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REVIEW

Racial/ethnic differences in the burden of type 2 diabetes over the life course: a focus on the USA and India

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Abstract

Type 2 diabetes is a common disease worldwide, but its prevalence varies widely by geographical region and by race/ethnicity. This review summarises differences in the frequencies of type 2 diabetes according to race, ethnicity, socioeconomic position, area of residence and environmental toxins. Type 2 diabetes susceptibility often begins early in life, starting with genetic susceptibility at conception and continuing in later life, via in utero, childhood and adult exposures. Early-life factors may lead to overt type 2 diabetes in childhood or in later life, supporting the concept of developmental origins of health and disease. The causes of the racial/ethnic differences in incidence of type 2 diabetes are not well understood. Specifically, the relative contributions of genetic and environmental factors to such differences are largely unknown. With a few exceptions in isolated populations, there is little evidence that differences in frequencies of known type 2 diabetes susceptibility genetic alleles account for racial/ethnic differences, although the search for genetic susceptibility has not been uniform among the world's racial/ethnic groups. In the USA, race/ethnicity is associated with many other risk factors for type 2 diabetes, including being overweight/obese, diet and socioeconomic status. Some studies suggest that some of these factors may account for the race/ethnic differences in prevalence of type 2 diabetes, although there is inadequate research in this area. A better understanding of the impact of these factors on type 2 diabetes risk should lead to more effective prevention and treatment of this disease. This has not yet been achieved but should be a goal for future research.

Keywords Life course development · Race/ethnicity · Review · Type 2 diabetes mellitus

Abbreviations

GDM Gestational diabetes mellitus
NHIS National Health Interview Survey
SES Socioeconomic status

Introduction

Type 2 diabetes is a common disease worldwide, but its prevalence varies widely by geographical region and by race/ethnicity. For example, Fig. 1 shows age-specific prevalence of diagnosed diabetes in the USA, according to self-reported race/ethnicity. In older adults (≥75 years of age), prevalence ranges from 17.7% in non-Hispanic white individuals to 45.2% in American Indians/Alaska Natives [1].

Type 2 diabetes is considered a complex disease, in that many known genetic, environmental and personal behavioural risk factors affect disease susceptibility and few, if any, variables are completely determinative. Other, yet undiscovered, risk factors also likely contribute to this disease. In this article, we review these complex causes and discuss the extent to which they may explain the racial/ethnic differences in type 2 diabetes prevalence. We focus on research from the USA and India, regarding factors influencing the development of type 2 diabetes, rather than those influencing management and consequences of the disease, such as the development of acute

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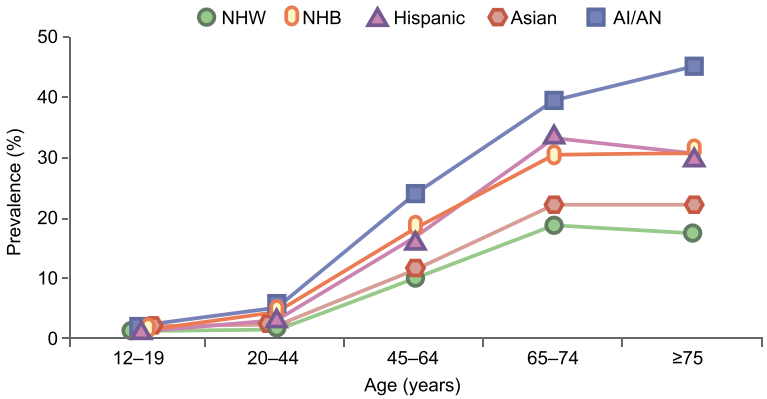

Fig. 1 Age-specific prevalence of diagnosed diabetes in the USA by race/ethnicity. Data from the NHIS, 2011–2015, reported in [1]. AI/AN, American Indian/Alaska Native; NHB, non-Hispanic black; NHW, non-Hispanic white. This figure is available as part of a downloadable slideset

metabolic and chronic vascular complications. Because the incidence of complications is strongly related to duration of diabetes, factors leading to younger age of onset of type 2 diabetes are also associated with greater prevalence of complications over the lifetime, but whether differences in the prevalence or incidence of complications are due to factors other than those leading to type 2 diabetes itself is beyond the scope of this review. While not a meta-analysis or systematic review, this paper includes findings that we consider representative and relevant to racial/ethnic differences in type 2 diabetes susceptibility.

Although previously considered primarily a disease only of adults (and formerly called 'adult-onset diabetes'), what is now called type 2 diabetes also occurs in children. Evidence suggests that susceptibility often begins early in life, starting at conception, owing to genetics, and continues in later life via in utero, childhood and adult exposures. Early-life factors may lead to overt type 2 diabetes in childhood or later, confirming the concept of developmental origins of health and disease.

Although race and ethnicity are associated with health and disease incidence [2–4], these terms have not been used consistently in the medical literature. In the USA, 'race' indicates continent or region of ancestral origin and 'ethnicity' (Hispanic or not) indicates cultural identity. Hispanic ethnicity refers to people who identify with a Spanish-speaking culture. Any racial group may also identify as Hispanic or non-Hispanic. Thus, in the USA 'non-Hispanic black' refers to people of African descent who do not identify as Hispanic; 'non-Hispanic white' refers to those with ancestry from Europe or the Mediterranean who do not identify as Hispanic; Asian-American refers to individuals of East Asian, South Asian, South East Asian and Pacific Island ancestry; and American Indian/Alaska Native to descendants of the original inhabitants of the Americas [5, 6]. These categories are based on self-report and include heterogeneous groups. Analogous terms are not used uniformly in other parts of the world. In this review, when studies are discussed that use more specific terms in defining racial/ethnic subgroups, we will use them accordingly.

Genetics and differences in diabetes prevalence

Given the many genetic differences among racial/ethnic groups and the well-recognised genetic influences on type 2 diabetes, genetic factors probably account, in part, for the differences in diabetes prevalence. However, few studies have quantified the contributions of genetic factors to these racial/ethnic differences. In Mexican-Americans, a higher proportion of American Indian ancestry, determined by skin reflectance, was associated with higher prevalence of diabetes [7]; similar findings were seen in Pima Indians, with American Indian ancestry determined by self-report [8]. Studies that used 'traditional' genetic markers, such as blood groups, to estimate American Indian heritage also found positive associations with diabetes in Pima and Mexican-American populations [9–11]. With the advent of modern genetic techniques, large numbers of ancestry-informative genetic markers can be typed, resulting in more robust estimates of genetic ancestry. Studies using these techniques in Hispanic populations have also found that a higher level of American Indian ancestry is associated with higher prevalence of diabetes [12–15]. However, American Indian ancestry was also associated with socioeconomic status (SES), and adjustment for SES greatly attenuated the risk associated with genetic admixture. In studies of African-American individuals, a higher proportion of African ancestry was associated with increased prevalence of diabetes and this finding persisted with adjustment for SES [16]. Given the imprecision in assessing environmental sociocultural factors shared within ancestry groups, genetic ancestry associations may be confounded by environmental factors. One might expect comparisons of genetic ancestry estimates within sibships to be robust to such confounding, but such studies require large sample sizes and large numbers of genetic markers to confidently assess the modest differences in genetic admixture among siblings.

Genome-wide association studies have now identified over 200 genetic variants that are reproducibly associated with type 2 diabetes across multiple racial/ethnic groups [17]. Most

have small effects on diabetes risk, but a few, which are rare in most global populations, have strong effects. A few of these rare variants are considerably more common in certain, relatively isolated populations, and these variants may explain a substantial portion of the excess risk in these isolated populations. Examples include an *HNF1A* variant in Oji-Cree Indians and a *TBC1D4* variant in Inuit people [18, 19]. For multiple 'established' diabetes variants, one approach to assessing the importance of genetic factors in racial/ethnic differences is to compare allele frequencies across these susceptibility variants, for example, by analysis of polygenic risk scores. Several studies have shown that allele frequencies diverge markedly at established type 2 diabetes susceptibility variants across continental ancestry groups, with the greatest genetic risk occurring in African populations, the lowest genetic risks in East Asians and American Indians, and an intermediate risk in Europeans (for example, see Fig. 2) [20–23]. This pattern does not correspond to the epidemiological risk of diabetes, which is highest in American Indians and, thus, these allele frequency differences cannot account for the high prevalence of diabetes in American Indians, though they may partially explain some of the differences between African-Americans and European-Americans [23]. These studies were conducted with relatively small numbers of established variants, and they are limited by incomplete ascertainment of genetic variants influencing diabetes (many likely remain unknown) and by incomplete knowledge of the causal variants underlying the associations (which may differ across race/ethnicities due to different linkage disequilibrium patterns).

Early-life risk factors for type 2 diabetes

Some evidence of early-life determinants of type 2 diabetes comes from India and is discussed here as a model of diabetes susceptibility in economically deprived societies. With rapid economic growth, India has had an alarming rise in type 2 diabetes prevalence out of proportion to its increase in affluence [24]. The rise has been most pronounced in the states that have suffered financial, geographical or sociopolitical difficulties. This points towards a role for previous deprivation in the evolution of the diabetes epidemic. Traditionally, type 2 diabetes susceptibility is ascribed to a 'thrifty genotype' that evolved over millennia. However, the 'thrifty phenotype' hypothesis [25] suggests a more recent establishment of susceptibility through epigenetic programming due to enhanced survival in the setting of intergenerational undernutrition, especially during the first 1000 days of life (intrauterine and first 2 years). Thus, intergenerational influences seem to operate both genetically and epigenetically.

Adults with type 2 diabetes in the Indian subcontinent differ in phenotype from the 'textbook' description of European individuals [26]. The differences may be explained, at least in part, by early-life exposures. Indian individuals with type 2 diabetes are diagnosed at least a decade earlier and have a lower BMI but higher central obesity at diagnosis [27]. Body fat percentage in Indian populations is higher than that in European individuals at a given BMI [28, 29]; this 'thin-fat' phenotype is associated with higher insulin resistance and diabetic dyslipidaemia. Recent investigations also revealed that Indian people with type 2 diabetes have reduced beta cell function compared with Europeans [30]. This phenotype is clearly not attributable to adult lifestyle factors only; a comparison of newborn Indian and English babies revealed that it originates during intrauterine development [31], supporting the 'thrifty phenotype' hypothesis [25, 32]. This 'thin-fat' and impaired beta cell function phenotype suggests a new explanation for the high susceptibility of Indian individuals to type 2 diabetes since more than a quarter of Indian babies have low birthweight (<2.5 kg), multigenerational undernutrition with small maternal size is common, and Indian babies are among the smallest in the world. A small and thin Indian newborn (mean weight 2.7 kg) has comparable subscapular skinfold thickness to an English baby (mean weight 3.5 kg) [32] and higher subcutaneous and visceral fat as assessed by MRI [33]. The cord blood of Indian babies also has higher concentrations of leptin and insulin, but lower concentrations of adiponectin, confirming a high-risk profile for future type 2 diabetes [34]. The contribution of genetics and epigenetics to this phenotype is currently being actively investigated [35, 36].

The Pune Children's study demonstrated that children born small had higher glucose and insulin concentrations during a glucose tolerance test [37]. Babies born small who grew to have high fat mass later in childhood had the highest levels of risk factors for type 2 diabetes and cardiovascular disease (insulin resistance, high adiposity, lipid abnormalities and high blood pressure) [38]. The Delhi cohort expanded these findings in young individuals with glucose intolerance: glucose intolerant individuals were born smaller compared with glucose tolerant participants, grew poorly in the first 2 years of life, and then progressively increased in weight and BMI until adult age. Though not obese by international criteria, individuals who had greater weight gain in relation to their early years were at higher risk of type 2 diabetes [39].

This life course trajectory exemplifies the risk of 'double burden' of malnutrition on lifetime risk for type 2 diabetes, a common situation in the developing populations of the world. The 'dual teratogenesis' construct [40] describes the progressive evolution of risk factors and type 2 diabetes in the intergenerationally undernourished who tend to be 'thin-fat', insulin resistant and beta cell deficient in rural environments, but become obese and glucose intolerant when they live in more urbanised conditions. Urbanisation produces an unmanageable load of overnutrition and physical inactivity on a multigenerationally low capacity system [41, 42]. This is

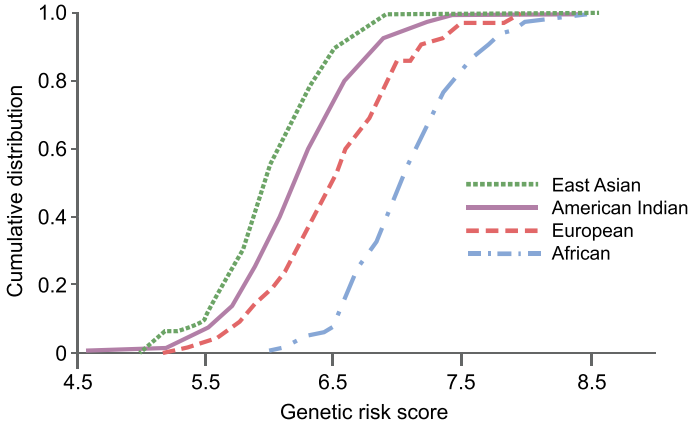

Fig. 2 Cumulative distribution of genetic risk score for type 2 diabetes, calculated by summing the number of risk alleles weighted by the published effect size across 63 established variants, in different racial/ethnic groups. American Indians were Pima Indians who participated in a longitudinal study; the other populations were derived from the International HapMap project and included Han Chinese individuals from Beijing (East Asians), Centre d'Etude du Polymorphisme Humain families from Utah (Europeans) and Yoruba people from Ibadan Nigeria (Africans). A rightward shift of the curve is suggestive of a higher genetic risk for type 2 diabetes. Adapted from [23], American Diabetes Association (2015). Copyright and all rights reserved. Material from this publication has been used with the permission of American Diabetes Association. This figure is available as part of a downloadable slideset

supported by the finding that urban middle-class Indians were more insulin resistant than urban slum dwellers and individuals living in rural areas [43]. In addition, beta cell responses in South Asian individuals were incommensurate with the degree of insulin resistance, signifying beta cell dysfunction [44] and suggesting that pancreatic development is suboptimal in early life.

Diet probably plays a major role in influencing intergenerational susceptibility to type 2 diabetes. In Indian and other populations in which vegetarianism is common, there is a substantial prevalence of vitamin B_{12} deficiency. Maternal vitamin B_{12} deficiency and hyperhomocysteinaemia are related to poor fetal growth, and subsequent insulin resistance and adiposity in childhood [45]. High folate status worsens the situation, suggesting that a balance between vitamin B_{12} and folate is essential. Moreover, Indian diets are associated with macronutrient imbalances; they tend to be high in energy and carbohydrates and have a high glycaemic index [46]. In addition to diet, South Asians, as a group, seem to be less physically active than their European counterparts [47]. All these factors combine to bring about the higher, earlier susceptibility to type 2 diabetes in South Asian populations.

Prevalence and incidence of type 2 diabetes in youth

There are limited global data on prevalence and incidence of newly diagnosed type 2 diabetes in children and adolescents. Among the earliest reports of type 2 diabetes in children were those from the Pima Indians, where prevalence was based on case finding by glucose tolerance testing [48]. The prevalence of type 2 diabetes in youth has increased over time in the Pima Indian population; for example, in girls aged 15–19 years, type 2 diabetes prevalence increased from 2.73% in 1967–1976 to 5.31% in 1987–1996, while, in boys, it increased from 2.43% to 3.78% over the same time periods [49]. Much less is known about type 2 diabetes in children in other populations because most studies have relied on clinical diagnoses rather than case finding by glucose tolerance testing, unlike the Pima Indian studies. Data on clinically diagnosed type 2 diabetes in different racial/ethnic groups were obtained in the SEARCH for Diabetes in Youth Study [50]. Prevalence of type 2 diabetes was generally very low in children aged 0–9 years, regardless of race/ethnic group. The highest reported prevalence was observed in American Indian children and adolescents: 0.021 and 1.45 per 1000 people at 0–9 and 10–19 years of age, respectively (Table 1). In non-Hispanic black children and adolescents aged 10–19 years, the prevalence was slightly lower than in American Indian children and adolescents (1.06 per 1000 people). The SEARCH study ascertained incidence rates of clinically diagnosed type 2 diabetes from 2003 through to 2012. Rates were lowest and more stable, or increased only slightly in most USA race/ethnic groups, but were highest and increased rapidly over the study period in non-Hispanic black and American Indian/Alaska Native youth (Fig. 3) [51]. The reported diabetes prevalence in Asian/Pacific Island and Hispanic-American children and adolescents aged 10–19 years is 0.52 and 0.46 per 1000 people, respectively (Table 1) [52–54], while non-Hispanic white children and adolescents have a very low prevalence of type 2 diabetes at 10–19 years of 0.18 per 1000 people. During 2011–2012, 5300 children and adolescents aged 10–19 years were diagnosed with type 2 diabetes and the incidence rates were higher among USA youth in minority groups (especially non-Hispanic black individuals and American Indians) compared with non-Hispanic white youth [55].

Table 1 Prevalence of diagnosed type 2 diabetes in youth in the USA by race/ethnicity

Race/ethnicity	Type 2 diabetes prevalence (per 1000 people)		Reference
	0–9 years	10–19 years	
Non-Hispanic white	0.0046	0.18	[55]
Non-Hispanic black	0.0005	1.06	[52]
Hispanic-American	0.0003	0.46	[53]
Asian and Pacific Islander	0.014	0.52	[54]
American Indian	0.021	1.45	[50]

In some racial/ethnic groups, in utero and infant conditions are risk factors for obesity or type 2 diabetes in later life. In studies in India, as described above, small size at birth and nutritional deficiencies (e.g. in vitamin B_{12}) [45] are associated with other diabetes risk factors. In Pima Indians in the USA, exposure to maternal diabetes in utero is a strong risk factor for obesity and type 2 diabetes in the offspring, especially in childhood and early adulthood [56, 57]. Because type 2 diabetes often develops before or during childbearing years, the daughters of mothers who had diabetes during pregnancy then perpetuate the process during their own pregnancies, thus leading to a vicious cycle of diabetes in one generation begetting diabetes in the subsequent generation, as illustrated in Fig. 4 [48]. This cycle has resulted in increasing obesity and type 2 diabetes prevalence and incidence rates over a period of several decades; it is estimated that the type 2 diabetes risk attributable to exposure to diabetes in utero increased from 18.1% in 1967–76 to 35.4% in 1987–1996 [49]. Increased type 2 diabetes incidence in children and young adults exposed to maternal type 2 diabetes in utero has also been observed in Hispanic-Americans and other populations [58]. The prevalence of pre-existing diabetes in pregnancy in the USA was estimated to vary almost threefold, from 0.60% in non-Hispanic white individuals to 1.72% in American Indians/Alaska Natives [59]. Being overweight and obese contribute to gestational diabetes mellitus (GDM), defined as diabetes or impaired glucose tolerance first recognised in pregnancy. In California (USA), the estimated prevalence of GDM in pregnancies during 2007–2009 ranged from 5.4% in white women to 11.9% in Asian/Pacific Island women. The fraction of GDM attributed to being overweight or obese ranged from 41.2% in white women to 57.8% in American Indians [60].

We hypothesise that the effects of low birthweight, early nutritional deficiencies, and in utero exposure to maternal type 2 diabetes are not limited to any racial/ethnic group, but are magnified in certain groups with high risk of young-onset type 2 diabetes, especially American Indians. The vicious cycle of transgenerational inheritance of diabetes risk probably exists in all populations in which type 2 diabetes occurs before reproductive age, but it may be evident only in those racial/ethnic groups in which type 2 diabetes frequently occurs at young ages. This likely explains the more rapid rise in incidence of type 2 diabetes from 2003–2012 in American Indians and non-Hispanic black individuals vs other racial/ethnic groups in the USA, in which rates were lower at the start of the study (Fig. 3) [51]. Similarly, the effects of early nutritional deficiencies and developmental delays are likely to have the greatest population-level impact and, thus, be most evident in racial/ethnic groups that have higher type 2 diabetes incidence rates at young ages.

Prevalence and incidence of type 2 diabetes in adults

Diabetes in adults: prevalence In the USA, an estimated 12.2% of adults (age ≥18 years), or 30.2 million people, have diabetes; the prevalence of diagnosed and undiagnosed diabetes are 9.3% and 2.9%, respectively [55]. The highest prevalence of diagnosed diabetes was observed among American Indians/Alaska Natives (Table 2). Non-Hispanic white individuals and Asian-Americans have similar prevalences of diabetes, whereas, in comparison, the non-Hispanic black population and Hispanic-Americans overall have higher prevalences (Table 2). Among Hispanic-American populations,

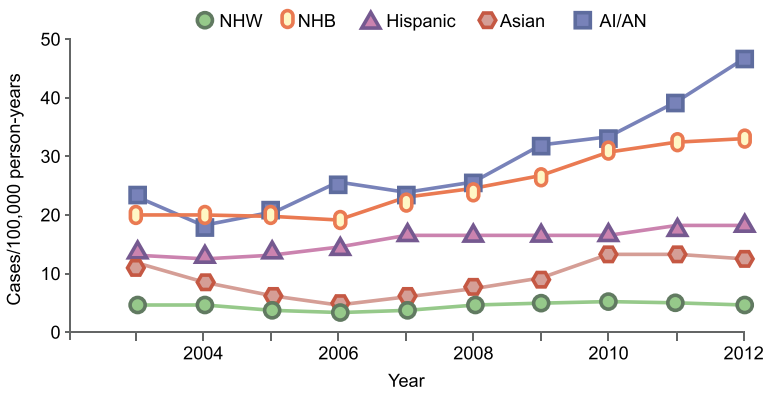

Fig. 3 Incidence of diagnosed type 2 diabetes in youth (aged 10–19 years) in the USA by race/ethnicity according to the SEARCH study. This figure was created using data in Table 2 of reference [51]. AI/AN, American Indian/Alaska Native; NHB, non-Hispanic black; NHW, non-Hispanic white. This figure is available as part of a downloadable slideset

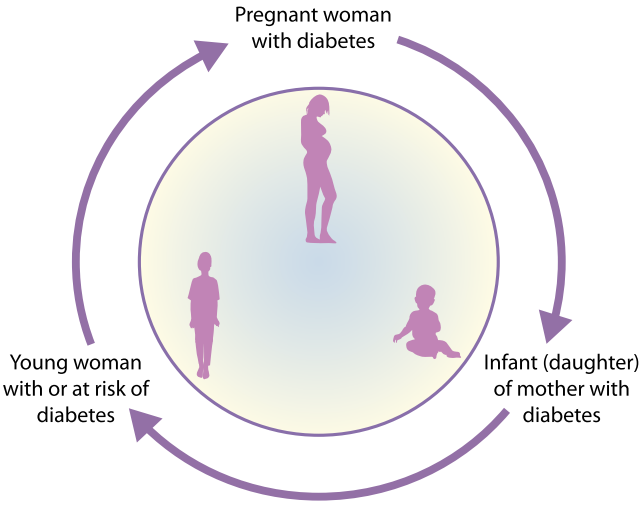

Fig. 4 Infants of mothers with diabetes, at least in high-risk populations such as American Indians, are at high risk of developing diabetes as children and young adults. By the time they become pregnant, these female offspring may already have diabetes and, thus, perpetuate this vicious cycle. Adapted from [48], with permission from John Wiley and Sons. This figure is available as part of a downloadable slideset

prevalence varies based on country of origin. Mexican-Americans had the highest prevalence of diabetes, followed by Puerto Ricans, Cubans and Central/South Americans. Diabetes prevalences among Asian-Americans also differ by countries of origin, being highest among Asian Indians and lowest among people from China [55]. The racial/ethnic differences in type 2 diabetes prevalence in the USA are likely to be confounded and modified by SES, body size and diet. In the Boston Area Community Health Survey, SES was associated with race/ethnicity, but SES was more strongly related to type 2 diabetes than was race/ethnicity; when adjusted for SES, black and Hispanic race/ethnicity was no longer significantly associated with the prevalence of type 2 diabetes [61]. In the Multi-Ethnic Study of Atherosclerosis in the USA, the effect of BMI in predicting incident diabetes differed significantly by race/ethnicity, being greatest in Chinese–Americans and lowest in black individuals [62]. In contrast, in the same study, there was no significant interaction of race/ethnicity with dietary patterns in predicting diabetes [63].

Table 2 Age-adjusted prevalence of diagnosed type 2 diabetes in the USA by race/ethnicity in adults ≥18 years of age [55]

Racial/ethnic group	Age-adjusted prevalence (%)
Non-Hispanic white	7.4
Asian-American	8.0
Hispanic-American	12.1
Non-Hispanic black	12.7
American Indian/Alaska Native	15.1

Table 3 summarises the age-adjusted prevalence of diabetes in various regions of the world [64]. In 2017, 365 million people worldwide had a diagnosis of diabetes. The Western Pacific region had the highest number of individuals (159 million) diagnosed with diabetes, with an age-adjusted prevalence of 8.6%. The North America/Caribbean region had the highest prevalence (11.0%) and Africa had the lowest prevalence (4.4%); however, the Africa region has the highest proportion of undiagnosed diabetes (≥70%) [64].

The Indian subcontinent is an epicentre of diabetes burden [10, 65]. India is second only to China in the number of people with diabetes. There is great population diversity within India, and data are available by state, urban/rural residence, and socioeconomic position, but not by 'race/ethnicity' as defined in the USA. The South Asian region is expected to have the world's largest number of individuals living with diabetes by 2030 [30]. The prevalence varies by country within the South Asian region, with India having the largest burden.

There have been a large number of epidemiological reports of diabetes prevalence in India over the last 30 years, most from South India. The recently reported Indian Council of Medical Research–India Diabetes (ICMR–INDIAB) study was the largest population-based study, carried out over 15 states, representing half of India's vast population [24]. The overall prevalence of diabetes was estimated at 7.3%. Highlighting the heterogeneity of the population of India, there was wide variation in the prevalence of type 2 diabetes in different states, which paralleled the per capita gross domestic product (GDP). Prevalence was higher in urban vs rural areas. While diabetes was higher among the affluent in rural areas, in urban areas it was more common in those with lower socioeconomic scores [24].

The rise in diabetes prevalence in India parallels a worldwide rise from 4.7% in 1980 to 8.5% in 2014 [66]. In a recent comparison between two surveys in the southern Indian state of Tamil Nadu, using similar methods carried out 10 years apart (2006 and 2016) [67], diabetes prevalence increased significantly in a city (from 18.6% to 21.9%), a town (16.4% to 20.3%), and in peri-urban villages (9.2% to

Table 3 Age-adjusted prevalence of diagnosed type 2 diabetes in adults aged 20–79 years, in different regions of the world in 2017 [64]

Region	Age-adjusted prevalence (%)
Africa	4.4
Europe	6.8
Middle East and North Africa	10.8
North America and the Caribbean	11.0
South and Central America	7.6
South East Asia	10.1
Western Pacific	8.6

13.4%). At both time points, there was an urban–village gradient, with prevalences being highest in the city (defined as having a population ≥4 million) and lowest in villages, where occupations were primarily agricultural. In addition to age and family history of diabetes, central obesity was associated with increases in prevalence.

Diabetes prevalence and migration Studies that compare prevalence of diabetes in migrants to that of individuals in their country of origin can yield information about the importance of environmental factors, under the assumption that the two groups are genetically similar. In general, migrants to more urbanised, industrialised countries have a higher prevalence of diabetes than individuals in their countries of origin [68]. For example, populations of African origin living in the USA or the UK have higher prevalence of diabetes than those living in African countries, whereas prevalence is intermediate in individuals of African ancestry living in Jamaica [69, 70]. Similarly, migrants from the Polynesian atoll of Tokelau living in New Zealand had a higher risk of diabetes than those who remained in Tokelau [71], and second-generation Indian immigrants in Singapore had a higher prevalence of diabetes than first-generation migrants [72]. On the other hand, in a comparison between Indians living in the USA and those living in urban India (Chennai), those in India had higher prevalence of diabetes than the Indian-Americans [73]. In addition, the prevalence of diabetes in urban Ghana was much higher than in rural Ghana and comparable with that of African-origin populations in urban Europe [74]. Moreover, among Peruvians who migrated from rural to urban areas, the risk of developing diabetes was much higher than among those who remained in the rural regions [75]. These studies implicate environmental factors associated with urbanisation as contributing to the high risk of diabetes in migrant populations.

Diabetes in adults: incidence In adults from the USA, aged ≥18 years, there were approximately 1.5 million new cases of diabetes according to the National Health Interview Survey (NHIS) in 2015 [55]. The annual age-adjusted incidence of diagnosed diabetes was higher in non-Hispanic black individuals (9.0 per 1000 people) and individuals of Hispanic origin (8.4 per 1000 people) compared with non-Hispanic white individuals (5.7 per 1000 people) and Asians (6.0 per 1000 person-years). Overall diabetes incidence in the NHIS increased rapidly during 1990–2008, followed by a levelling off and then a decrease from 2008–2012; however, this primarily occurred in non-Hispanic white individuals, while the incidence continued to rise in non-Hispanic black people and Hispanic individuals during this same time period [1]. We were unable to identify regional data on worldwide diabetes incidence.

Other factors that may contribute to racial/ethnic differences in type 2 diabetes

Genetic variation, as discussed above, is an obvious candidate that may explain racial/ethnic variation in type 2 diabetes. A limitation is that most research on genetics of diabetes has been conducted in the USA, Europe or eastern Asia, but most areas of the world have not been well represented. Therefore, genetic variants that may have large effects but are found only in some populations may not have been discovered. Factors in the external environment must also be considered. Arsenic is a naturally occurring toxin in many parts of the world. Exposure to it has been associated with the prevalence of type 2 diabetes in several different countries, including Bangladesh [76, 77], Mexico [78] and the USA [79, 80]. Environmental exposure to persistent organic pollutants and several heavy metals has also been associated with diabetes [81–83]. There is also evidence that infection with the hepatitis C virus, and perhaps other viruses, may increase diabetes risk [84]. Such environmental factors vary geographically, so they may increase diabetes incidence in areas that are inhabited predominantly by certain racial/ethnic groups. Thus, some racial/ethnic differences in disease susceptibility could be caused by environmental exposures that differ by race/ethnicity. If the environmental exposures are not known or considered, these differences could be erroneously attributed to genetics or other factors.

Race/ethnicity in preventing type 2 diabetes

Despite the large differences in diabetes incidence rates among different populations around the world, the progression from high-risk states (such as being overweight or obese with impaired glucose regulation, or so-called ‘prediabetes’) to overt diabetes has been shown to occur at similar rates and responded similarly to preventive interventions among different racial/ethnic groups in the USA Diabetes Prevention Program [85]. Most behavioural or medical interventions for diabetes prevention have worked in racially/ethnically diverse populations around the world [86]. The achieved reductions in rates of type 2 diabetes incidence differed among clinical trials conducted in different countries, but the differences may be due to differences in the types or intensities of interventions among the studies rather than race/ethnicity. To our knowledge, only the USA Diabetes Prevention Program compared effects of the same interventions given to different racial/ethnic groups; the effects of the metformin and lifestyle interventions on reducing progression to type 2 diabetes did not differ significantly by race/ethnicity [85]. Thus, despite the racial/ethnic differences in diabetes prevalence, current methods for diabetes prevention are the same across racial and ethnic categories.

Conclusions

This review summarises differences in the frequencies of type 2 diabetes according to race, ethnicity, socioeconomic position, area of residence and environmental toxins. The causes of these differences are not well understood. Specifically, the relative contributions of genetic and environmental factors to racial/ethnic differences are largely unknown. With a few exceptions in isolated populations, there is little evidence that differences in frequencies of known type 2 diabetes susceptibility genetic alleles account for racial/ethnic differences in type 2 diabetes, although the search for genetic susceptibility has not been uniform among the world's racial/ethnic groups. In the USA, race/ethnicity is associated with many other risk factors for type 2 diabetes, including being overweight/obese, diet and SES. Some studies suggest that some of these factors may account for the race/ethnic differences in prevalence of type 2 diabetes, although there is inadequate research in this area. Better understanding of these factors should lead to more effective prevention and treatment. This has not yet been achieved to a great extent but should be a goal for the future.

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Contribution All authors were responsible for drafting the article and revising it critically for important intellectual content. All authors approved the version to be published.

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