# The association between race/ethnicity and risk of type 2 diabetes in women varies by body mass index: a pooled analysis of individual data from 15 cohort studies

**Short title: Race/ethnicity, BMI, and diabetes risk in women**

Kazue Nagai PhD[1,2]*, Hsin-Fang Chung PhD[2,3]*, Kunihiko Hayashi PhD[2,4], Annette J. Dobson PhD[3], Yuki Ideno PhD[1,2], Sven Sandin PhD[5,6], Yvonne T. van der Schouw PhD[7], Rebecca Hardy PhD[8], Debra J. Anderson PhD[9], Panayotes Demakakos PhD[10], Eric J. Brunner PhD[10], Ellen S. Mitchell PhD[11], Nancy F. Woods PhD[12], Sophie V. Eastwood PhD[13], Samar R. El Khoudary PhD[14], Monique M. Hedderson PhD[15], Elisabete Weiderpass PhD[16], Gita D. Mishra PhD[2,3]

** These two authors contributed equally to this work.*

1 Centre for Food Science and Wellness, Gunma University, Gunma, Japan

2 Gunma University Initiative for Advanced Research, Gunma, Japan

3 Australian Women and Girls' Health Research Centre, School of Public Health, The University of Queensland, Queensland, Australia

4 School of Health Data Sciences, Juntendo University, Chiba, Japan

5 Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden

6 Department of Psychiatry, Icahn School of Medicine at Mount Sinai, New York, USA

7 Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, University Utrecht, Utrecht, The Netherlands

8 School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, UK

9 Faculty of Health, University of Technology Sydney, New South Wales, Australia

10 Department of Epidemiology and Public Health, University College London, London, UK

11 Family and Child Nursing, School of Nursing, University of Washington, Seattle, USA

12 Biobehavioral Nursing and Health Systems, School of Nursing, University of Washington, Seattle, USA

13 Medical Research Council Unit for Lifelong Health and Ageing at UCL, London, UK

14 Department of Epidemiology, School of Public Health, University of Pittsburgh, Pennsylvania, USA

15 Division of Research, Kaiser Permanente Northern California, California, USA.

16 International Agency for Research on Cancer, World Health Organisation, Lyon, France

**Corresponding author:** Dr Hsin-Fang Chung

Australian Women and Girls' Health Research Centre, School of Public Health,

The University of Queensland, Brisbane, Queensland 4006, Australia

Email: h.chung1@uq.edu.au

TEL: +61 7 3346 4649

**Twitter summary:** South/Southeast Asian women face a markedly greater risk of type 2 diabetes, which is further exacerbated by elevated BMI, highlighting the need for tailored, ethnicity-specific prevention strategies.

**Keywords:** race/ethnicity; body mass index; type 2 diabetes; women

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## Abstract

**Objective:** To examine the association between race/ethnicity and type 2 diabetes risk in women and assess the interaction between race/ethnicity and body mass index (BMI).

**Research design and methods:** We analysed individual-level data from 730,408 women across 15 cohort studies. Six racial/ethnic groups were identified: White, Chinese, Japanese, South/Southeast Asian, Black, and Mixed/Other. Cox proportional hazards models with study as a random effect were used to estimate hazard ratios (HRs) for type 2 diabetes associated with race/ethnicity. The joint association of race/ethnicity and BMI was assessed using BMI categories incorporating Asian-specific cutoffs (<18.5, 18.5-22.9, 23.0-24.9, 25.0-27.4, 27.5-29.9, and ≥30 kg/m$^2$), with White women having a BMI of 18.5-22.9 kg/m$^2$ as the reference.

**Results:** Overall, 37,329 (5.1%) women were diagnosed with type 2 diabetes. By age 70, the cumulative incidence was highest among South/Southeast Asian (24.6%) and Black women (23.6%), with baseline obesity rates of 40.0% (BMI ≥27.5 kg/m$^2$) and 45.6% (BMI ≥30 kg/m$^2$), respectively. After adjusting for BMI, South/Southeast Asian women had the highest diabetes risk compared with White women (HR:4.13, 95%CI 3.78-4.51), while other racial/ethnic groups had about twice the risk. Joint effect analysis showed South/Southeast Asian women with a BMI ≥23 kg/m$^2$ had a substantially greater diabetes risk than other racial/ethnic groups with the same BMI, especially those with BMI 27.5-29.9 kg/m$^2$ (HR:23.17, 19.21-27.95) and ≥30 kg/m$^2$ (HR:35.52, 30.57-41.28).

**Conclusions:** South/Southeast Asian women have a markedly elevated risk of type 2 diabetes, further amplified by modestly higher BMI, highlighting the need for ethnicity-specific diabetes prevention strategies for women.

## Article highlights

**Why did we undertake this study?**

- Asian and Black populations have elevated type 2 diabetes risk compared with White populations; however, evidence in women, especially by Asian subgroups and BMI interaction, remains limited.

**What is the specific question we wanted to answer?**

- What is the association between race/ethnicity and type 2 diabetes risk in women, and does this vary by BMI?

**What did we find?**

- South/Southeast Asian women had over four times the diabetes risk compared with White women, while Black, Chinese, Japanese, and Mixed/Other women had twice the risk. Among those with BMI≥23 kg/m², risk in South/Southeast Asian women was nearly 10-fold, higher than in other groups.

**What are the implications of our findings?**

- Early, ethnicity-specific diabetes prevention strategies are urgently needed, especially for South/Southeast Asian women with elevated BMI.

## Introduction

Diabetes is a critical global health challenge, with its prevalence reaching alarming levels worldwide. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) estimated that 529 million people were living with diabetes in 2021, a figure projected to rise to 1.31 billion by 2050.[1] The global age-standardised prevalence of diabetes was 6.1% in 2021,[1] but substantial variations exist across regions and countries, particularly among diverse racial and ethnic groups.[2,3] Studies conducted in the US, UK, and Europe have reported higher diabetes prevalence among racial/ethnic minority groups, including Asian, Black, Hispanic, and Mixed populations, compared with White populations.[2-7] Only one US cohort study has specifically examined racial/ethnic differences in diabetes among women, highlighting that increasing body mass index (BMI) and greater weight gain are particularly detrimental for Asian women.[4] However, population-based evidence remains limited for specific Asian subgroups, such as South Asian, Chinese, and Japanese women, as well as for comparisons between Asian women residing in Asia and those living in Western countries.[8,9]

Although the global prevalence of diabetes is slightly lower in women than in men (10.2% vs 10.8%),[10] women often face a greater burden of risk factors at diagnosis, with obesity being particularly prominent.[11] Across their lifespan, women experience greater hormone fluctuations and weight changes than men, largely due to reproductive events, such as pregnancy and menopause.[11] Adverse reproductive outcomes may disproportionately increase the risk of type 2 diabetes among certain racial/ethnic groups.[12-14] These racial/ethnic disparities likely reflect the interplay of genetic, social, and environmental factors, with obesity playing a key role.[15] Previous studies have demonstrated that non-White populations experience a greater burden of diabetes at lower BMI thresholds compared with White populations.[16-20] However, the interaction of race/ethnicity and BMI on diabetes risk remains unclear (additive or multiplicative), particularly in women.

The International Collaboration Approach to Reproductive Health and Chronic Disease Events (InterLACE) consortium pools individual-level data from multiple cohort studies of women. Using data from 15 cohorts, we aimed to examine the association between race/ethnicity and type 2 diabetes risk in women, including three Asian subgroups, and to compare the risk between Asian women living in their countries of origin and those living in Western countries. We further investigated the interaction (joint effect) between race/ethnicity and BMI in relation to diabetes risk.

## Research Design and Methods

### Ethics

Ethical approval was obtained from the Institutional Review Board or Human Research Ethics Committee at each participating institution, and all participants provided informed consent. InterLACE used non-identifiable data from existing studies and received an ethics exemption from the University of Queensland (2024/HE000390).

### Study design and participants

The data for this study were obtained from InterLACE, an ongoing women's health consortium integrating 27 observational studies on women's reproductive health and chronic disease. The study design and data harmonisation have been previously published.[21] For this analysis, we excluded 10 studies that did not collect data on diabetes or diagnosis age, and two studies with participants who were significantly younger (all born in 1970 or later). The sample included individual-level data from 15 studies (n=760,478) across seven countries, with information on race/ethnicity, BMI, and type 2 diabetes. These studies included the Australian Longitudinal Study on Women's Health (ALSWH), Melbourne Collaborative Cohort Study (MCCS), Healthy Ageing of Women Study (HOW), Medical Research Council National Survey of Health and Development (NSHD), National Child Development Study (NCDS), English Longitudinal Study of Aging (ELSA), Whitehall II, Southall and Brent Revisited (SABRE), UK Biobank, Women's Lifestyle and Health Study (WLHS), Prospect cohort of the European Prospective Investigation Into Cancer and Nutrition (Prospect-EPIC), Study of Women's Health Across the Nation (SWAN), Seattle Middle Women's Health Study (SMWHS), Japanese Nurses' Health Study (JNHS), and China Kadoorie Biobank. Study characteristics are summarised in **Supplemental Table 1**.

Women were excluded from the study if there was insufficient information to define diabetes (n=8,943), they had been diagnosed with type 1 diabetes or reported a diagnosis age younger than 30 years (n=3,793) or were younger than 30 years at the last follow-up (n=294). Women with missing data on key variables, including race/ethnicity, cohort entry age, BMI, birth year, education level, and smoking status, were also excluded (n=17,040). The analytic sample comprised 730,408 women with complete data.

**Exposure and outcome variables**

Race/ethnicity was self-identified in eight studies (MCCS, NCDS, ELSA, Whitehall II, SABRE, UK Biobank, SWAN, and SMWHS), accounting for 310,330 participants (42.5% of the sample). Three studies (Prospect-EPIC[22], JNHS[23], and China Biobank[24]) did not collect data on race/ethnicity due to the homogeneity of their source populations at the time of recruitment, where over 95% of participants identified as Dutch, Japanese, or Chinese, respectively (n=359,540; 49.2%). The remaining four studies (ALSWH, HOW, NSHD, and WLHS) relied on proxy indicators, such as country of birth, country of childhood residency, or language spoken at home, to infer ethnicity (n=60,538; 8.3%). For the analysis, race/ethnicity was categorised into six groups: White, Chinese, Japanese, South/Southeast Asian, Black (including African American, Caribbean, and other Black identities), and Mixed/Other (including a small sample of Hispanic/Latino, Middle Eastern, Indigenous, or Pacific Islander).

BMI was calculated as weight (in kilograms) divided by the square of height (in meters), based on data collected at cohort entry (or by participants' early 40s in birth cohorts), which served as the study baseline. Weight and height were measured in eight studies (MCCS, NSHD, NCDS, ELSA, WHITEHALL, SABRE, UK Biobank, and China Biobank; n=603,501, 82.6%). The remaining seven studies relied on self-reported data. BMI was classified using standard World Health Organization categories, with additional cutoffs at 23.0 and 27.5 kg/m$^2$ recommended for public health actions in Asian populations.[25] For analysis, BMI was grouped into six categories across all racial/ethnic groups: <18.5, 18.5–22.9 (reference), 23.0–24.9, 25.0–27.4, 27.5–29.9 and ≥30 kg/m$^2$.[25]

The primary outcome was time to onset of type 2 diabetes. Information on physician-diagnosed type 2 diabetes and/or diabetes medication use (after age 30) was obtained through self-reported questionnaires across all studies. Additionally, ALSWH, UK Biobank, WLHS, and Prospect-EPIC provided administrative health data, including hospital, emergency department, and death records, where type 2 diabetes was identified using ICD-10 code E11 or ICD-9 code 250.x0 or 250.x2 (x=0-9). In cases where subtype details were unavailable, broader diagnosis codes (ICD-10: E13, E14; ICD-9: 250 unspecified) were used, as diabetes diagnosed after age 30 was less likely to be type 1 diabetes. Women diagnosed with diabetes before age 30 were excluded. ALSWH also provided pharmaceutical data (Anatomical Therapeutic Chemical code A10: anti-diabetes therapies, including biguanides, sulfonylureas, and insulins, with the first prescription after age 30 years) and aged care records (Aged Care Assessment Program code 403: type 2 diabetes). Age at onset of type 2 diabetes was defined as the earliest recorded age of diagnosis, based on either self-report or administrative health data (available for four studies).

**Covariates**

We harmonised sociodemographic and lifestyle factors collected at baseline (i.e., cohort entry or early 40s for birth cohorts) as potential confounding factors for racial/ethnical differences. These included baseline age (continuous), birth year (<1940, 1940-1949, 1950-1959, or ≥1960), education level (no formal qualification, year 10, year 12, trade/other, or university degree), and smoking status (never, past, or current smoker).

**Statistical analyses**

We analysed pooled individual-level data from all cohorts. Participants contributed person-years from 30 years of age until diagnosis of type 2 diabetes, loss to follow-up, death, or end of follow-up, whichever occurred first. The cumulative incidence (%) between ages 30 and 70 years was estimated by race/ethnicity using the Kaplan–Meier method.

Because most cohorts recruited participants in midlife (ages 40-60 years), a substantial proportion of women with type 2 diabetes had been diagnosed prior to baseline (18,423 out of 37,329; 49.4%). These women were excluded from the following perspective analyses, leaving 711,987 participants. Incidence rates (per 1000 person-years) after baseline were calculated by race/ethnicity. Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between race/ethnicity and diabetes risk, with White women as the reference group. Study-level variability was included in the model as a random effect. The proportional hazards assumption was assessed using log-cumulative hazard plots, with no violations detected. Models were sequentially adjusted for baseline age (Model 1), birth year, education level, and smoking status (Model 2), with further adjustment for BMI (Model 3). For Chinese and Japanese women, we conducted separate Cox models to compare diabetes risk between those residing in their countries of origin and those living in Western countries.

To assess whether the joint effect of race/ethnicity and BMI was additive or multiplicative, we included an interaction term in the Cox model. Where there was strong evidence of interaction, we generated a combined variable with 36 categories (six race/ethnicity groups × six BMI groups) to aid the interpretation of the joint effect, using White women with a BMI of 18.5-22.9 kg/m² as the reference.

**Sensitivity analyses**

First, evidence suggests that central adiposity is a stronger predictor of type 2 diabetes than overall obesity, particularly among women.[26] We substituted BMI with waist circumference as the measure of adiposity. Eight cohorts (MCCS, NSHD, ELSA, UK Biobank, Prospect-EPIC, SWAN, JNHS, China Biobank) that collected waist circumference data at baseline were included in this analysis (n=638,580). Waist circumference was categorised using an additional cutoff recommended for Asian women: <80 (reference), 80-87, and ≥88 cm.[26,27] Second, given nearly half of diabetes cases were diagnosed prior to baseline and excluded from the main analyses, we conducted a sensitivity analysis including these women for comparison (n=730,408).

**Data and resource availability**

The data sets generated for this pooled analysis are not publicly available because of the data transfer agreements or restrictions under license for the current study. However, data from some studies can be accessed by submitting an application (e.g., ALSWH [https://alswh.org.au/for-data-users/applying-for-data/] and UK Biobank [https://www.ukbiobank.ac.uk/enable-your-research/apply-for-access]).

## Results

### Study characteristics

Overall, data from 730,408 women from 15 studies across seven countries were included (**Supplemental Table 1**). Six racial/ethnical groups were identified: White (n=370,937; 50.8%), Chinese (n=297,550; 40.7%), Japanese (n=46,759; 6.4%), South/Southeast Asian (n=5162; 0.7%), Black (n=6430; 0.9%), Mixed/Other (n=3570; 0.5%). Over 98% of the Chinese and Japanese participants were derived from cohorts based in their respective countries, specifically the China Kadoorie Biobank and the Japan Nurses' Health Study, with only 493 (1.1%) Japanese and 1242 (0.4%) Chinese women living in Western countries. In contrast, other non-White groups were represented in studies conducted in Western countries. **Table 1** presents the baseline characteristics stratified by race/ethnicity. The median age at baseline was 51 years (interquartile range: 44-60). Overall, 37,329 (5.1%) women had been diagnosed with type 2 diabetes, with half (49.4%) of the cases being diagnosed prior to baseline and half (52.2%) identified through administrative records.

The proportion of women living with obesity (BMI ≥30 kg/m$^2$) was highest among Black women (45.6%), followed by Mixed/Other (25.0%) and South/Southeast Asian women (23.0%). In contrast, obesity rates were notably lower among Chinese (4.7%) and Japanese women (1.9%). When applying the Asian-specific cutoff (BMI ≥27.5 kg/m$^2$), the prevalence of obesity increased to 40.0% among South/Southeast Asians, 14.1% among Chinese, and 5.0% among Japanese.

**Race/ethnicity and risk of type 2 diabetes**

**Figure 1** illustrates the cumulative incidence between ages 30 and 70 years across racial/ethnic groups. By age 70, nearly 1 in 4 South/Southeast Asian and Black women had diabetes, compared to 7% of White women (**Supplemental Table 2)**.

For the prospective analyses, we excluded women with type 2 diabetes at baseline (n=711,987; **Table 2**). During follow-up, the incidence of type 2 diabetes was highest among South/Southeast Asian and Black women (3.4 per 1000 person-years) compared with 1.1 per 1000 person-years among White women. In the multivariable-adjusted model excluding BMI (Model 2), South/Southeast Asian (HR:3.96, 95% CI 3.63-4.33) and Black women (HR:3.80, 3.49-4.15) had nearly a 4-fold increased diabetes risk compared with White women. Mixed/Other (HR:2.33, 2.07-2.63) and Chinese women (HR:1.43, 1.11-1.85) also had an elevated risk of diabetes, whereas no clear evidence was observed for Japanese women (HR:1.13, 0.75-1.69). When additionally adjusted for BMI (Model 3), the 4-fold increased risk for South/Southeast Asian women remained unchanged (HR:4.13, 3.78-4.51. However, the risk for Black women was attenuated, decreasing from an HR of 3.80 (3.49-4.15) to 2.61 (2.40-2.85), suggesting that high BMI partially explained the association. Conversely, the diabetes risk for Chinese (HR:2.77, 2.14-3.58) and Japanese women (HR:2.29, 1.53-3.45) was more than doubled after accounting for their lower BMI levels. Furthermore, Chinese and Japanese women living in Western countries seemed to have a lower diabetes risk compared with those residing in their countries of origin, though the confidence intervals were wide due to the small sample size (**Supplemental Table 3**).

**Joint effect of race/ethnicity and BMI**

There was a statistically significant interaction between race/ethnicity and BMI on type 2 diabetes risk ($p<0.001$). To assess the joint effects, we compared each race/ethnicity and BMI category to the reference category of White women with a BMI of 18.5-22.9 kg/$m^2$ within a single model. South/Southeast Asian women with a BMI ≥30 kg/$m^2$ had an exceptionally high diabetes risk, with a 35-fold increased risk (HR:35.52, 30.57-41.28) (**Figure 2**). Black women with a BMI ≥30 kg/$m^2$ showed a 25-fold increased risk (HR:24.15, 21.45-27.19), and Japanese (HR:19.67, 12.45-31.08) and Mixed/Other women (HR:15.74, 12.99-19.06) with a BMI ≥30 kg/$m^2$ exhibited approximately 15-20-fold higher risks. In contrast, Chinese and White women with a BMI ≥30 kg/$m^2$ had around a 10-fold increased risk compared to the reference group. Importantly, South/Southeast Asian women with a BMI of 23.0-29.9 kg/$m^2$ also had markedly higher risks than other ethnic groups with the same BMI.

**Sensitivity analyses**

When BMI was replaced with waist circumference, the association between race/ethnicity and diabetes remained consistent, with South/Southeast Asian women showing the highest risk (HR:4.30, 3.90-4.74), while other race/ethnic groups had more than double the risk compared with Whtie women (**Supplemental Table 4**). A significant interaction was observed between race/ethnicity and waist circumference ($p<0.001$). Joint effect analysis further revealed that South/Southeast Asian women with a waist circumference of 80-87 cm (HR:13.12, 10.60-16.22) and ≥88 cm (HR:32.16, 28.26-36.59) had an exceptionally higher risk of diabetes than other racial/ethnic groups with the same waist circumference, compared with White women with a waist circumference <80 cm (**Supplemental Figure 1**). When women with diabetes at baseline were included, the association between race/ethnicity and diabetes (**Supplemental Table 5)** and the joint effects of race/ethnicity and BMI (**Supplemental Figure 2**), remained consistent.

## Conclusions

This pooled analysis of 15 cohort studies demonstrated that South/Southeast Asian women had the highest risk of type 2 diabetes, with a 4-fold increased risk compared with White women, even after accounting for BMI or waist circumference. Black, Chinese, Japanese, and Mixed/Other women had over double the risk. Among Chinese and Japanese women, those residing in their countries of origin had a higher diabetes risk compared with their counterparts living in Western countries; however, these results were inconclusive due to the small number of migrants. Joint effect analysis showed that South/Southeast Asian women with a BMI ≥23 kg/m$^2$ had a substantially greater diabetes risk than other racial/ethnic groups with the same BMI, compared with White women with a BMI of 18.5-22.9 kg/m$^2$. For instance, South/Southeast Asian women with a BMI ≥30 kg/m$^2$ had a 35-fold increased risk, compared with a 10-fold risk among White women with the same BMI. The results were consistent when BMI ≥30 kg/m$^2$ was substituted with waist circumference ≥88 cm.

Our findings confirm significant racial/ethnic disparities in type 2 diabetes risk among women. These results align with those from the US Nurses' Health Study (n=78,419 women), which demonstrated that, after adjusting for age and BMI, Asian (RR:2.26, 1.70-2.99), Hispanic (RR:2.18, 1.82-2.61), and Black women (RR:1.34, 1.12-1.61) were at a higher type 2 diabetes risk compared with White women.[4] Similarly, a large UK cross-sectional study (n=404,318; 51% women) found that Asian (OR:2.36, 2.26-2.47), Black (OR:1.65, 1.56-1.73), and Mixed/Other ethnic groups (OR:1.17, 1.08-1.27) had an elevated risk of diabetes compared with the White group, although this study did not adjust for BMI.[3] Asians are generally considered a high-risk group for type 2 diabetes; however, limited population-based evidence is available for specific Asian subgroups. A systemic review and meta-analysis of ethnic minority groups in Europe (20 studies) revealed that South Asians had the highest odds of diabetes (OR:3.74, 2.74-5.12) compared with White Europeans, but data on other Asian subgroups were unavailable.[7] The study also suggested the association may be stronger in women (OR:4.40, 3.06-6.31) than in men (OR:3.45, 2.52-4.71).[7] South Asians in Western countries tended to experience an earlier onset of diabetes with a mean age at diagnosis of 46-49 years compared to 58 years in White Europeans.[28,29] Studies conducted in Asian countries further indicated that Indians were at higher diabetes risk compared with Chinese and Japanese individuals,[8,9] with the peak prevalence of diabetes occurring approximately 10 years earlier in Indian populations.[8] Our pooled analysis from 15 cohort studies showed a similar effect estimate of a 4-fold increased diabetes risk for South Asian women (residing in Western countries) compared with White women. Additionally, Chinese and Japanese women residing in China and Japan may have a higher diabetes risk than their counterparts living in Western countries, suggesting that environmental, lifestyle, sociocultural factors, along with differences in healthcare access and screening, may influence the risk.

Ethnicity-specific studies have shown that South Asian and Chinese populations reach an equivalent age- and sex-adjusted incidence of type 2 diabetes at lower BMI thresholds of 23.9 kg/m$^2$ and 26.9 kg/m$^2$, respectively, compared to a BMI of 30 kg/m$^2$ in White populations.[17] A key novelty of the present study is its exploration of the joint effect of race/ethnicity and BMI on diabetes risk in women. Our findings demonstrated that the diabetes risk was substantially amplified among South/Southeast Asian women with elevated BMI levels, with a nearly 10-fold increased risk for those with a BMI ≥23 kg/m$^2$. Specifically, South/Southeast Asian women with a BMI ≥30 kg/m$^2$ had a 35-fold increased risk of diabetes, compared with a 10-fold risk among Chinese and White women with the same BMI, relative to White women with a BMI of 18.5-22.9 kg/m$^2$. In this study, 80% of South/Southeast Asian women had a BMI ≥23 kg/m$^2$, and nearly 25% had a BMI ≥30 kg/m$^2$, highlighting a substantial proportion of this population at elevated risk of diabetes.

Asians, particularly South Asians and women, tend to have a phenotype characterised by higher fat mass (especially ectopic fat), lower lean mass, and larger adipocyte size for a given BMI compared with White and Black populations.[30-33] These traits may account for elevated fasting insulin levels, increased insulin resistance, and lower levels of HDL-cholesterol and adiponectin, which may increase diabetes risk.[30-33] Studies suggest that South Asians consistently exhibit low bone breadth relative to length, reflecting low lean mass for their stature; however, whether this arises from genetic or epigenetic mechanisms remains unknown.[34] Low skeletal muscle mass is strongly associated with poor insulin sensitivity and a higher risk of prediabetes.[35] A recent review also identified sarcopenic obesity as an emerging public health challenge in the Asia-Pacific region.[36] Beyond impaired insulin action due to low lean mass, South Asians may have reduced beta-cell function, which limits their insulin secretion capacity and reduces their compensatory reserves when exposed to unhealthy lifestyle factors.[37] Therefore, prevention strategies in Asian populations should address not only central obesity but also focus on preserving lean muscle mass through lifestyle modifications, such as regular resistance training, adequate protein intake, and balanced nutrition.[36] In contrast, Black women are disproportionately affected by obesity,[38] with 45% of Black women in the present study classified as having a BMI ≥30 kg/m$^2$. The elevated risk of diabetes in Black women was largely attenuated after adjusting for BMI, indicating that living with obesity plays a substantial role.

The strengths of our study include: (1) a large number of women with type 2 diabetes from 15 cohort studies, with nearly 40% of whom being non-White; (2) representation of diverse racial/ethnic groups, including three distinct Asian subgroups; (3) harmonisation of variables across studies to ensure consistency; (4) adjustment for a range of confounding factors; and (5) the use of robust analytical approach to explore joint effect of race/ethnicity and BMI. However, several limitations need to be acknowledged. First, over 98% of the Chinese and Japanese participants were drawn from cohorts based in their countries of origin, whereas other non-White groups were primarily represented in cohorts from Western countries. Although the numbers of Japanese, South/Southeast Asian, and Black women were considerably smaller than those of White women, the narrow and statistically significant 95% CIs for hazard ratios support the precision of our estimates and suggest that the study had sufficient power to detect racial/ethnic differences in diabetes risk. Our findings suggest that Chinese and Japanese women residing in their countries of origin may have a higher risk of diabetes compared to their counterparts living in Western countries; however, these results should be interpreted with caution due to limited statistical power (<50%), as indicated by the wide 95% CIs. Future studies should include large samples of Asian women in Western countries to ensure adequate power.

Furthermore, some of the observed racial/ethnic differences may reflect variations between studies, including sources of data and health system differences. We accounted for study heterogeneity by modelling it as a random effect in the Cox model. Second, although half of the diabetes cases were self-reported, data from four studies with linked health records demonstrated moderate to substantial agreement (kappa=54%–72%) between administrative and self-reported data,[12] supporting the reasonable validity of our findings. Additionally, the Prospect-EPIC study verified diabetes diagnosis using GP and pharmacist records and reported high confirmation rates.[39] Third, BMI can change with age, particularly around menopause. However, longitudinal BMI data were not consistently collected across cohorts or survey intervals, and in some cases, diabetes onset occurred before follow-up assessments. As a result, we were limited to using baseline BMI in this pooled analysis. Fourth, BMI cannot differentiate between visceral and subcutaneous fat, which may vary by ethnicity. We conducted a sensitivity analysis substituting BMI with waist circumference, a marker more closely associated with visceral fat. The results remained consistent, suggesting that the observed racial/ethnic differences in diabetes risk were not solely attributable to this limitation. Finally, while obesity is a key risk factor for type 2 diabetes among women across racial/ethnic groups, unmeasured reproductive and sociocultural factors, such as socioeconomic status, diet, physical activity, stress, and access to healthcare, may also contribute to the observed racial/ethnic disparities in diabetes risk among women. These factors could not be examined in our analysis due to inconsistent data collection across studies.

Given the greater burden of risk factors and complications associated with type 2 diabetes in women compared to men,[11] and in non-White compared to White populations, prevention strategies should be specific to women and non-White populations. Our findings suggest that Asian women, particularly South/Southeast Asians, may have unique risk profiles for diabetes, highlighting the need for targeted prevention and treatment strategies. In particular, ethnicity-specific approaches that extend beyond obesity alone, such as interventions to increase and preserve lean muscle mass and improve metabolic health, are essential for Asian women.[36]

In conclusion, this study represents the largest investigation to date, demonstrating that non-White women were at a higher risk of type 2 diabetes compared with White women, with South/Southeast Asian women being particularly vulnerable. The joint effect analysis showed that South/Southeast Asian women with a BMI ≥23 kg/m$^2$ had a markedly higher diabetes risk than other racial/ethnic groups at the same BMI levels. Early and targeted diabetes screening should prioritize South/Southeast Asian women, including those with a normal or modestly elevated BMI, to facilitate timely intervention and reduce the burden of diabetes-related complications.

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Clinical Centers: *University of Michigan, Ann Arbor – Carrie Karvonen-Gutierrez, PI 2021 – present, Siobán Harlow, PI 2011 – 2021, MaryFran Sowers, PI 1994-2011*; *Massachusetts General Hospital, Boston, MA – Sherri-Ann Burnett-Bowie, PI 2020 – Present; Joel Finkelstein, PI 1999 – 2020*; *Robert Neer, PI 1994 – 1999; Rush University, Rush University Medical Center, Chicago, IL – Imke Janssen, PI 2020 – Present; Howard Kravitz, PI 2009 – 2020*; *Lynda Powell, PI 1994 – 2009; University of California, Davis/Kaiser – Elaine Waetjen and Monique Hedderson, PIs 2020 – Present; Ellen Gold, PI 1994 - 2020*; *University of California, Los Angeles – Arun Karlamangla, PI 2020 – Present; Gail Greendale, PI 1994 - 2020*; *Albert Einstein College of Medicine, Bronx, NY – Carol Derby, PI 2011 – present, Rachel Wildman, PI 2010 – 2011; Nanette Santoro, PI 2004 – 2010; University of Medicine and Dentistry – New Jersey Medical School, Newark – Gerson Weiss, PI 1994 – 2004;* and the *University of Pittsburgh, Pittsburgh, PA – Rebecca Thurston, PI 2020 – Present; Karen Matthews, PI 1994 - 2020.*

NIH Program Office: *National Institute on Aging, Bethesda, MD – Rosaly Correa-de-Araujo 2020 - present; Chhanda Dutta 2016- present; Winifred Rossi 2012–2016; Sherry Sherman 1994 – 2012; Marcia Ory 1994 – 2001; National Institute of Nursing Research, Bethesda, MD – Program Officers.*

Central Laboratory: *University of Michigan, Ann Arbor – Daniel McConnell* (Central Ligand Assay

Satellite Services).

<u>Coordinating Center:</u> *University of Pittsburgh, Pittsburgh, PA – Maria Mori Brooks, PI 2012 - present; Kim Sutton-Tyrrell, PI 2001 – 2012; New England Research Institutes, Watertown, MA - Sonja McKinlay, PI 1995 – 2001.*

Steering Committee: Susan Johnson, Current Chair

Chris Gallagher, Former Chair

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## Declaration of interests

No potential conflicts of interest relevant to this article are reported.

## Author contributions

KN conducted statistical analyses and wrote the initial draft of the manuscript. HFC and GDM conceptualised the research question and study design. HFC conducted data harmonisation across studies, supervised statistical analysis and data interpretation, and wrote/revised the manuscript. KH, AJD, SS, and GDM critically reviewed the statistical methods and edited the manuscript. All the other authors contributed study data and provided critical revision of the manuscript for intellectual content. All authors approved the final manuscript. HFC and GDM are the guarantors of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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**Table 1** Baseline characteristics based on race/ethnicity (n=730,408)

| **Baseline characteristics** | **Overall** | **White** | **Chinese** | **Japanese** | **South/Southeast Asian** | **Black** | **Mixed/Other** |
|---|---|---|---|---|---|---|---|
| Number of women | 730,408 | 370,937 | 297,550 | 46,759 | 5,162 | 6,430 | 3,570 |
| Age at baseline, median (interquartile) | 51 (44-60) | 54 (46-62) | 50 (42-58) | 41 (35-48) | 52 (46-59) | 50 (45-56) | 49 (45-55) |
| Birthyear, n (%) | | | | | | | |
| Born before 1940 | 67,936 (9.3) | 37,217 (10.0) | 29,975 (10.1) | 117 (0.3) | 132 (2.6) | 295 (4.6) | 200 (5.6) |
| Born 1940-1949 | 228,638 (31.3) | 158,785 (42.8) | 60,617 (20.4) | 5,053 (10.8) | 1,559 (30.2) | 1,552 (24.1) | 1,072 (30.0) |
| Born 1950-1959 | 236,298 (32.4) | 119,134 (32.1) | 95,844 (32.2) | 15,757 (33.7) | 1,866 (36.1) | 2,483 (38.6) | 1,214 (34.0) |
| Born 1960 or later | 197,536 (27.0) | 55,801 (15.0) | 111,114 (37.3) | 25,832 (55.2) | 1,605 (31.1) | 2,100 (32.7) | 1,084 (30.4) |
| Education level, n (%) | | | | | | | |
| No formal qualification | 96,827 (13.3) | 21,283 (5.7) | 74,687 (25.1) | 3 (0.0) | 342 (6.6) | 223 (3.5) | 289 (8.1) |
| year 10 | 334,315 (45.8) | 160,274 (43.2) | 168,549 (56.6) | 16 (0.0) | 1,813 (35.1) | 2,489 (38.7) | 1,174 (32.9) |
| year 12 | 100,682 (13.8) | 57,977 (15.6) | 40,314 (13.5) | 415 (0.9) | 689 (13.3) | 760 (11.8) | 527 (14.8) |
| Trade/diploma/other | 87,769 (12.0) | 32,383 (8.7) | 8,870 (3.0) | 44,538 (95.3) | 533 (10.3) | 1,068 (16.6) | 377 (10.6) |
| University degree | 110,815 (15.2) | 99,020 (26.7) | 5,130 (1.7) | 1,787 (3.8) | 1,785 (34.6) | 1,890 (29.4) | 1,203 (33.7) |
| Smoking status, n (%) | | | | | | | |
| Never | 533,589 (73.1) | 206,249 (55.6) | 282,569 (95.0) | 33,107 (70.8) | 4,678 (90.6) | 4,819 (74.9) | 2,167 (60.7) |
| Past | 130,113 (17.8) | 119,799 (32.3) | 2,624 (0.9) | 5,608 (12.0) | 302 (5.9) | 900 (14.0) | 880 (24.6) |
| Current | 66,706 (9.1) | 44,889 (12.1) | 12,357 (4.2) | 8044 (17.2) | 182 (3.5) | 711 (11.1) | 523 (14.6) |
| Body mass index (kg/m$^2$), n (%) | | | | | | | |
| <18.5 | 20,812 (2.8) | 3,571 (1.0) | 12,808 (4.3) | 4,327 (9.3) | 55 (1.1) | 20 (0.3) | 31 (0.9) |
| 18.5-22.9 | 239,182 (32.7) | 91,778 (24.7) | 116,233 (39.1) | 29,016 (62.1) | 929 (18.0) | 524 (8.1) | 702 (19.7) |
| 23.0-24.9 | 150,313 (20.6) | 72,889 (19.7) | 67,839 (22.8) | 7,322 (15.7) | 914 (17.7) | 685 (10.7) | 664 (18.6) |
| 25.0-27.4 | 142,028 (19.4) | 76,525 (20.6) | 58,772 (19.8) | 3,754 (8.0) | 1,203 (23.3) | 1,060 (16.5) | 714 (20.0) |
| 27.5-29.9 | 83,387 (11.4) | 51,451 (13.9) | 27,823 (9.4) | 1,463 (3.1) | 876 (17.0) | 1,207 (18.8) | 567 (15.9) |
| ≥30 | 94,686 (13.0) | 74,723 (20.1) | 14,075 (4.7) | 877 (1.9) | 1,185 (23.0) | 2,934 (45.6) | 892 (25.0) |
| Mean ± SD | 25.1 ± 4.6 | 26.4 ± 5.0 | 23.8 ± 3.4 | 21.8 ± 3.0 | 27.0 ± 4.9 | 30.3 ± 6.1 | 27.3 ± 5.4 |
| Type 2 diabetes mellitus, n (%) | | | | | | | |
| No | 693,079 (94.9) | 348,058 (93.8) | 287,047 (96.5) | 45,353 (97.0) | 4,124 (79.9) | 5,337 (83.0) | 3,160 (88.5) |
| Yes | 37,329 (5.1) | 22,879 (6.2) | 10,503 (3.5) | 1,406 (3.0) | 1,038 (20.1) | 1,093 (17.0) | 410 (11.5) |
| Identified at baseline | 18,423 (49.4) | 7,618 (33.3) | 9,222 (87.8) | 533 (37.9) | 492 (47.4) | 433 (39.6) | 125 (30.5) |
| Identified by linked records | 19,495 (52.2) | 17,503 (76.5) | 57 (0.5) | 4 (0.3) | 890 (85.7) | 776 (71.0) | 265 (64.6) |

**Table 2** The association between race/ethnicity and risk of incident type 2 diabetes (n=711,985)*

| Race/Ethnicity | Number of women | Person-years | Women with incident diabetes | IR/1000 person-years | BMI at baseline Mean ± SD | Model 1 HR (95% CI) | Model 2 HR (95% CI) | Model 3 HR (95% CI) |
|---|---|---|---|---|---|---|---|---|
| White | 363,319 | 13,627,841 | 15,261 | 1.1 | 26.3 ± 4.9 | Reference | Reference | Reference |
| Chinese | 288,328 | 6,118,740 | 1,281 | 0.2[$] | 23.7 ± 3.4 | 1.27 (0.98-1.63) | 1.43 (1.11-1.85) | 2.77 (2.14-3.58) |
| Japanese | 46,226 | 713,285 | 873 | 1.2 | 21.8 ± 3.0 | 0.99 (0.67-1.47) | 1.13 (0.75-1.69) | 2.29 (1.53-3.45) |
| South/Southeast Asian | 4,670 | 161,450 | 546 | 3.4 | 26.8 ± 4.7 | 3.49 (3.20-3.81) | 3.96 (3.63-4.33) | 4.13 (3.78-4.51) |
| Black | 5,997 | 193,417 | 660 | 3.4 | 30.1 ± 6.0 | 3.75 (3.44-4.09) | 3.80 (3.49-4.15) | 2.61 (2.40-2.85) |
| Mixed/Other | 3,445 | 112,292 | 285 | 2.5 | 27.1 ± 5.2 | 2.28 (2.02-2.58) | 2.33 (2.07-2.63) | 2.05 (1.81-2.31) |

Abbreviations: IR, incidence rate; BMI, body mass index (kg/$m^2$).

*Women with type 2 diabetes at baseline (n=18,423) were excluded.

[$]The China Biobank provided only baseline data and limited follow-up for 5% of participants. The low incidence rate among Chinese women was attributed to the short follow-up duration in a sub-cohort, which was accounted for in the Cox regression model.

Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (95% CIs) for the incidence of type 2 diabetes, with study as a random effect.

Model 1: Adjusted for baseline age.

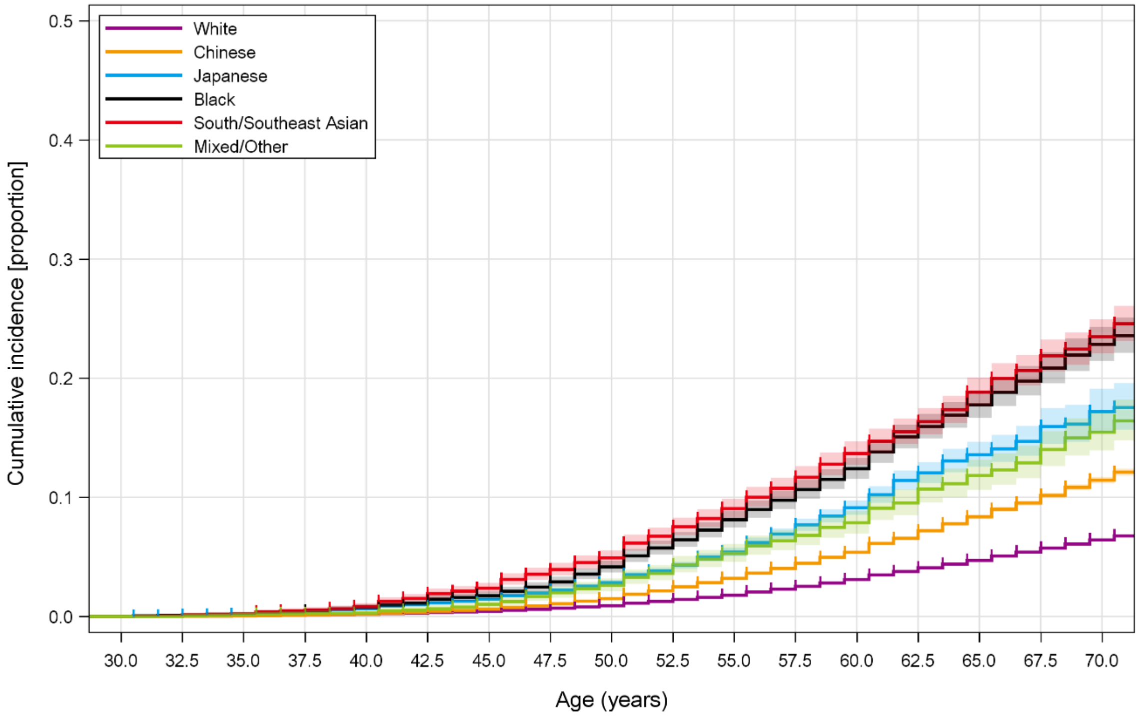
Model 2: Adjusted for baseline age, birth year, education level, and smoking status.

Model 3: Adjusted for baseline age, birth year, education level, smoking status, and BMI.

## Figure legends

**Figure 1** Cumulative incidence (proportion) of type 2 diabetes between ages 30 and 70 years across racial/ethnic groups (n=730,408).

**Figure 2** The joint effect between race/ethnicity and body mass index on the risk of incident type 2 diabetes (n=711,985). The model was adjusted for baseline age, birth year, education level, and smoking status.




No. at risk

| | 30.0 | 32.5 | 35.0 | 37.5 | 40.0 | 42.5 | 45.0 | 47.5 | 50.0 | 52.5 | 55.0 | 57.5 | 60.0 | 62.5 | 65.0 | 67.5 | 70.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| White | 370937 | 370812 | 370705 | 370399 | 370093 | 369385 | 368468 | 366661 | 362045 | 354226 | 335417 | 311547 | 280639 | 257803 | 221990 | 195638 | 158396 |
| Chinese | 297550 | 297107 | 291477 | 277334 | 250256 | 229545 | 198090 | 183236 | 156709 | 134985 | 104349 | 85754 | 63838 | 51427 | 36697 | 27701 | 15768 |
| Japanese | 46759 | 45221 | 40244 | 37016 | 32002 | 28317 | 22813 | 19264 | 14460 | 11312 | 7302 | 5185 | 2914 | 1802 | 876 | 541 | 239 |
| Black | 6430 | 6422 | 6416 | 6389 | 6363 | 6309 | 6242 | 6129 | 5971 | 5754 | 4997 | 4271 | 3328 | 2719 | 2018 | 1603 | 1161 |
| South/Southeast Asian | 5162 | 5155 | 5151 | 5130 | 5111 | 5043 | 4995 | 4899 | 4819 | 4662 | 4184 | 3711 | 3189 | 2763 | 2200 | 1839 | 1409 |
| Mixed/Other | 3570 | 3568 | 3565 | 3557 | 3545 | 3519 | 3464 | 3399 | 3289 | 3152 | 2827 | 2496 | 2031 | 1696 | 1310 | 1075 | 798 |

**Figure 1** Cumulative incidence (proportion) of type 2 diabetes between ages 30 and 70 years across racial/ethnic groups (n=730,408).

| Race/ethnicity and BMI (kg/m$^2$) | Sample | T2D | HR (95% CI) |
|---|---|---|---|
| **White** | | | |
| BMI <18.5 | 3,556 | 70 | 1.39 (1.09-1.77) |
| **BMI 18.5-22.9** | **91,387** | **1,219** | **Reference** |
| BMI 23-24.9 | 72,380 | 1,502 | 1.64 (1.52-1.77) |
| BMI 25-27.4 | 75,622 | 2,437 | 2.74 (2.56-2.94) |
| BMI 27.5-29.9 | 50,212 | 2,704 | 4.88 (4.56-5.23) |
| BMI ≥30 | 70,162 | 7,329 | 10.48 (9.84-11.16) |
| **Chinese** | | | |
| BMI <18.5 | 12,629 | 33 | 2.76 (1.80-4.22) |
| BMI 18.5-22.9 | 113,716 | 313 | 4.10 (3.11-5.39) |
| BMI 23-24.9 | 65,742 | 242 | 5.52 (4.15-7.34) |
| BMI 25-27.4 | 56,485 | 344 | 8.62 (6.52-11.40) |
| BMI 27.5-29.9 | 26,516 | 203 | 10.13 (7.55-13.58) |
| BMI ≥30 | 13,240 | 146 | 13.88 (10.22-18.85) |
| **Japanese** | | | |
| BMI <18.5 | 4,314 | 36 | 2.63 (1.56-4.44) |
| BMI 18.5-22.9 | 28,854 | 399 | 3.03 (1.99-4.60) |
| BMI 23-24.9 | 7,203 | 173 | 4.11 (2.66-6.33) |
| BMI 25-27.4 | 3,639 | 130 | 6.14 (3.95-9.54) |
| BMI 27.5-29.9 | 1,395 | 66 | 9.04 (5.65-14.46) |
| BMI ≥30 | 821 | 69 | 19.67 (12.45-31.08) |
| **South/Southeast Asian** | | | |
| BMI <18.5 | 53 | <5 | N/A |
| BMI 18.5-22.9 | 899 | 44 | 5.08 (3.76-6.88) |
| BMI 23-24.9 | 858 | 65 | 8.83 (6.87-11.34) |
| BMI 25-27.4 | 1,098 | 102 | 12.57 (10.25-15.41) |
| BMI 27.5-29.9 | 774 | 124 | 23.17 (19.21-27.95) |
| BMI ≥30 | 988 | 208 | 35.52 (30.57-41.28) |
| **Black** | | | |
| BMI <18.5 | 20 | <5 | N/A |
| BMI 18.5-22.9 | 512 | 21 | 4.83 (3.13-7.45) |
| BMI 23-24.9 | 668 | 35 | 7.17 (5.11-10.05) |
| BMI 25-27.4 | 1,003 | 61 | 8.59 (6.62-11.15) |
| BMI 27.5-29.9 | 1,126 | 116 | 14.24 (11.70-17.33) |
| BMI ≥30 | 2,668 | 427 | 24.15 (21.45-27.19) |
| **Mixed/Other** | | | |
| BMI <18.5 | 31 | <5 | N/A |
| BMI 18.5-22.9 | 698 | 25 | 3.16 (2.13-4.70) |
| BMI 23-24.9 | 654 | 39 | 5.56 (4.03-7.66) |
| BMI 25-27.4 | 693 | 41 | 6.08 (4.44-8.33) |
| BMI 27.5-29.9 | 546 | 60 | 12.71 (9.78-16.50) |
| BMI ≥30 | 823 | 118 | 15.74 (12.99-19.06) |

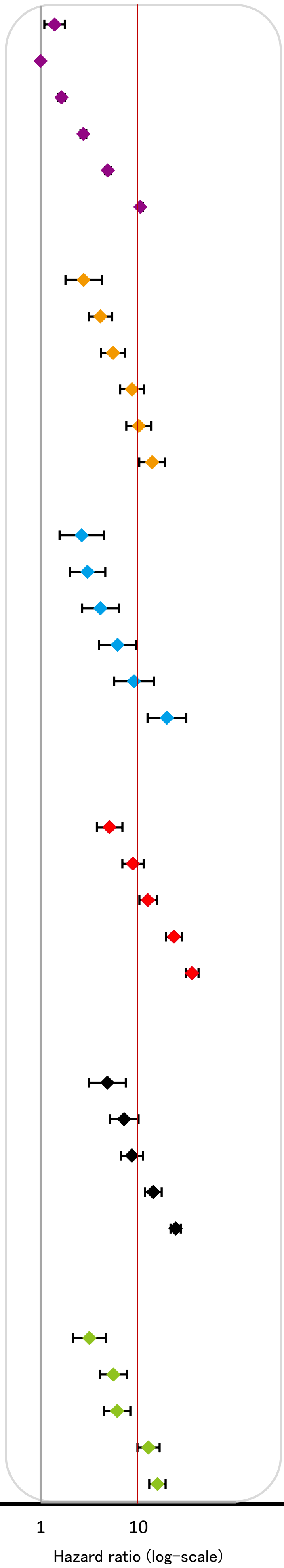


**Figure 2** The joint effect between race/ethnicity and body mass index on the risk of incident type 2 diabetes (n=711,985). The model was adjusted for baseline age, birth year, education level, and smoking status.