

Climate Change and Type 2 Diabetes

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Abstract: Diabetes is a global epidemic impacting the lives of many people on a daily basis. At present, it is estimated that 366 million people are living with diabetes globally and this number is expected to increase by 50.8 percent to 552 million by the year 2030. Paralleling the epidemic of type 2 diabetes is the phenomena of climate change, which has long been overlooked. However, these environmental changes are no longer scenarios of the future and the effects of climate change are observable today through variable weather patterns and rising sea levels, to name a few. Together, these global issues are impacting the health and well-being of the world's most vulnerable populations, especially the health of women, children, the elderly, the poor and those in low socio-economic statuses (low SES), and those with underlying health conditions.

By observing the global impact of climate change on T2D and the future changes in this metabolic disorder's prevalence and incidence that may ensue, researchers may be able to curtail the detrimental effects of the associated comorbid conditions associated with diabetes (such as hypertension, cardiovascular disease and the Metabolic Syndrome) amongst the world's most susceptible individuals.

Keywords: Climate change, global health, type 2 diabetes, thrifty genotype hypothesis, metabolic syndrome, maternal-child health.

INTRODUCTION

Climate Change

The World Health Organization (WHO) estimates that the last 30 years of anthropogenic climate change has resulted in more than 150,000 deaths annually [1, 2]. Potential health impacts of climate change include temperature-related morbidity and mortality, injuries due to extreme weather events (i.e., flooding, tornadoes, hurricanes, and drought), water-, food-, and vector-borne infectious diseases, and respiratory and cardiovascular problems due to worsening air pollution and increased aero-allergen production [3]. Indirect effects of climate change can lead to malnourishment and starvation due to crop shortages, conflicts and increased urbanization due to demographic shifts in populations [4]. The health outcomes of climate change will disproportionately affect those more vulnerable -- including children, elderly, the socially isolated, and persons with chronic disease and mental health conditions.

The climate change factors that will have an effect on diet and nutrition are most important in order to glean the impact of climate change on the future burden of type 2 diabetes (T2D). With the predicted rises in sea levels, intermittent and variable precipitation and drought episodes, and increases in

extreme weather events, global agriculture and food production has and will continue to be affected worldwide (IPCC) [5]. As of 2009 approximately one billion people were undernourished, of which a third are children [6]. With the effects of climate change expected to impact food production due to the changes in precipitation levels, the burden of disease is expected to increase in low-to-middle income countries because the effects of climate change are expected to exacerbate the current trends of undernourishment and a high prevalence of T2D. Moreover, the predicted increase in extreme climate events -- heat waves, which are known to have a direct impact on health -- will alter the health status of people living with chronic conditions, thereby not only impacting the prevalence of the disease, but also increasing the difficulty in managing the symptoms [7].

Type 2 Diabetes

Diabetes is a global phenomenon impacting countless lives on a daily basis. Presently, it is estimated that 366 million people are living with diabetes globally and this number is expected to rise to 552 million by the year 2030 [8]. Not solely a cause of morbidity and mortality, diabetes also hinders economic growth and places a large financial burden on gross domestic product [8]. Obesity and T2D are complex metabolic disorders, caused by multiple genetic and environmental factors. In recent decades there has been a dramatic rise in the prevalence of T2D in the Western developed countries and the developing world [9]. The global rise in T2D is of

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concern to public health officials, as it is estimated that two thirds of all cases are now occurring in low and middle-income countries [10]. With an expected cost to hit \$490 million by the year 2030, the global epidemic of T2D has the capability to set back any economic progress made by the developing countries of the world. This statement is particularly true for Asia where 60% of the world's diabetic population resides, thereby leaving these countries at a great risk facing both a major health crisis, but also a major economic crisis due to a change or lack in available economic resources [10].

While the prevention and management of T2D as a chronic condition differs amongst men and women, when considering diabetes from a global perspective, the main emphasis should be on diabetes' unique impact during pregnancy and the "threat" it poses to the health of both a mother and her child [10]. According to the International Diabetes Federation (IDF) [11], gestational diabetes, an often overlooked form of diabetes affects only pregnant women; and therefore, calls for specialized attention for mothers and children. It is estimated that 60 million of women of reproductive age have T2D, and 15% have gestational diabetes; with 4% of the cases located in India alone (IDF) [11]. Because many of these cases go undiagnosed, the lives of both mothers and children continue to be at risk. In the long term, half of all women who have gestational diabetes tend to develop T2D within 5-10 years of delivery (IDF) [11]. Additionally, children of women with gestational diabetes are at a higher likelihood of being obese and a higher risk of developing T2D (IDF) [11]. If these issues are left unaddressed, they will continue to impact both the social, economic, and health livelihoods of these individuals, which affects not only the families on the micro level, but also the entire nation and the globe.

LITERATURE SEARCH

The inclusion criteria for this paper were broad searches of PubMed, CINAHL, and Science Direct. Articles were considered for inclusion if they were related to T2D in women and children. Specific keywords used in the literature searches consisted of combinations of "climate change AND T2D"; "chronic conditions AND climate change"; "global warming AND T2D"; and "maternal health AND T2D". Within these overarching themes, other searches were performed focusing on children, obesity, malnutrition, food shortages, unreliable food supplies, air pollution and extreme weather events. Research pertaining to developing countries was of particular interest as it is

the scope of this paper. Therefore, studies conducted in the Western world were used as tools of comparison.

Further to the above literature searches using the keywords mentioned, two separate searches were conducted on research relating to climate change and its impacts on T2D. Literature addressing the issue of climate change and its impact on food supply and agriculture were also included. Papers addressing issues in low and middle-income countries were included, while research from Western societies was of less importance. For T2D, general information was obtained by searching for T2D, cardiovascular disease (CVD), emerging chronic conditions and chronic epidemics worldwide. These searches were helpful in generating a literature "bank" on which further research could be added.

EFFECT OF CLIMATE CHANGE ON DIET AND NUTRITION

The International Diabetes Federation (IDF) has recognized that diabetes and climate change are two inter-related epidemics impacting human health at an accelerated rate (IDF) [11]. These concerns are addressed in a report compiled by the federation that emphasizes the increased risk for low- and middle-income countries (IDF) [11]. It has been established that these increased risks are caused by the impact that extremes in climate have on agriculture production, which in turn threaten food security [8].

Agriculture is most vulnerable to the impacts of climate change due to its high reliance on weather [12]. Extreme weather events as a result of climate change are a cause of great concern for those reliant on agriculture for food and income. These people tend to be poorer than their counterparts and dwell in rural areas [12]. In the Asia-Pacific region, more than 60% of the population relies on agriculture as a source of livelihood. In recent decades, the impacts of climate change have been felt by the Asia-Pacific region with more intense and frequent weather events such as droughts, cyclones, floods, and hailstorms [12]. Consequently, crop production fails and food shortage occurs.

Thrifty Gene Hypothesis

The thrifty gene hypothesis is often used to explain why T2D persists in the global environment today. The premise of this hypothesis is "adaptations that allowed an organism to rapidly lay down fat in times of food surplus would have a survival advantage" in periods of

food shortages and famine [13]. These adaptations that were advantageous in the past have now been rendered useless due to the increase in food supply globally [13]. Instead they are problematic as the body continues to maximize fat storage in an environment where there is a surplus of food.

The thrifty phenotype hypothesis focuses on nutritional influences in early life and how that impacts a disease onset in adulthood. This concept formulated by Hales and Barker [14] asserts that a fetus that is undernourished perhaps through maternal undernutrition undergoes metabolic adaptations to increase its chances of survival [13]. These adaptations can then become fixed and be of benefit to the individual if he or she lives in an environment with a shortage of food supply [13]. The problem arises when the child slowly shifts away from this environment towards one in which food is plentiful. The body's adaptive mechanisms remain in place and cause more harm than good.

Thrifty Gene Hypothesis and Metabolic Disorders

According to the thrifty genotype hypothesis, the high prevalence of T2D and obesity is a consequence of genetic variants that have undergone positive selection during historical periods of erratic food supply [15]. In the current climate of sedentary lifestyle and over-abundance of food, this thrifty genotype is suggested to lead to metabolically disadvantageous phenotype [15]. This hypothesis is one of the leading evolutionary theories explaining the global rise of obesity, T2D, and associated co-morbid conditions (such as the Metabolic Syndrome/MetS). This hypothesis proposes the existence of thrifty genes that promote more efficient food utilization, fat deposition, and rapid weight gain during times of food abundance and confer to their carriers a higher chance of survival during famine times [16]. In ancient era of cycles of feast and famine, adaptation of these thrifty genes to the ancient "hunter-gatherer" lifestyle occurred [16]. In our current and modern society with excess energy availability, sedentary lifestyle, dependency on cars, mobile technology, and neighbourhood design effects these genes became maladaptive and unresponsive to surmounting demands of modern society leading to high prevalence of metabolic disorders such as obesity, T2D, and the MetS [17].

Thrifty Gene Hypothesis and Maternal-Child Health

With the knowledge that climate change impacts agriculture adversely and many residents of low- to

middle- income countries rely on agriculture for food -- there is a possibility of fluctuating food supply depending on the time of year and the severity of the climate event. Women who are pregnant in these conditions will not fulfill their nutritional requirements and will likely be undernourished. This in turn means that their fetus will also be undernourished. The thrifty phenotype hypothesis plays an important role here as it dictates that the fetus will undergo adaptations that allow it to survive in a nutrient-deficient environment. Children born under these conditions will prosper in the years that the food shortage persists. However, because climate change causes erratic weather patterns, it is expected that food supply will fluctuate. Once food is available again, children with these adaptations will be at a disadvantage. While they begin to intake a normal calorie diet, their bodies will still feel that they are in a deficient environment and try to maximize energy from each meal. This would in turn lead to storage of fat and ultimately to obesity. This would be perpetuated further if the child was to move to the urban environment where globalization has made its mark with the spread of fast food chains. As obesity is the major independent risk factor for T2D, the development of this chronic disease in these children is almost an inevitable result or outcome.

KNOWLEDGE GAPS

This paper briefly outlines the effect of climate change on the global rise of T2D, and how it relates to maternal and child health. Due to the novelty and growing importance of this topic, there is yet a lot to be learned about this complex relationship between climate change and T2D and other metabolic disorders such as the Metabolic Syndrome (MetS). Most of the literature that was found and reviewed herein covered the two topics of climate change and T2D as separate entities. Furthermore, there is lack of understanding and research as to how the triad of climate change, T2D, and maternal-child health are inter-related.

It has taken 25 years for climate change and global health to be recognized as requiring attention and to be positioned on the international health agenda [18]. There is still much to be studied in this important area. Moreover, further research on the indirect health impacts of climate change have yet to be studied in detail, such as how climate change impacts the prevalence of water-borne and vector-borne diseases.

There is very little research studying the linkage between the indirect effects of climate change and

T2D, and much less with a focus on developing nations. These nations are experiencing an escalating rise in T2D and there are many areas that need to be explored. More research is required in terms of how climate change is impacting food production in developing countries, and what this means for populations who are heavily reliant on agricultural products. Globalization and urbanization have the ability to shift dependence from agriculture to other sources of livelihood which may not be as reliant upon the weather as agriculture, and such a shift would change the assumption of inadequate food supply.

Diabetes in women and diabetes in pregnancy (gestational diabetes) also needs to be explored in a more specific focus in relation to climate change. Gestational diabetes in women with multiple pregnancies and the likelihood of their children developing diabetes regardless of childhood nutrition should also be explored. Before climate change and diabetes can be connected further, more overall foundation knowledge on the development of diabetes in women living in rural areas needs to be explored. Socioeconomic status (SES) plays a large factor in health status and can change how one perceives their own health to be. Women who are pregnant and socioeconomically disadvantaged (i.e., in low socioeconomic status/SES) may experience diabetes in a way that is distinct from their counterparts who are well off (i.e., in higher SES). It is possible that women of low SES may experience nutritional scarcity in times of food surplus. This may be due in part to the cultural and social norms of providing food for their spouses and their children before their own needs, but also may be largely due to food insecurity attributable to low SES.

DISCUSSION

Research in both the developing and developed countries concerning women and children has the added challenge of taking into account the social determinants of health, which include education attainment, household income level, and employment/occupation status [19]. This is true whether one resides in the Western world or in low and middle-income countries. However, environmental, social, and ecological factors play a role in determining which social determinants are more important and relevant. For example, women living in the developing countries may face certain socio-cultural constraints in comparison with women living in the Western world. Women of low SES tend, on average, to often bear

multiple children and head all major household chores in addition to other general responsibilities [18]. Due to this, the health of women becomes very significant in the well-being of the family. Women living in poverty are expected to complete their core responsibilities and duties with the available funds which may not always be sufficient. In such cases, the health and well-being of their spouses and children are put forth before their own. This may mean that in times of food shortages, women are impacted the most.

Type 2 Diabetes (T2D) and climate change are two inter-related epidemics facing the global population today. It is clear that both are challenges recognized on the international level in terms of requiring some level of intervention. Of particular concern, is T2D in women in developing countries due to its impact on both fetal growth and child health and development. Gestational diabetes has begun to generate more recent attention due to the impact it can have on the development of chronic conditions in children.

Climate change has been recognized as an issue on the global forefront and has been receiving a lot of attention on the international arena. Much of the international attention of climate change effects have focused on broader issues such as the direct impacts of climate change on infectious diseases. Nonetheless, climate change and its effect on chronic conditions is now beginning to be explored. This research is important so that it is possible to see how much of T2D prevalence can be attributed to climate change. As mentioned in this paper, there are many missing gaps that need to be fully explored to understand the scope of the problem. A key overarching theme appears to be a lack of literature on this topic in developing countries. As this topic is relatively new, much of the research seems focused on affluent and prosperous countries. It is concerning however to note that countries that are being impacted the most are not being studied (i.e., the developing countries).

International collaborative action combating both issues would be an ultimate way to address the problem at hand. Recognizing climate change and T2D as global health issues has been a first step in the right direction, drawing support from multiple sources. Framing the two issues together as global health challenges is a good way to combat two important problems at once. The relationship between the two is novel and newly recognized -- it will take a long time for action to occur globally and internationally to address

this triad of climate change, type 2 diabetes (T2D), and maternal-child health together.

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