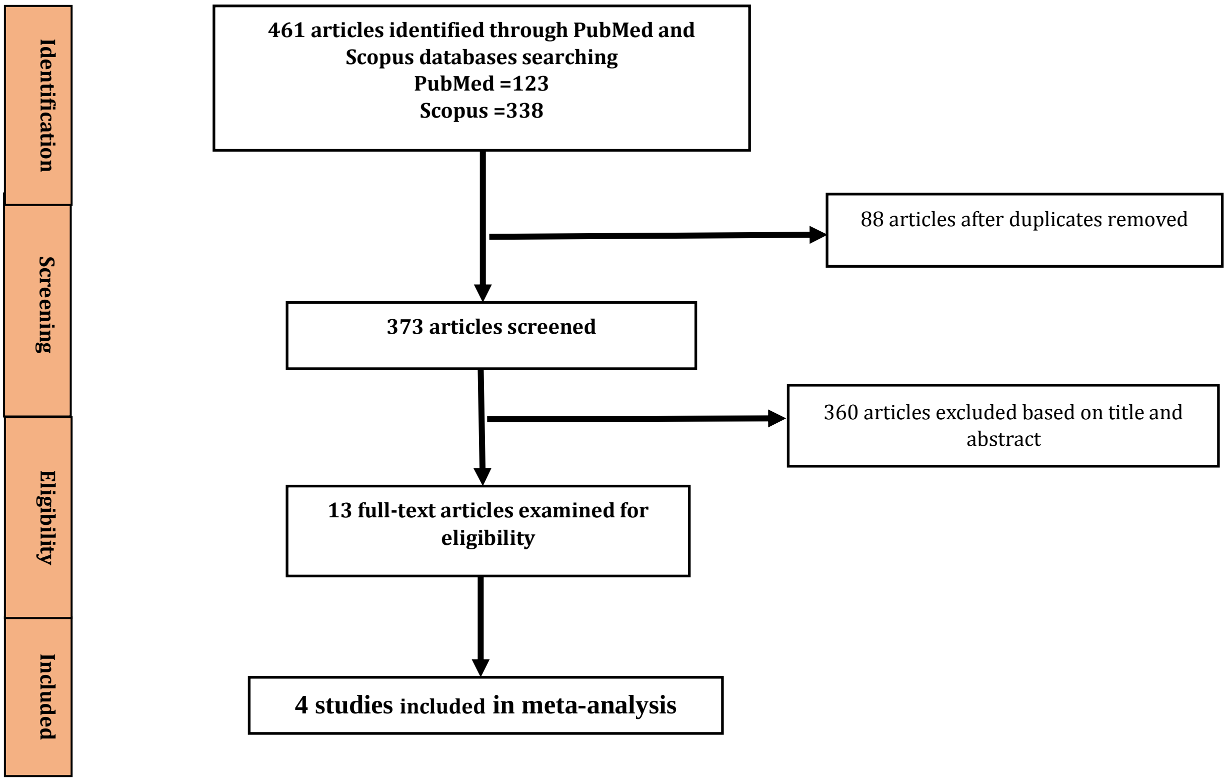

Figure 1: e.g., full search strategy

Eligibility Criteria

Relevant articles were retrieved and selected for the review if they examined air temperature, considered obesity measures (e.g., odds ratio, relative risk, or hazard ratio), and evaluated adult subjects. Articles were excluded if they only examined individual nutrients or did not examine all dietary components, provided no reports on the obesity risk data in an extractable format, used study samples that were not population-based (e.g., pregnant/lactating women, infants, children/adolescents), involved non-human studies, and were reviews, case reports, conferences, letters, and non-English studies.

Study Selection

The titles and abstracts of all the articles were retrieved in the initial search, and the articles not meeting the eligibility criteria were excluded using a screening form with a hierarchical approach based on the study design, population/exposure, and outcome. Afterwards, the full-text articles were retrieved if the citation was considered eligible and subjected to secondary evaluation for relevance by the same reviewers. Disagreements were discussed and resolved by another investigator.

Data Extraction and Qualitative Assessment of the Studies

The extracted data from the articles included the name of the first author, publication year and country, study design, sample size, number of cases and controls, temperature measurements, and the estimates of associations. If a study provided several estimates with the adjustment of various confounders, the results would be reported for the adjustment that covered the largest number of the confounders. Two reviewers independently performed the data extraction and settled the differences by consensus. If more details were required, we contacted the authors for additional information.

Furthermore, the Newcastle-Ottawa scale (NOS) was used to assess the quality of the cross-sectional studies.

Results

Literature Search

In total, 461 studies were identified. During the first screening, 373 articles remained in the study after eliminating the duplicates. Afterwards, 373 studies were excluded due to irrelevant data, no focus on the main exposure (ambient temperature) or main outcome (obesity), non-human experimental studies, chemistry/cell line studies, editorials, commentaries, review articles, and case reports. During the secondary screening, full-text articles were retrieved (n=13), nine articles were excluded due to inadequate data, and four studies were considered eligible for this meta-analysis (Figure 1; Tables 1-2).

Table 1. Quality assessment for study examined and included into the meta-analysis.

Newcastle-Ottawa Scale adapted for cross-sectional studies	Selection	Comparability	Outcome	Total
Michael Daly, 2014.England	*****	*	***	9
JDVoss,2013, United States	*****	*	***	9
Hae Kyung Yang, 2015, Korea	*****	*	***	9
Sergio Valdes ,2014, Spanish	*****	*	***	9

Tables 2. Characteristics of studies examined and included into the meta-analysis.

First Author, Year Of Publication, Country	Sample Size	Age	Exposure(Ambient Temperature Range)	Definition Of Outcome	Area	The Relationship Between
Michael Daly, 2014. England	100152	16	19-23≤	relative	16	B(SE)
JDVoss, 2013, United States	422603	18	5-20≤	BMI=30≤	3134	OR
Hae Kyung Yang, 2015, Korea	124354	20	-5-25≤	BMI=25≤	71	OR and r
Sergio Valdes , 2014, Spanish	5061	18	10.4-21.3	BMI=30≤	100	OR

Study Characteristics

In total, 652,170 subjects participated in the selected studies. A study conducted by Michael Daly on individuals aged more than 16 years was conducted in the regions with the temperature range of ≥19-23°C in the United Kingdom, and a correlation was reported between the body mass index (BMI) and air temperature based on regression analysis [16]. However, in three studies that were carried out by J. D. Voss in the United States, Sergio Valdes in Spain, and Hae Kyung Yang in Korea, the temperature ranges were ≥0.0-24.9°C, 10.4-21.3°C, and ≥-5-25°C, respectively. The findings of the mentioned research indicated an association between obesity and the average annual temperature based on the risk odds ratio. The data of the reviewed articles are presented in Table 2.

All the four studies that were systematically reviewed had been conducted on adult subjects, demonstrating a positive association between ambient temperature and risk of obesity.

Main Findings

The study by Daly et al. (2014) was conducted in 100,152 subjects aged >16 years in the United Kingdom, and the association between indoor temperatures of the TNZ for clothed humans (>23°C) with reduced BMI was confirmed [16]. After the adjustment of the age, gender, social class, health status, and month/year of assessment, it was observed that per every degree of increase in higher temperatures than 23°C, the BMI decreased at the rate of 0.233 (B=-0.233; SE=0.053). Moreover, high indoor temperatures were associated with reduced BMI in winter and non-winter months, as well as early (1995-2000) and later (2001-2007) survey waves.

In another research that was performed in Spain, the possible association between ambient temperature and obesity was investigated in order to assess the risk of obesity based on four quartiles of temperature (quartile 1: 10.4-14.5°C; OR=1, quartile 2: 14.5-15.5°C; OR=1.2, quartile 3: 15.5-17.8°C; OR=1.35, quartile 4: 17.8-21.3°C; OR=1.38). The OR of obesity in

quartile one increased from 10.4 to 21.3 compared to quartiles two, three, and four.
In a US population, Voss et al. (2013) examined the correlation between obesity and elevation of ambient temperature. In the mentioned study, ambient temperature was divided into five quartiles, and it was observed that the increased average of the annual temperature from <5°C to +20°C caused an increment in the overall OR of obesity after adjustment for temperature, diet, physical activity, smoking habits, and demographic factors. In another research conducted in Korea, Yang et al. (2015) observed that BMI was positively correlated with the mean annual temperature (r=0.0078; P=0.0065). In the mentioned study, the average of annual temperature was divided into five quartiles of Q1-Q4 (<14.1°C) and Q5 (-14.1°C), and Q5 was compared with Q1-Q4 (OR=1.045; 1.010-1.081) for obesity, and OR was estimated at 1.082 (1.042-1.124) for abdominal obesity. In addition, the days of the year were classified into five categories based on the average daily temperature, including <-5°C (DMT-5), <0°C (DMT0), 5°C (DMT5), and 25°C (DMT25).
The same classification was performed based on altitude (height of the observation area above the mean sea level), and the findings indicated that DMT-5 and DMT0 were negatively correlated with BMI and waist circumference (WC; r=-0.0047, r=0.0040, r=-0.0129, and r=-0.0123, respectively), while DMT5 had a positive correlation with BMI and WC (r=0.0070 and r=-0.0157, respectively). On the other hand, DMT25 had a negative correlation with BMI and WC (r=0.0024 and r=-0.058, respectively), while positive correlations were observed between altitude, BMI, and WC (r=-0.0005 and r=0.0042, respectively).

Tables 3: Reported linking obesity with an average annual temperature.

Mean annual temperature	Quartile 1, 10.4-14.5_C	Quartile 2, 14.5-15.5_C	Quartile 3, 15.5-17.8_C	Quartile 4, 17.8-21.3_C	P-value for difference
Prevalence of obesity (%)	26.9	30.5	32	33,6	.003
number	1,312	1,489	1,245	1,015	

Tables 4: Reported linking obesity with an average annual temperature into for risk odd ratio

Mean annual temperature	Quartile 1, 5_C<	Quartile 2, 5–9.9 C	Quartile 3, 10–14.9 1C	Quartile 4, 15–19.9 1C	Quartile 5 20+ C
OR (95% confidence interval (CI))	0.96(0.85-1.08)	1.03(0.93-1.13)	1.00(0.92-1.09)	1.03(0.94-1.13)	**Referent**

Discussion

According to the extensive literature review in the present study, only four studies met the eligibility criteria, including four cross-sectional studies conducted in the United Kingdom, Korea, Spain, and the United States to examine the association between various areas with ambient temperature and obesity. Due to the limited number of the retrieved studies, a unified outcome could not be achieved to determine the effect of ambient temperature on the prevalence of obesity within a particular temperature range.
Previous studies have denoted a correlation between ambient temperature and energy expenditure in the body, so that increased or decreased body temperature would increase the activity of the brown adipose tissue outside the TNZ, thereby increasing energy expenditure and reducing body fat and BMI in the body [9, 10, 12-15]. In a study conducted in the United Kingdom, 100,152 individuals aged more than 16 years were evaluated in terms of the indoor temperatures of their residence (23°C), and those living at the temperatures below 19°C were reported to have lower BMI [16]. Therefore, it could be inferred that appetite control and increased metabolic rate may be involved in increasing ambient temperature in a combined manner, thereby leading to weight loss and BMI reduction [11, 17-19].
In another cross-sectional study conducted within the temperature range of 10.4-21.3°C in Spain, Sergio Valdes demonstrated a positive correlation between obesity and increased ambient temperature, and the highest incidence of obesity was observed within the temperature range of 17.8-21.3°C [20]. Furthermore, Voss et al. (2013) reported a parabolic correlation between obesity and mean annual temperature, as well as decreased OR and increased temperature to maximum temperature, while

the highest prevalence of obesity was observed in the temperatures close to 18°C [21].
In this regard, Yang et al. (2015) conducted a research in Korea, reporting a significant correlation between the prevalence of obesity or abdominal obesity with the mean annual temperature, so that OR would be higher for obesity and abdominal obesity in the individuals living in the higher quartile of temperature. On the other hand, OR was higher the individuals living in the quartile in less than DMT0 compared to those living in the higher quartile of DMT0 [22].
Experimental studies have indicated a graded association between an acute mild cold and human energy expenditure over the range of temperatures relevant to indoor heating trends. Meanwhile, recent studies regarding the role of the brown adipose tissue (BAT) in human thermogenesis have suggested that increased time spent in conditions of thermal comfort may lead to the loss of BAT and reduction of thermogenic capacity. However, the pathways linking cold exposure and adiposity have not been directly tested in humans [6].
One of the limitations of the current research was in the case of the cross-sectional studies as they could not explain the effect of ambient temperature on the prevalence of obesity. Another limitation was the difference in the temperature ranges reported in the reviewed studies; in the study performed in the United Kingdom, obesity was assessed in the domestic temperature range of 19-23°C. In Spain, the mean annual temperature range was 10.4-21.3°C, while it was 0.0-24.9°C in the United States and 6.6-16.6°C in Korea. Furthermore, some inconsistencies were observed in the definition of obesity as obesity was defined as the BMI of >30 kg/m^2 in the studies by J. D. Voss et al. and Sergio, while in the research by Yang, obesity was defined as the BMI of >25 kg/m^2. In the study by Michael Daly, the correlation and definition of obesity was unclear. These differences across the reviewed studies regarding obesity and ambient temperature may be due to several factors, such as the differences in the mean annual temperature in various areas, limited studied temperature ranges, differences in the age and income status of the individuals living in various regions, cultural differences, differences in the height of the studied areas, not considering the non-residents, and different studies to adjust various confounders.

Conclusion
According to the results of this review, ambient temperature may affect the prevalence of obesity. It is recommended that further investigations be conducted within wider temperature ranges in order to determine the correlation between ambient temperature and prevalence of obesity.

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