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# An Investigation of the Effect of Latitude on the Incidence of Type 1 Diabetes: A Systematic Review


## Abstract

Background: Numerous epidemiological studies have demonstrated the prevalence of type 1 diabetes among various age groups, and geographic locations around the globe. The purpose of this study was to investigate the effect of latitude on the incidence of type 1 diabetes in light of its high prevalence, which has caused a variety of problems for children and adolescents, and the rise in prevalence of this disease worldwide.

Material and Methods: Using a predetermined search strategy, the ISI, Pubmed, Proquest, and Willey databases were combed for all epidemiological studies conducted in Iran and the rest of the world up until 2023. Following the search, 871 articles were located. After removing duplicates and screening the title, abstract, and main text, 200 articles were extracted, and finally 15 articles were selected for the study.

Results: Studies published up to 2022 were looked at, and it was found that there is a positive correlation between type 1 diabetes and increasing latitude. It means that the number of people with diabetes goes up the farther away from the equator you are.

Conclusion: Given that geographic and environmental factors play a significant role in the etiology of diseases, it can be beneficial for research if decision-makers in the health and sanitation sectors pay attention to these factors. Additionally, planning in the health and sanitation sector can be done for each region following the climatic, environmental, geological, etc. conditions of that region.


**Keywords:** *Effect, Type 1 Diabetes, Latitude, Incidence*


**Fereshte Hosseinifar[1], Fatemeh Rezaei Nadeh[2], Maryam Nasirian[3]***

*[1]Ph.D. in Epidemiology, Department of Pediatrics, Child Growth and Development Research Center, Research Institute for Primordial Prevention of Noncommunicable Disease, Isfahan University of Medical Sciences, Isfahan, Iran.*

*[2]Masters Student, Epidemiology, Faculty of Health, Isfahan University of Medical Sciences, Isfahan, Iran*

*[3] PhD of Epidemiology, Infectious Diseases and Tropical Medicine Research Center; and Epidemiology and Biostatistics Department, Health School, Isfahan University of Medical Sciences, Isfahan, Iran*

***Corresponding author:** Maryam Nasirian, PhD of Epidemiology, Infectious Diseases and Tropical Medicine Research Center; and Epidemiology and Biostatistics Department, Health School, Isfahan University of Medical Sciences, Isfahan, Iran*

*phone: + 98-913-229-803, e-mail: Maryamnasirian17@gmail.com*


## 1. Introductions

Diabetes is a metabolic disorder brought on by inadequate insulin secretion, insulin dysfunction, or occasionally both. Type 1 diabetes, type 2 diabetes, and gestational diabetes are the three main subtypes of this illness. Type 1 diabetes, also referred to as insulin-dependent diabetes, is a common metabolic disorder of childhood brought on by insufficient pancreatic insulin production. Although type 1 diabetes can occur at any age, it tends to occur more frequently in children and adolescents aged 7–15 years [1, 2]. Defects in insulin receptor cells and the body's resistance to insulin are what causes type 2 diabetes [3]. In addition to being diagnosed during pregnancy, gestational diabetes is also known as glucose intolerance [4].

Although the exact cause of type 1 diabetes is still unknown, it is thought that a combination of genetic, familial, and environmental factors contributes to the disease's onset. Type 1 diabetes symptoms include constant hunger and thirst, frequent urination, visual disturbances, and weight loss [5]. The oral glucose test and the measurement of glycosylated hemoglobin (HbA1c), which is less sensitive than the oral glucose test, are used to diagnose diabetes. It is somewhat challenging to prevent type 1 diabetes due to the unknown role of heredity in its onset. At this time, type 1 diabetes can't be stopped completely, but making changes to your lifestyle, like eating the right foods and working out regularly, can help lessen some of its problems [5].

Type 1 diabetes causes not only physical problems but also adverse psychological effects. According to research, those who have type 1 diabetes are more likely to experience psychiatric disorders like social anxiety [6]. Additionally, it has been noted that type 1 diabetics experience more anxiety than healthy individuals [7]. Due to their fear of having high blood sugar and their inability to relate to their peers, children with diabetes experience social anxiety when they interact with others [6]. According to Springer et al.'s study on type 1 diabetic children in California, girls have higher levels of HbA1c than boys [8], which is consistent with Hanberger's study in Sweden [9].

Approximately 15 million children have type 1 diabetes, according to estimates [10]. The incidence and prevalence of type 1 diabetes have increased worldwide, with the greatest increase occurring in children younger than five years old. Consequently, one of the objectives of the World Health Organization is to halt the rise of diabetes and obesity by 2025 [5, 11]. In Asia, Africa, Europe, and the United States, the prevalence of type 1 diabetes are estimated to be 6.9, 3.5, 12.2, and 12.2 per 10,000 people, respectively [12]. The global prevalence of type 1 diabetes is estimated to increase by 3% per year [13].

Environmental risk factors have been linked in numerous studies to the development of type 1 diabetes. In addition to differences in lifestyle, mother's age, nutrition, and exposure to infections, socioeconomic status influences the incidence of type 1 diabetes in individuals. Some studies have found that the incidence of type 1 diabetes is higher in urban areas than in rural areas, while others have found that the difference between urban and rural areas is strongly correlated with socioeconomic status [14].

Time and seasonal c… diabetes, with the majority of cases diagnosed in the fall and winter due to viral infections [13]. Population growth has altered regions in such a way that the likelihood of certain diseases has increased or, conversely, immunity has increased. Doctors introduced the term "medical geography" in the 18th and 19th centuries to examine extensive information about human diseases, cultures, and environments [15]. Different latitudes affect people's health, as evidenced by the prevalence of malaria at latitudes 23.5 north and 23.5 south, known as tropical regions [16]. Given that geographic and environmental factors play a significant role in the etiology of diseases, it can be advantageous for policymakers in the health sector to pay attention to these factors in their research. Planning can therefore be done for each region based on its specific climatic, environmental, geological, etc. conditions. This study's objective was to investigate the effect of latitude on the occurrence of type 1 diabetes, given the high prevalence of this disease, which is associated with a variety of problems for children and adolescents, the global increase in the prevalence of this disease, and the importance of understanding the risk factors influencing the prevalence of this disease.

## 2. Material and Methods

This study followed a set of guidelines called PRISMA (Preferred Reporting of Items for Systematic Reviews and Meta-Analyses) for how to report and analyze research findings. The PRISMA statement is about how to do research reviews and meta-analyze data from different studies.

**Data source and search strategy:**

Initially, four foreign databases were examined, including ISI, Pubmed, Proquest, and Willey, before articles were searched using a designed search strategy. The search strategy is divided into three sections. The keywords "incidence" and its synonyms were searched in the first section, "type 1 diabetes" and its synonyms in the second section, and "latitude" and its synonyms in the third section. The AND operator connects these four parts, and the OR operator connects the synonyms within each section. Table 1 depicts the search strategy.

**Table 1**

| |
|---|
| (Incidence) AND ("Type 1 diabetes "OR "diabetes mellitus, type1 "OR "diabetes insipidus") AND ("Latitude "OR "geographical locations "OR "Geography") |

keywords. All sections of the article, including the title, abstract, keywords, and body, were scanned for keywords without imposing a time constraint.

**Inclusion and exclusion criteria:**

The inclusion criteria included epidemiological studies (cross-sectional, case-control, retrospective cohort, prospective cohort, clinical trial, structured review, meta-analysis, and molecular epidemiology) that reported the incidence of type 1 diabetes in Iran and worldwide. Exclusion criteria included studies that looked at other types of diabetes, had insufficient or no data, were in the form of letters to the editor or were presented at conferences.

**Study quality:**

We used a checklist called STROBE (The Strengthening the Reporting of Observational Studies in Epidemiology) to check how good each study was. It has six main sections: title and abstract, introduction, methods, results, discussion and extra information. There are 22 paragraphs in this statement. 18 of them apply to all types of research, while 4 are only relevant to certain studies.

## 3. Results

Figure 1 illustrates the process of identifying articles, removing duplicates, and screening based on the article's title, abstract, and full text using the PRISMA structure. After searching the databases, a total of 886 articles were found, and after removing duplicates, 871 articles were identified and analyzed based on their title, abstract, and full text. Next, 200 articles were deemed admissible for full-text review. In the end, 15 articles were incorporated into the study

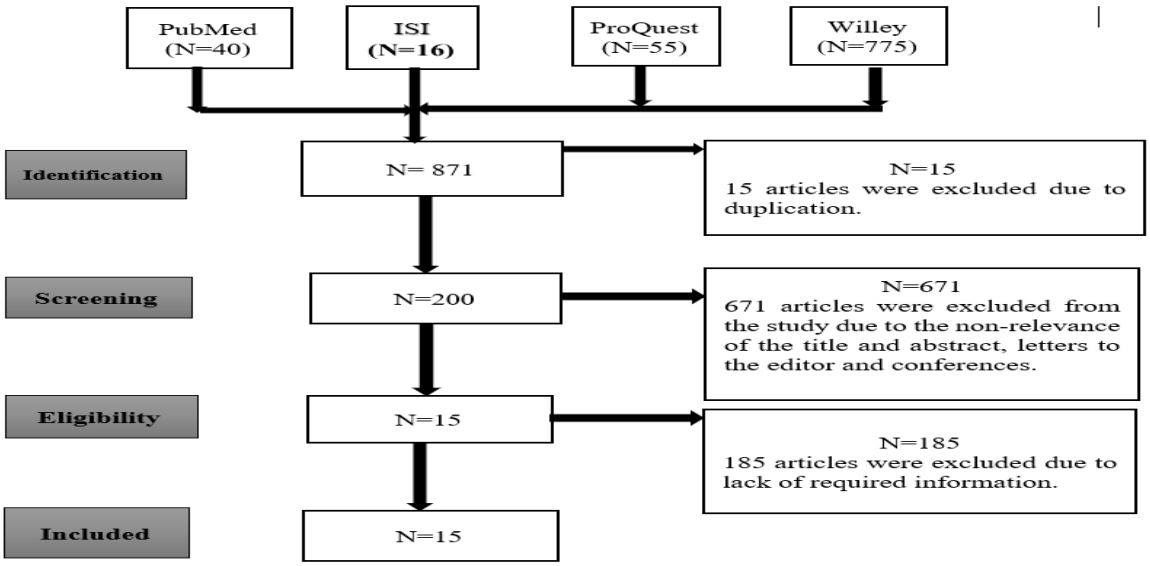


**Figure 1.** The process of identifying the evidence of studies based on the structure of PRISMA

The influence of latitude on the incidence of type 1 diabetes was determined after a review of previous studies. Then, after repeatedly summarizing and classifying the collected data, it took
the form of table 2.

In each of the aforementioned studies, it has been demonstrated that there is a positive correlation between type 1 diabetes and increasing latitude, such that the prevalence of type 1 diabetes increases with distance from the equator. However, in 2004, during an ecological analysis of the incidence and prevalence of type 1 diabetes in childhood, Fernando Collado-Mesa reported a negative correlation (r = -0.22, p = 0.512) between the incidence of type 1 diabetes and latitude [17]. In addition, when investigating the effect of altitude on diabetes, Orison O. Woolcott (2014) discovered that the risk of developing diabetes is lower in people who live between 1500 and 3500 meters compared to people who live between 0 and 499 meters (OR = 0.88, CI: 0.96-0.81) and that there is an inverse relationship between diabetes and height [18].

Chakhtoura (2012) and Sb Mohr (2007) investigated the relationship between ultraviolet B radiation, vitamin D status, and the incidence of type 1 diabetes, and their findings revealed that vitamin D deficiency has increased the incidence of type 1 diabetes in high latitudes (R 2 = 0.25, p 0.0001) [19, 20]. Furthermore, in her study of the seasonal relationship with the clinical onset of type 1 diabetes, E. V. Moltchanova (2009) discovered that the seasonal incidence of type 1 diabetes increases as one moves away from the equator (p = 0.0002) [21].

**Table 2**

| Author | Year | Location | Sampling method | Age | Gender | Results | Ref |
|---|---|---|---|---|---|---|---|
| Stephen J Ball | 2014 | Australia | census | Under 15 | girls and boys | The incidence of diabetes increases by 3.5% for every degree away from the equator (95% CI: 0.2-7.2). | [14] |
| Matthew L. McCullough | 2020 | U.S.A | census | 19 | girls and boys | Strong positive correlation between incidence of type 1 diabetes and latitude in the 15-to-60 age group (r=0.75 p<0.0001) | [13] |
| Leigh A Newhook | 2012 | Canada | census | Under 14 | girls and boys | Diabetes incidence increases by 3.3% for each degree of latitude north of the equator (p<0.05) (95% CI: 0.156-4.884) | [22] |
| Fernando Collado-Mesa | 2004 | U.S.A | census | Under 14 | girls and boys | The incidence of type 1 diabetes is significantly associated with northern latitudes (p<0.05). | [17] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Orison O. Woolcott | 2014 | U.S.A | census | Under 20 | girls and boys | Negative correlation between type 1 diabetes incidence and latitude (r=-0.22, p=0.519) | [18] |
| Jinli Liu | 2017 | world | census | all ages | girls and boys | People who live between 1500 and 3500 meters have a lower risk of diabetes than those who live between 0-499 meters (OR=0.88, CI: 0.96-0.81). | [23] |
| Mohr SB | 2007 | world | cluster | Under 14 | girls and boys | An increase in the prevalence of type 1 diabetes in 18 geographical areas | [20] |
| Scott Sloka | 2008 | Finland | census | Under 15 | girls and boys | West Africa (129.6%) and Sub-Saharan Africa (123.2%) have seen the greatest increase in the incidence of type 1 diabetes. | [24] |
| P. Jarosz-Chobot | 2010 | Poland | census | Under 15 | girls and boys | High incidence of type 1 diabetes in high latitudes (R2=0.25, p<0.0001) | [25] |
| A. Gerasimidi Vazeou | 2016 | Europe | census | Under 20 | girls and boys | Type 1 diabetes incidence and latitude have a positive correlation (r=0.086, CI: 0.00596-0.1645). | [26] |
| Alexia G. Abela | 2018 | world | cluster | all ages | girls and boys | Significant correlation between latitude and the frequency of type 1 diabetes (r=-0.013, p=0.002) and diabetic ketoacidosis (r=-0.014, p=0.002) | [27] |
| E. V. Moltchanova | 2009 | world | cluster | all ages | girls and boys | The incidence of type 1 diabetes is higher in northern latitudes than in southern latitudes on average (p0.05). | [21] |
| Peter Fsadni | 2012 | the world | cluster | all ages | girls and boys | There is no correlation between latitude and the seasonal incidence of type 1 diabetes (p>0.05). | [28] |
| Niels H. Wache | 2019 | Mexico | census | Under 19 | girls and boys | Distance from the equator and high seasonal incidence of type 1 diabetes (p=0.0002) | [29] |
| Jianping Weng | 2017 | China | cluster | all ages | girls and boys | A high prevalence of type 1 diabetes at high latitudes (R2 = 0.25, p 0.0001) | [30] |

**4. Discussion**

According to their distance from the equator to the pole, the various regions of the earth are divided into different belts that are referred to as equatorial, tropical, subtropical, temperate, subarctic, and polar from a climate perspective. Some diseases are only found in specific areas of the world due to climatic factors and natural barriers like the ocean [31]. The climatic conditions of the area, which are an important component of the physical environment and depend on latitude, roughly determine the amount of temperature and sunlight, which can have a significant impact on human health, for multiple sclerosis, rheumatoid arthritis, and inflammatory bowel disease, increased autoimmunity has been noted at higher latitudes. Vitamin D deficiency has been linked to this relationship because of decreased sun exposure, and research has shown that vitamin D affects the immune system by maintaining and stimulating immune cells [32]. Due to variations in genetic and environmental factors, the prevalence of type 1 diabetes in various regions may vary. When individuals with HLA (3DR4-DR) genes, who are genetically predisposed to the disease, are in advantageous geographic locations, their likelihood of contracting the illness rises. Even though there is no denying that genetics is the primary cause of this disease, genetic predisposition cannot account for the variations in some parts of the world. As a result, additional factors are crucial in the development of this disease, though their importance and potency may vary depending on the region. The sun's ultraviolet radiation, which affects vitamin D, is another candidate factor that is frequently associated with this latitude and may be important in the causality. Latitude is also frequently used as one of the factors in geo-epidemiology. Without supplementation, the main source of 25-hydroxyvitamin D levels in the body is exposed to UVB

wavelengths of sunlight, which are dependent on the season and latitude [33].

After analyzing studies from 2000 to 2022, it was determined that, globally, the risk of type 1 diabetes increased with increasing latitude. As one moves away from the equatorial orbit and into higher latitudes, the incidence of type 1 diabetes increases. According to the findings of an Australian study, type 1 diabetes is prevalent in regions far from the equator, and it can be said that in low latitudes, high exposure to ultraviolet rays has an effect on vitamin D levels as a disease-protective factor [20, 34]. In tropical regions, the difference between day and night and summer and winter is minimal, whereas in temperate regions it is greater and reaches its greatest value at the North and South Poles [35]. This phenomenon affects people's exposure time to sunlight, which is considered a source of vitamin D [20]. According to research findings, the incidence of type 1 diabetes increases as one moves away from the equator and approaches northern latitudes. Also, the number of people with diabetes changes with the seasons. Most people have diabetes between December and February [36].

Finland and Sardinia have the highest rates of type 1 diabetes in the world (37–45 per 100,000 children under the age of 15), which is 400 times higher than Venezuela and some regions of China, which have the lowest rates (0.5–0.1 per 100,000 children). 15 years). The likelihood of developing diabetes rises as we move away from the equator [37]. Understanding the environmental factors that affect the disease not only helps to create the disease's current distribution map but also identifies how the disease's distribution may change as a result of geographic and climatic changes [33]. In medical geography, ecological and health studies of broad scope are used to address a variety of science-related issues on geography and medicine. In other words, the core of the field of medical geography is the study of the environmental and economic factors that influence human health and disease. The distribution of natural and human patterns according to their real-world interactions and internal connections that manifest in a specific location is the subject of new geography. In light of this idea, it can be said that medical geography investigates the patterns of disease distribution that are related to the circumstances and opportunities of local life. In other words, certain diseases spread in particular geographic areas and are impacted by those regions' characteristics [38]. The disease process in type 1 diabetes is likely started by an environmental stimulus in genetically predisposed individuals, and the rate of clinical onset may be influenced by environmental determinants [39]. Although the connection between vitamin D and type 1 diabetes has been extensively studied, this connection may be one of the factors contributing to the disease's higher prevalence in high latitudes. Other, unexplored explanations for the disease's occurrence in high latitudes may exist. For instance, socioeconomic status or a viral infection may be affected by latitude [40].

## 5. Conclusions

Environmental and genetic factors contribute significantly to the etiology of disease; therefore, if health policymakers pay attention to these factors in their research, the results can be beneficial for the health of society. Therefore, in the health and sanitation sectors, planning should be done based on the climatic, environmental, geological, etc. conditions of each region.

**Conflict of interest:**

The authors declared no conflict of interest.

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