Differences in the risk of cardiovascular disease across ethnic groups: UK Biobank observational study

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KEYWORDS
Ethnicity; Ethnic differences; Cardiovascular disease; South Asian; Black African or Caribbean; Observational study; UK Biobank

Abstract  Background and aims: To describe sociodemographic, lifestyle, environmental and traditional clinical risk factor differences between ethnic groups and to investigate the extent to which such differences confound the association between ethnic groups and the risk of cardiovascular disease (CVD)

Methods and results: A total of 440,693 white European (55.9% women), 7305 South Asian (48.6%) and 7628 black African or Caribbean (57.7%) people were included from UK Biobank. Associations between ethnicity and cardiovascular outcomes (composite of non-fatal stroke, non-fatal myocardial infarction and CVD death) were explored using Cox-proportional hazard models. Models were adjusted for sociodemographic, lifestyle, environmental and clinical risk factors. Over a median (IQR) of 12.6 (11.8, 13.3) follow-up years, there were 22,711 (5.15%) cardiovascular events in white European, 463 (6.34%) in South Asian and 302 (3.96%) in black African or Caribbean individuals. For South Asian people, the cardiovascular hazard ratio (HR) compared to white European people was 1.28 (99% CI [1.16, 1.43]). For black African or Caribbean people, the HR was 0.80 (0.66, 0.97). The elevated risk of CVD in South Asians remained after adjusting for differences in sociodemographic, lifestyle, environmental and clinical factors, whereas the lower risk in black African or Caribbean was largely attenuated.

Conclusions: South Asian, but not black African or Caribbean individuals, have a higher risk of CVD compared to white European individuals. This higher risk in South Asians was independent of sociodemographic, lifestyle, environmental and clinical factors.

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1. Introduction

Cardiovascular diseases (CVD) are the most prevalent and costly non-communicable diseases worldwide, with ischaemic heart disease and stroke both ranked within the top three causes of death globally [1]. Differences in CVD risk between ethnicities is well evidenced, with South Asian (SA) and black African or Caribbean (BAC) individuals displaying an increased risk of developing and dying from CVD, compared to white European (WE) individuals within the UK [2–4] and other European countries [5,6]. SA individuals display a particularly high risk of ischaemic heart diseases, while black Caribbean individuals report elevated risk of cerebrovascular diseases.

Understanding the reasons behind this increased risk is important for public health strategies. Lifestyle behaviours, such as smoking, physical activity, physical function/capability (measured via simple to measure behaviours such as walking pace), sedentary time and diet have been found to be important risk factors that may contribute towards CVD [7–14]. Furthermore, lifestyle behaviours have consistently demonstrated to improve cardiovascular health and reduce the risk of CVD, diabetes and mortality in all ethnicities [15–19]. Minority ethnic groups have been noted to possess different dietary [20] and sleep [21] habits compared to WE individuals, whilst engaging in less physical activity [22] and having lower cardiorespiratory fitness [23]. In addition to lifestyle behaviours, wider sociodemographic and environmental factors, such as levels of deprivation and air pollution, are also important determinants of cardiovascular and wider health [24–26], with exposures reported to differ by ethnicity [27,28]. Clinical risk factors have also been established as risk factors for CVD [29], with known differences in clinical risk factors between ethnic groups potentially contributing to (confounding) the increased risk between ethnic groups [30,31].

Although there is some evidence that differences in individual lifestyle behaviours or risk factors, such as physical activity or fitness, may explain some of the excess risk of cardiovascular disease in minority ethnic groups [32,33], the full extent to which wider differences in lifestyle, sociodemographic, and environmental factors act as confounders in the association between ethnicity and CVD risk has not yet been fully explored.

Therefore, the aim of this study was to describe sociodemographic, lifestyle, environmental and traditional clinical risk factor differences between WE, SA and BAC individuals in the UK Biobank cohort and to investigate the extent to which such differences confound the association between ethnicity and risk of fatal and non-fatal CVD events.

2. Methods

2.1. UK Biobank

Data from 502,539 participants from UK Biobank were included, the methods and aims of which have been described elsewhere [34]. In brief, UK Biobank is a prospective cohort of middle-aged adults designed to support health research focused on improving the prevention, diagnosis, and treatment of chronic diseases. Between March 2006 and July 2010, individuals living within 25 miles of one of the 22 study assessment centres located throughout England, Scotland and Wales were recruited and attended data collection. All participants provided written informed consent and the study was approved by the NHS National Research Ethics Service (Ref: 11/NW/0382).

For each variable reported in this analysis, we provide the UK Biobank Data-Field (DF) number. Each DF is linked to detailed information on measurement procedures in the UK Biobank showcase.

2.2. Study population, participant inclusion and classification of ethnicity

From the initial 502,539 participants, we included those without prevalent CVD at baseline, a valid censor date and defining themselves as white (British, Irish, white or any other white background; n = 440,693; 96.7%), SA (Asian or Asian British, Indian, Pakistani or Bangladeshi; n = 7,305; 1.6%) or BAC (black or black British, Caribbean, African or any other black background; n = 7,628; 1.7%). Other ethnicities were excluded due to low numbers. From this sample, only subjects with data for each exposure variable investigated were included (Supplementary Fig. S1 and Table S1). Recruitment to UK Biobank occurred between the 2001 and 2011 national census dates.

2.3. Lifestyle, environmental, sociodemographic, medical history and traditional clinical risk factors

The following variables were included as possible factors that may be important in confounding the higher risk of CVD in minority ethnic groups. These factors were chosen based on a combination of previous evidence suggesting that traditional clinical, medical history and sociodemographic risk factors such as triglycerides, previous chronic disease and deprivation are associated with CVD, in addition to emerging risk factors such as environmental, lifestyle and sociodemographic factors like air pollution and walking pace, where there are known differences between ethnic groups.

2.3.1. Lifestyle behaviours, physical function and body mass index

We included mean handgrip strength (DF 46 and 47), walking pace (DF 924), time spent watching TV (DF 1070), sleep duration (DF 1060), processed meat consumption (DF 1349), fruit and vegetable score (DF 1289, 1299, 1309 and 1319), red meat score (DF 1369, 1379 and 1389), milk type mainly used (DF 1418), spread type mainly used (DF
2.3.2. Environmental
We included nitrogen dioxide (NO$_2$) air pollution (DF 24003), particulate matter air pollution <2.5 μm (PM$_{2.5}$) (DF 24006), particulate matter air pollution <10 μm (PM$_{10}$) (DF 24005) and averaged 24-hr sound level of noise pollution LA$_{eq24}$ (DF 24024).

The environmental exposure noise estimates were assigned to residential address at recruitment in year 2005–10. NO$_2$ and PM measures were modelled to participant address using land use regression (LUR) models originally developed for the European Study of Cohorts for Air Pollution Effects (ESCAPE) [36,37]. Particulate matter ESCAPE estimates were not available for addresses >400 km away from Greater London as the model evaluations were poor. Noise estimates were modelled as recommended by the European Noise Directive 2002/49/EC and relate to 2009 [38]. As the spatial structure of air pollution and noise exposure is relatively stable over time (as road networks, land use characteristics change slowly), estimates are valid across the recruitment period.

2.3.3. Sociodemographic
Age (DF 34), ethnicity (DF 21000), sex (DF 31), deprivation (DF 189), employment status (DF 6142), qualifications (DF 6138) and household income (DF 738) were included.

2.3.4. Medical history
Number of medications/treatments taken (DF 137), number of self-reported cancer illnesses (DF 134) and number of self-report non-cancer illnesses (DF 135) were included.

2.3.5. Traditional clinical risk markers
Glycated haemoglobin (HbA1c (mmol/mol); DF 30740), fasting blood glucose (mmol/l; DF 30740), fasting triglycerides (mmol/l; DF 30870), HDL-cholesterol (mmol/l; DF 30760), C-reactive protein (mg/l; DF 30710), cholesterol–HDL ratio (cholesterol:HDL) and automated systolic BP (mmHg; DF 4080) were used for this analysis.

Total cholesterol (mmol/l; DF 30690), LDL cholesterol (mmol/l; DF 30780) and body fat percentage (%; DF 23099) were additionally used. Participants provided blood samples at their assessment centre visit, which was taken by a trained healthcare professional. Glucose, triglycerides, HDL-cholesterol, C-reactive protein and total cholesterol serum samples were measured using the Beckman Coulter AU5800 analytical platform and analysis method was by hexokinase, GPO-POD, enzyme immunoinhibition, immunonoturbidimetric -high sensitivity and CHO-POD, respectively [34]. HbA1c red blood cell samples were measured using the Bio-Rad VARIANT II Turbo analytical platform and analysis method was by HPLC.

2.4. Cardiovascular events
Three-point major adverse cardiovascular events (3P-MACE) was defined as a combined outcome of non-fatal stroke, non-fatal myocardial infarction (MI) and CVD death. UK Biobank undertook comprehensive data linkage for mortality status. Date and cause of death were obtained from the National Health Service (NHS) Information Centre for participants from England and Wales, and from the NHS Central Register, Scotland, for participants from Scotland. We defined cardiovascular disease mortality using the International Classification of Diseases edition 10 (ICD-10) codes I05-I89.9. Incidence of MI (DF 42000) and stroke (DF 42006) were quantified using a validated UK Biobank algorithm that triangulates nurse-confirmed self-report and hospital admissions data [39]. Linkage captured fatal and non-fatal events occurring until 30 September 2021 for England and Wales and 31 October 2021 for Scotland, with these dates being used as censor dates. Individuals with prevalent CVD at baseline were removed from the cohort (Fig. S1).

2.5. Statistical analysis
Unadjusted generalised linear models and nonparametric tests were used to explore differences in sociodemographic, lifestyle, environmental and traditional clinical risk factors between ethnic groups.

The associations between ethnicity and cardiovascular outcomes were explored using Cox-proportional hazard models with years of follow-up as the time scale. Clustering by UK Biobank assessment centre was included in our models to account for potential differences by assessment centre. Analyses were performed using 3P-MACE as an outcome. The results were reported as hazard ratios (HRs). WE individuals were used as the reference group. First, we estimated the association in an unadjusted model (model 0). Models were then adjusted for key sociodemographic factors considered to be potential confounders, namely age, sex, self-reported cancer illnesses, number of self-reported non-cancer illnesses, number of medications/treatment taken, deprivation, employment status, qualifications and household income (model 1). Model 1 was subsequently considered the base model. To model 1 we added markers of physical function (handgrip...
strength, walking pace; model 2), lifestyle (MET score for leisure time physical activity, TV viewing, sleep duration, processed meat consumption, red meat score, fruit and veg score, milk type used, spread type used, alcohol intake, BMI, smoking status; model 3), environmental (NO$_2$ and PM$_{2.5}$ air pollution, LA$_{eq24}$ noise; model 4) and traditional clinical risk factors (HbA1c, glucose, triglycerides, HDL-cholesterol, C-reactive protein, cholesterol-HDL ratio and systolic blood pressure; model 5) considered to be potential confounders to the base model. A final model which included all factors was also considered (model 6). This analysis plan was developed to assess the degree to which the risk of cardiovascular outcomes between different ethnic groups were independent of differences in assessed sociodemographic, lifestyle, environmental and traditional clinical risk factors. This clustering of factors allowed us to evaluate the comparative impact of lifestyle vs environmental vs clinical factors as we separately added these to the same base model. The degree of attenuation upon adjustment was interpreted as the extent to which ethnic differences in the risk of cardiovascular outcomes were independent of differences in assessed sociodemographic, lifestyle, environmental and traditional clinical risk factors. A further analysis that separately adjusted for each individual lifestyle, environmental and traditional clinical risk factor, instead of grouping them together, was conducted.

In order to maximise power, a complete case sample was used for each model individually; Fig. S1 and Tables S1 and S2 report the flow of data inclusion/exclusion and numbers in each model. To account for missing data in the multivariable models, multiple imputation using chained equations were performed using mi impute in Stata for all variables with missing data, and results were obtained using Rubin rules to combine 10 imputed datasets. We undertook a further complete case sensitivity analysis where only individuals without missing data for any of the variables used across all models were included.

Analyses were performed using Stata; results are reported with 99% confidence intervals (CIs) and a two-sided p-value < 0.01 was considered statistically significant to account for multiple testing in models. Descriptive data is reported as median (IQR) unless stated otherwise.

3. Results

Of the 502,539 participants, 455,626 from the relevant ethnic backgrounds were included. Baseline characteristics are reported in Table 1. Median (IQR) age was higher in WE individuals (58 years [50, 63]) vs. SA (52 [46, 60]) and BAC individuals (50 [45, 57]). Women represented a greater proportion of the WE (55.9% women) and BAC (57.7%) samples, compared to the SA cohort (48.6%).

Table 1 displays the lifestyle, environmental, sociodemographic and traditional clinical risk factors for each ethnicity. BMI was higher among BAC than WE and SA individuals. SA and BAC individuals reported similar levels of physical activity, which was lower than WE individuals. SA individuals also reported the lowest levels of handgrip strength and brisk walking pace compared to both WE and BAC individuals. Whereas, WE and BAC individuals reported the highest levels of TV viewing. Conversely, SA individuals reported eating the least red and processed meat and the most fruit and vegetables, whilst also being more likely to report never drinking alcohol or being a current or previous smoker. Both minority ethnic groups had greater exposure to noise and air pollution and greater levels of deprivation compared to WE individuals, with levels tending to highest in BAC individuals.

SA and BAC individuals had similar levels of HbA1c that were 2.9 mmol/mol (0.2% DCCT unit) higher than WE individuals. SA individuals also reported 0.2 and 0.7 mmol/l higher triglycerides levels and 0.3 and 0.6 higher cholesterol-HDL ratio than WE and BAC individuals, respectively, whilst additionally reporting 0.1 mmol/l higher glucose levels than BAC individuals, with WE individuals reporting similar glucose levels to SA individuals. SA individuals also displayed 0.2 mmol/l lower HDL-cholesterol levels than both WE and BAC individuals. C-reactive protein in SA individuals was 0.3 mg/l and 0.2 mg/l higher than WE and BAC individuals, respectively. Systolic blood pressure was 3 mmHg lower in SA individuals compared to WE individuals, with no differences observed between WE and BAC individuals. SA and WE individuals had similar levels of body fat percentage that were 2.3–2.4% lower than BAC individuals.

3.1. Cardiovascular events

Over a median (IQR) of 12.6 (11.8, 13.3) years of follow-up, there were 22,711 (5.15%) 3P-MACE events in WE, 463 (6.34%) in SA and 302 (3.96%) in BAC individuals available for analysis in the unadjusted model; this corresponded to 4.2, 5.3 and 3.3 events per 1000 person years, respectively. Age and sex adjusted values were 4.3, 6.5 and 4.7 events per 1000 person years, respectively.

The number of events across each adjustment model is shown in Table S2. Ethnicity was associated with 3P-MACE across all sociodemographic, lifestyle, environmental and clinical models, with the risk being higher in SA individuals than WE (unadjusted HR: 1.28; 99% CI: 1.16, 1.43) (Fig. 1; Table S3). Results remained largely unchanged after adjustment for sociodemographic, lifestyle, environmental and traditional clinical risk factors (Fig. 1). The higher SA risk remained after combining all factors (sociodemographic, lifestyle, environmental and traditional clinical risk factors) in the model (model 6 HR: 1.24; 99% CI: 1.03, 1.48). When examining each factor individually, HbA1C contributed the greatest reduction (HR 1.23; 1.11, 1.36) (Table S4; Fig. S2) however, the elevated risk in SA individuals was still found to be independent of all individual risk factors.

In the unadjusted model, BAC individuals were at lower risk of 3P-MACE compared to WE individuals. Such lower risk was largely attenuated in the majority of adjusted models, except for the clinical model where the lower risk in BAC individuals was independent of traditional clinical risk factors (HR 0.76; 0.60, 0.96) (Fig. 1; Table S3). While the risk of 3P-MACE was found to be non-significant.
<table>
<thead>
<tr>
<th>Variable</th>
<th>White European</th>
<th>South Asian</th>
<th>Black African or Caribbean</th>
<th>WE v SA</th>
<th>p value</th>
<th>WE v BAC</th>
<th>p value</th>
<th>SA v BAC</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>58.0 (50.0–63.0)</td>
<td>52.0 (46.0–60.0)</td>
<td>50.0 (45.0–57.0)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Sex N [%]</td>
<td>246,387 (55.9%)</td>
<td>3547 (48.6%)</td>
<td>4404 (57.7%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Social deprivation (Townsend score)</td>
<td>–2.3 (–3.7–0.2)</td>
<td>0.1 (–2.2–2.4)</td>
<td>2.8 (–0.4–5.6)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Employment status N [%]</td>
<td>Employed</td>
<td>259,448 (59.3%)</td>
<td>4629 (65.6%)</td>
<td>5128 (69.1%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Qualifications N [%]</td>
<td>College or university degree or above</td>
<td>143,645 (39.6%)</td>
<td>2840 (50.1%)</td>
<td>2511 (39.7%)</td>
<td>&lt;0.0001</td>
<td></td>
<td>0.643</td>
<td>&lt;0.0001</td>
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<tr>
<td>Household income N [%]</td>
<td>Less than £18,000</td>
<td>79,343 (21.0%)</td>
<td>1674 (31.1%)</td>
<td>1989 (34.0%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Number of medications</td>
<td>2.0 (0.0–3.0)</td>
<td>2.0 (0.0–3.0)</td>
<td>2.0 (0.0–3.0)</td>
<td>0.039</td>
<td>0.053</td>
<td>0.900</td>
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<tr>
<td>Number of self-reported non-cancer illnesses</td>
<td>0.0 (0.0–1.0)</td>
<td>0.0 (0.0–0.0)</td>
<td>0.0 (0.0–0.0)</td>
<td>0.127</td>
<td>&lt;0.0001</td>
<td>0.015</td>
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<tr>
<td>Markers of physical function</td>
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<td>Grip strength (kg)</td>
<td>29.0 (22.0–39.0)</td>
<td>25.5 (19.0–34.0)</td>
<td>30.0 (23.0–39.0)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Walking pace N [%]</td>
<td>Slow pace</td>
<td>28,953 (6.6%)</td>
<td>1159 (16.4%)</td>
<td>978 (13.1%)</td>
<td>&lt;0.0001</td>
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<td>&lt;0.0001</td>
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<tr>
<td>Average pace</td>
<td></td>
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<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Brisk pace</td>
<td>229,638 (52.4%)</td>
<td>4463 (63.2%)</td>
<td>4882 (60.0%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<td>Lifestyle</td>
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<tr>
<td>MET (minutes/week) score for leisure time PA</td>
<td>174.4 (124.9)</td>
<td>225.7 (708.8)</td>
<td>164.6 (708.8)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
<td>0.001</td>
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<tr>
<td>Sleep duration (hrs/day)</td>
<td>3.0 (2.0–4.0)</td>
<td>2.0 (1.0–3.0)</td>
<td>3.0 (2.0–4.0)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Processed meat (portions/week)</td>
<td>1.0 (0.5–3.0)</td>
<td>0.5 (0.0–1.0)</td>
<td>0.5 (0.5–1.0)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Fruit and veg score (portions/day)</td>
<td>4.0 (2.7–6.0)</td>
<td>5.0 (3.3–7.7)</td>
<td>4.3 (2.7–6.7)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Red meat score (portions/week)</td>
<td>2.0 (1.5–2.5)</td>
<td>1.0 (0.0–2.0)</td>
<td>2.0 (1.5–3.5)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Milk type mainly used N [%]</td>
<td>Full cream</td>
<td>28,294 (6.4%)</td>
<td>1396 (19.2%)</td>
<td>1194 (15.7%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Semi-skimmed</td>
<td>286,009 (64.9%)</td>
<td>4565 (62.9%)</td>
<td>3954 (52.1%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Skimmed</td>
<td>89,705 (20.4%)</td>
<td>861 (11.9%)</td>
<td>871 (11.5%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Soya</td>
<td>16,769 (3.8%)</td>
<td>248 (3.4%)</td>
<td>782 (10.3%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Other type of milk or never/rarely use milk</td>
<td>19,621 (4.5%)</td>
<td>188 (2.6%)</td>
<td>791 (10.4%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Spread type mainly used N [%]</td>
<td>Never/rarely use</td>
<td>46,140 (10.6%)</td>
<td>960 (13.4%)</td>
<td>1315 (17.5%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Other type of spread/margarine</td>
<td>161,806 (37.0%)</td>
<td>2201 (30.8%)</td>
<td>2740 (36.5%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>Alcohol consumption N [%]</td>
<td>75,470 (17.1%)</td>
<td>4684 (64.5%)</td>
<td>3844 (50.6%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>1-3 per month or less</td>
<td>49,368 (11.2%)</td>
<td>530 (7.3%)</td>
<td>1004 (13.2%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>1-2 per week</td>
<td>116,510 (26.5%)</td>
<td>979 (13.5%)</td>
<td>1518 (20.0%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tr>
<tr>
<td>3-4 per week</td>
<td>106,125 (24.1%)</td>
<td>592 (8.2%)</td>
<td>739 (9.7%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
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</tr>
<tr>
<td>Daily</td>
<td>92,923 (21.1%)</td>
<td>473 (6.5%)</td>
<td>492 (6.5%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.6 (24.0–29.7)</td>
<td>26.6 (24.2–29.5)</td>
<td>28.7 (25.7–32.1)</td>
<td>0.070</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Smoking status N [%]</td>
<td>Current</td>
<td>241,884 (55.1%)</td>
<td>5784 (80.1%)</td>
<td>5328 (70.4%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
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</tr>
<tr>
<td>Never</td>
<td>152,132 (34.6%)</td>
<td>790 (10.9%)</td>
<td>1301 (17.2%)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
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</tr>
<tr>
<td>Alcohol consumption N [%]</td>
<td>25.9 (21.2–30.8)</td>
<td>31.3 (27.8–34.6)</td>
<td>34.1 (30.2–38.6)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
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</tr>
<tr>
<td>Average 24 h noise pollution (LAeq24)</td>
<td>54.9 (53.5–57.0)</td>
<td>55.5 (53.9–57.5)</td>
<td>55.3 (53.9–57.8)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.204</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c (mmol/mol)</td>
<td>35.0 (32.6–37.5)</td>
<td>37.9 (34.9–41.8)</td>
<td>37.9 (34.4–41.5)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>4.9 (4.6–5.3)</td>
<td>4.9 (4.6–5.4)</td>
<td>4.8 (4.5–5.3)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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</tbody>
</table>

(continued on next page)
between BAC and WE ethnic groups in sociodemographic, lifestyle, environmental and combined models (Fig. 1), the general patterns of all the models were similar and generally report a lower risk for BAC individuals compared to WE individuals.

Results from the multiple imputation (Table S5; Fig. S3) and complete case (Table S6; Fig. S4) sensitivity analyses were found to be similar to that of the main results, with no differences in patterns of association found between the sensitivity analyses and the main analysis.

4. Discussion

In a large contemporary UK population SA individuals had a higher risk of fatal and non-fatal CVD than WE individuals, which was independent of differences in a wide range of sociodemographic, lifestyle, environmental and clinical factors. BAC individuals, in contrast to SA individuals, did not appear to have a different risk profile for cardiovascular morbidity or mortality than WEs in fully adjusted models.

Our finding of an elevated risk of CVD events in a UK SA diaspora compared to WE individuals is consistent with previous research from developed countries [40,41]. However, as far as we are aware, this is the first study to examine the extent to which this elevated risk profile is independent of differences in sociodemographic, lifestyle, environmental and traditional clinical risk factors. Whilst large disparities in lifestyle behaviours and environmental risk factors were observed between ethnic groups, these differences did not meaningfully confound the elevated risk of CVD in SA individuals. This finding is in contrast to other studies that have investigated, using a similar methodology to the present study, the impact of individual measures of physical activity and fitness, which have been shown to explain a substantial proportion of the increased insulin resistance and risk of coronary heart disease mortality found in SA individuals [23,32]. However, whilst our study confirmed that levels of physical activity, function and strength were lowest in SA individuals, their dietary, alcohol and smoking choices were healthier. This is consistent with previous research [20] and may be related to dietary choices for cultural or religious reasons [42].

Interestingly, risk of fatal and non-fatal CVD was also found to be independent of BMI in SA individuals. Previous evidence has shown that adiposity is an important contributor to CVD in SA individuals [3]. However, the measurement of adiposity in our study may not fully capture the most suitable method to measure adiposity in minority ethnic groups and further examination of the relationship between measures of adiposity and CVD risk between ethnic groups is required. Therefore when considered overall, lifestyle did not confound the adverse fatal and non-fatal CVD event profile in SA individuals.

The higher risk of CVD in SA compared to WE individuals was also independent of traditional clinical markers. This is an important finding given levels of HbA1c, triglycerides, C-reactive protein and total-to-HDL cholesterol ratio were all higher in SA participants. If confirmed to be causal, these findings suggest that aggressive management of risk factors in SAs communities, whilst reducing overall risk, may not by itself fully eliminate the relatively higher risk of CVD within these populations [43,44]. Instead, a more holistic approach to CVD risk reduction may have to be considered, with a focus not only management of risk factors through pharmacological and lifestyle measures, but wider determinants and earlier intervention too.

BAC individuals, in contrast to SA individuals, did not have an elevated risk of CVD compared to WE individuals. This contrasts with some previous work that demonstrates that African or Caribbean individuals are at increased CVD and, particularly, stroke risk [2,31]. However, this ethnic group may also be at lower risk of coronary/ischaemic heart disease [31], which may partially explain our results. Recent population-level analysis of the leading causes of mortality in the UK by ethnic group found that all BAC individuals had lower rates of ischaemic heart disease (e.g. MI) than white individuals. Rates of cerebrovascular diseases (e.g. stroke) were found to be lower in black African individuals than white, while rates in black Caribbean individuals were found to be similar or higher in women and men.

### Table 1 (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>White European</th>
<th>South Asian</th>
<th>Black African or Caribbean</th>
<th>WE v SA p value</th>
<th>WE v BAC p value</th>
<th>SA v BAC p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol (mmol/l)</td>
<td>5.7 (5.0–6.5)</td>
<td>5.4 (4.7–6.0)</td>
<td>5.2 (4.5–5.9)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Triglycerides (mmol/l)</td>
<td>1.5 (1.0–2.1)</td>
<td>1.7 (1.2–2.4)</td>
<td>1.0 (0.8–1.4)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HDL-cholesterol (mmol/l)</td>
<td>1.4 (1.2–1.7)</td>
<td>1.2 (1.0–1.5)</td>
<td>1.4 (1.2–1.7)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LDL-cholesterol (mmol/l)</td>
<td>3.6 (3.0–4.2)</td>
<td>3.4 (2.8–3.9)</td>
<td>3.2 (2.7–3.8)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cholesterol-HDL ratio</td>
<td>4.0 (3.3–4.8)</td>
<td>4.3 (3.6–5.2)</td>
<td>3.7 (3.1–4.4)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>C-reactive protein (mg/l)</td>
<td>1.3 (0.7–2.7)</td>
<td>1.6 (0.8–3.4)</td>
<td>1.4 (0.6–3.0)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.081</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>138.0</td>
<td>135.0</td>
<td>138.0</td>
<td>&lt;0.0001</td>
<td>0.044</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(126.0–152.0)</td>
<td>(123.0–148.0)</td>
<td>(125.0–152.0)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Body fat percent (%)</td>
<td>31.1 (25.1–37.7)</td>
<td>31.2 (25.6–38.2)</td>
<td>33.5 (26.2–41.4)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Medians, counts and p-values for differences estimated using nonparametric tests and generalised linear models.

Numbers are median [IQR] or number [%].

MET: Metabolic Equivalent; PA: Physical Activity; BMI: Body Mass Index; NO2: Nitrogen Dioxide; PM: Particulate Matter; HbA1c: Glycated Haemoglobin; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; SBP: Systolic Blood Pressure.
men, respectively [4]. These results may further explain our findings. Our study also found that BAC individuals report some favourable biochemical cardiometabolic risk factors compared to WE and SA individuals, predominantly in relation to lipid based risk factors, such as triglycerides and HDL-cholesterol, which corroborates previous research [31].

Growing research has suggested that environmental factors, particularly air pollution, is closely associated with cardiometabolic health [24]. This study shows that both minority ethnic groups were exposed to worse air and noise pollution levels than WE individuals, with BAC individuals reporting the worst levels of air and noise pollution. This corroborates previous research showing black and Asian individuals were exposed to more PM2.5, PM10 and NO2 in London [45] and the Netherlands after adjustment for deprivation [27]. However, this study suggests that the more detrimental environmental conditions surrounding the homes of minority ethnic groups may not, by itself, confound the elevated CVD risk.

While a diverse range of factors were measured in this study, genetic and epigenetic factors cannot be discounted as potentially contributing to cardiometabolic risk between ethnicities. While several genes that potentially contribute to overall cardiometabolic risk are found in all ethnic groups, some of the susceptibility for certain genes attributing towards cardiometabolic disease are likely to be specific to certain populations [46]. However, it has been argued that genetic factors alone are unlikely to explain an increased risk of certain cardiometabolic diseases, such as type 2 diabetes, and rather that the interaction between environmental, lifestyle and genetic factors may be important [46].

5. Strengths and limitations

This study has important strengths, including the large sample size and large number of SA and BAC individuals, compared to previous research into ethnic health differences. The extensively phenotyped population also allowed for comprehensive investigation into a variety of different sociodemographic, lifestyle, environmental and clinical factors in a contemporary population. Nonetheless, important limitations remain. We recognise that this sample is not fully representative of modern Britain, with the number of individuals from minority ethnic groups being lower than the general population (2011 UK Census ethnic breakdown: 86% white British or European; 5.3% SA; 3.4% BAC [47]). The ethnic composition of the population from this study more closely reflects the Census figures from 2001. Additionally, the health status of this sample has been noted to be healthier than the national average [48]. However, when compared to other nationally representative cohort studies, risk factor associations have been shown to be generalisable to the general population [49]. It is also acknowledged that the terms ‘South Asian’ and ‘black African or Caribbean’ cover a wide range of different cultures, languages and religions with genetic heterogeneity. Consequently, our results may not apply to all SA or BAC populations. The majority of the lifestyle factors were obtained by self-reported measures. Further, literature and methods for collecting data on certain variables, such as dietary factors, has moved on from the time of baseline data collection in UK Biobank (e.g. measuring individual parameters to instead focusing on dietary

![Figure 1 Cox-proportional hazard models for 3P-MACE outcomes in South Asian and black African or Caribbean individuals. Reference (hazard ratio 1, blue dotted line) group is white European individuals; spikes indicate 99% CIs. SA: South Asian. BAC: black African or Caribbean. Model 0: unadjusted model. Model 1: age, sex, self-reported cancer illnesses, number of self-reported non-cancer illnesses, number of medications/treatment taken, social deprivation, employment status, qualifications and household income. Model 2: model 1 + handgrip strength mean and walking pace. Model 3: model 1 + MET score for leisure time physical activity, TV viewing, sleep duration, processed meat consumption, red meat score, fruit and vegetable score, milk type used, spread type used, alcohol intake, BMI and smoking status. Model 4: model 1 + environmental nitrogen dioxide, particulate matter2.5 and averaged 24-hr noise pollution. Model 5: model 1 + HbA1c, glucose, HDL-cholesterol, cholesterol-to-HDL ratio, triglycerides, C-reactive protein and systolic blood pressure. Model 6: model 1 + model 2 (markers of physical function) + model 3 (lifestyle), model 4 (environmental) and model 5 (traditional clinical risk marker). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

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patterns). In addition, the environmental factors were estimated at place of residence as individual monitoring of many thousand individuals is not feasible. These measurement limitations may have resulted in some residual confounding, potentially acting to dilute their relative importance in contributing to the ethnic risk of cardiovascular disease. Individual chronic morbidity data was unavailable in this analysis due to low event numbers in the minority ethnic groups, therefore the impact that individual diseases had was unavailable. Further, we recognise that other criteria than our own can be used for the identification of possible confounders and their clustering and progressive inclusion in the regression model, which will have an impact on the change in the estimates. Finally some key factors that may affect health that are unique to minority ethnic groups, such as racial discrimination, poor language skills, access to healthcare and lack of opportunity for social mobility were unavailable and may therefore have acted as further confounders of the observed differences in health status and incident CVD events.

6. Conclusion

To conclude, our data indicate that SA individuals have an increased risk of cardiovascular morbidity and mortality compared to WE and BAC individuals, and this higher risk was observed after accounting for a wide range of sociodemographic, lifestyle, environmental and clinical risk factors. This research therefore suggests addressing key disparities in sociodemographic, lifestyle, environmental and clinical factors between ethnic groups, whilst of vital importance for social reasons, may not by themselves fully address the inequalities seen in CVD health status. Further epidemiological and experimental research is needed to confirm these conclusions and their implications for public health policies.

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Author contribution statement

CR completed data acquisition, analysed the data and drafted the manuscript; TY assisted with data acquisition, data analysis and interpretation of data; FZ assisted with data acquisition and data analysis. JM assisted with data acquisition. TY, KK, MJD, FZ, JM and AH provided critical revision of the manuscript for important intellectual content; all the authors approved the manuscript for publication. CR will act as the guarantor for this work.

Data source

This research has been conducted using the UK Biobank Resource under Application Number 36371.

Declaration of competing interest

TY, MJD are supported by the National Institute for Health Research (NIHR) Leicester Biomedical Research Centre (BRC). KK is Director for the University of Leicester Centre for Ethnic Health Research, Trustee of the South Asian Health Foundation, national NIHR Applied Research Collaborations — East Midlands (ARC-EM) lead for Ethnicity and Diversity and a member of SAGE and Chair of the SAGE subgroup on ethnicity and COVID-19. AH acknowledges funding from the NIHR Health Protection Research Unit in Environmental Exposures and Health Development Award at University of Leicester. Other authors declare no conflicts of interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2022.08.002.

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