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ORIGINAL ARTICLE

Changes in cardiovascular risk factors for diabetes among young versus older English adult populations

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Abstract

Background To examine the prevalence of cardiovascular disease (CVD) risk factors among young, middle-aged and older adults with and without diabetes.

Method Among 23,501 participants of pooled nationally representative Health Survey for England years 2003, 2006, 2011 and 2017 (new sample was interviewed each year), CVD risk-factors associated with diabetes versus non-diabetes among young (18-54y), middle (55-74y) and older (≥ 75y) adults were assessed. Models were adjusted for age, sex, locality, ethnicity, qualification, survey year, cardiovascular disease, raised blood pressure, dyslipidaemia, combined obesity, current smoking, and excessive drinking.

Results 11.9% of adults had diabetes: prevalence was 5.3% in aged 18-54y, 18.1% in aged 55-74y, and 29.1% in older adults. Diabetes prevalence was higher in 2017 than 2003 in each age-group. After adjustments for confounding variables, significant predictors of diabetes among young were CVD history, raised BP, dyslipidaemia, combined obesity, and survey year 2006. Effect of dyslipidaemia in young adults on the risk of diabetes was stronger in more recent years 2006 (Odds Ratio =3.87), 2011 (3.04) and 2017 (3.42) as compared with 2003. Among middle age, CVD history, raised BP, dyslipidaemia, combined obesity and survey years 2006 and 2011 were significant predictors of diabetes whereas in older populations only dyslipidaemia, combined obesity and survey year 2011 showed strong association with risk of diabetes. Irrespective of age, smoking and excessive drinking were not significantly associated with diabetes.

Conclusion Young adults with diabetes have higher odds of having cardiovascular risk factors, with dyslipidaemia being the strongest risk factor. Early and specific intervention among young adults would delay CVD outcomes.

Keywords Cardiovascular risk factors · Diabetes · Age · Health examination survey · England

What is already known on this topic

In the UK and other high-income countries, diabetes prevalence has increased. Age-standardized prevalence of ever having any CVD was higher among people with doctor-diagnosed diabetes (24%) than those without a diabetes diagnosis (16%) in England. Furthermore, over the past 25 years, the prevalence of obesity among adults in England has also increased markedly from 16% in 1994 to 28% in 2018.

What this study adds

In England, although the trends of CVD prevalence with respect to age are published, the prevalence of CVD risk factors in populations with or without diabetes needs more attention for early preventative public health strategies. Using data from the Epidemiological Health Survey of England (HSE), we aimed to examine the prevalence of CVD risk factors in the survey years 2003, 2006, 2011, and 2017 and whether the association between CVD risk factors and diabetes has changed over time among different age-groups.

How this study might affect research, practice or policy

CVD risk factors have increased over a period of time though the proportion is different in each age group. This article implies the importance of targeted age-specific interventions in both diabetes and non-diabetes populations needed to prevent early morbidity.

Extended author information available on the last page of the article

Introduction

Cardiovascular disease (CVD) is a common complex entity that is a worldwide epidemic (La Sala and Pontiroli 2020). Each year 44,000 people in the UK and 35,000 people in England <75years die from heart disease (Hinton et al. 2018). According to the Health Survey for England (HSE) 2017, CVDs remain a major public health crisis with a prevalence of approximately 6.15 million people living with heart and circulatory diseases, and approximately 14% of adults (15% of men and 13% of women) ever having had any CVD condition (Health survey for England. 2017) . Behavioural risk factors (smoking, harmful alcohol use, unhealthy diet, sedentary lifestyle, and physical inactivity), physiological risk factors (hypertension, diabetes, obesity, and hyperlipidaemia), and non-modifiable risk factors i.e., age, gender, family history, and ethnicity are independently associated with CVD outcomes (World Health Organization. 2018) About 50-75% of reduction in deaths from cardiac

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causes can be achieved with an improvement in the major CVD risk factors, whereas the remaining 25-50% can be attributed to medical interventions (Al-Nooh et al. 2014).

Among CVD risk factors, diabetes mellitus, hypertension, and hyperlipidemia have become the most important public health challenges that can potentiate the risk for CVD complications (Suen et al. 2020). In young adults, the pathophysiology of type 2 diabetes (T2DM) has a more rapid onset of disease. Beta-cell function declines more rapidly among adolescents diagnosed with diabetes compared with older adults (Lascar et al. 2018). In the UK and other high-income countries, diabetes prevalence has increased alongside a substantial decline in CVD mortality (Pearson-Stuttard et al. 2021). Age-standardized prevalence of ever having any CVD was higher among people with doctor-diagnosed diabetes (24%) than those without a diabetes diagnosis (16%) in England (Scholes et al. 2018). Furthermore, over the past 25 years, the prevalence of obesity among adults in England has also increased markedly from 16% in 1994 to 28% in 2018 mainly due to energy-dense foods, and environmental barriers to physical activity (Scholes et al. 2020). But, in younger age groups, the rising trends in obesity and diabetes mask the valuable effects of reduced smoking, improved care, and treatment on ischaemic heart disease (IHD) mortality (Flaherty et al. 2008). Evidence of IHD mortality rates beginning to plateau in younger age groups has been demonstrated to varying extents and at differing time points in England and Wales, Scotland, USA, and Australia (Allender et al. 2008; Es and Capewell 2007). The UK Prospective Diabetes Study (UKPDS) showed that relatively longer follow-ups may be essential to see the benefit of diabetes therapies and to develop preventive measures for the significant reduction of CVD risk in people with T2DM (Zhang et al. 2020).

In England, although the trends of CVD prevalence with respect to age are published, (Smolina et al. 2012) the prevalence of CVD risk factors in populations with or without diabetes needs more attention for early preventative public health strategies. Using data from the epidemiological Health Survey of England (HSE), we aimed to examine the prevalence of CVD risk factors in the survey years 2003, 2006, 2011, and 2017. We also aimed to observe the key CVD risk factors among young, middle-aged, and older adults with and without diabetes in England.

Methods

Participants and data collection

The HSE is a continuous, annual, cross-sectional health examination survey of people living in private households in England. Details of the survey methods and protocol have been published elsewhere (Mindell et al. 2012). In brief, HSE used a multistage stratified probability sampling technique. At each selected household, HSE collected data in two home visits. At the first (interviewer) visit, each participant was interviewed and completed a structured questionnaire regarding personal demographic, social and health information. At the second (nurse) visit, measurements of blood pressure (BP), waist circumference (WC), and hip circumference, and non-fasting blood samples were obtained. Laboratory parameters for this study were glycated haemoglobin A1c, total cholesterol, and high-density lipoprotein (HDL)- cholesterol.

Inclusion and exclusion criteria

All individuals aged 18 years and above who had a nurse visit in the CVD survey years 2003, 2006, 2011, or 2017 were included. In 2003, 2006, 2011, and 2017, a total of 14,836, 14,142, 8610, and 7997 adults were interviewed (new sample was interviewed each year), respectively. Household response rates achieved were 73%, 68%, 59%, and 55%, respectively. Non pregnant women and participants with complete information of CVD risk factors were included, providing a final sample of 23,501 participants.

Groups of study participants

The analytical sample was categorized into three age groups as young adults (18-54 years), middle-aged adults (55-74 years), and older adults (≥ 75 years) (Pearson-Stuttard et al. 2021). To compare the CVD risk factors in the population by diabetes status, participants were also sub-categorized into those with versus those without diabetes. Participants having diabetes diagnosed by their physician and/or having a survey-measured HbA1c ≥6.5% or 48mmol/mol were classified as having diabetes. Those not reporting doctor-diagnosed diabetes and with HbA1c <6.5% or <48mmol/mol were classified as without diabetes (Health Survey for England. 2017).

Demographic and anthropometric measurements

Ethnicity was categorized as White, Black, Asians, and others; locality type into urban and rural; and qualification levels into no qualification, below degree qualification and degree/National Vocational Qualification 4 (NVQ4) and above. Height was measured by asking participants to stand in an erect position with the head in the Frankfort plane using a portable stadiometer with a measuring scale in centimeters (cm) then converted into meters (m).

Weight was measured with a digital weighing machine in kilograms (kg) on a flat surface. Using non-stretchable tape, waist circumference (WC) was measured midway between the centre points of the lower margin of the ribs and the top of the pelvis. BP was measured by the nurse with the participant in a relaxed sitting position using an appropriately sized cuff on the right arm, following a standardized protocol using an Omron digital monitor (Omron HEM-907, Omron Healthcare Co Ltd, Kyoto, Japan). This procedure was repeated three times at one-minute intervals after a five-minute rest. The mean of the second and third values was used for systolic (SBP) and diastolic pressure (DBP).

Definitions of CVD risk factors

History of cardiovascular disease was defined as reporting a history of IHD, angina, heart attack, stroke, abnormal heart rhythm, heart murmur, or other heart condition. Obesity was classified as generalized obesity and central obesity. The body mass index (BMI, or Quetelet Index) was calculated as weight in kilograms divided by height in metres squared (kg/m^2). Participants were classified into four mutually exclusive categories: underweight (<18.5kg/m^2); normal weight (18.5-24.9kg/m^2); overweight (25.0-29.9kg/m^2); and obese (≥30.0kg/m^2) (Scheelbeek et al. 2019). Generalized obesity was defined as BMI ≥30 kg/m^2. Abdominal or central obesity was considered as WC >102 cm in men and >88 cm in women in accordance with the report of the National Cholesterol Education Program Adult Treatment Panel III guideline (Hirani et al. 2008). Combined obesity was defined as participants having generalized obesity or central obesity.

Hypertension was defined as SBP/DBP ≥140mmHg/≥90mmHg or reporting taking medication prescribed for high BP. Untreated hypertension refers to those cases who had survey-detected raised blood pressure but were not taking medication for hypertension (Health Survey for England 2003). Smoking status was classified into current smoker, ex-smoker (used to smoke cigarettes regularly or had smoked at least 100 cigarettes in the past but who had quit smoking at the time of interview), or never smoked (Tompkins et al. 2021). Drinking frequency was categorized into three categories: those consuming alcohol at least three days a week as frequent drinker; at least once a week or month as an occasional drinker; and those who were non-drinkers or had consumed alcohol only once or twice in the past 12 months as rare/non-drinker. Excessive drinkers were considered as consuming more than 14 units in a week (Homlmes et al. 2020).

HSE used the National Institute of Health and Clinical Excellence (NICE) guideline to define raised total cholesterol as ≥5 mmol/L; HDL-cholesterol was defined as low at a level of less than 1.0 mmol/L (Tompkins et al. 2021). Total cholesterol (TC) to HDL ratio was calculated by dividing TC by HDL-cholesterol. Dyslipidaemia was defined as having TC to HDL (TC/HDL) ratio ≥6 or using lipid lowering medicines. Untreated dyslipidaemia refers to those cases who had a history of abnormal lipid levels or had TC/HDL ≥6 and were not taking any lipid-lowering medications (Christianson et al. 2006).

Ethical approval and informed consent

Ethical approval was granted prior to data collection by a relevant NHS Research Ethics Committee at the time of the survey. Verbal consent prior to enrolment in the study and written consent prior to taking biological samples were obtained in each survey from each study participant. Further ethical approval was not needed for this secondary analysis.

Statistical analysis

The survey design variables were used to take account of the complex survey design of the Health Survey for England (HSE). Non-response weights for the interview, nurse visit, and blood sampling, as appropriate, were used to obtain better nationally-representative estimates (Health Survey for England 2003). Age standardization was carried out using the direct standardization method. Statistical Package for Social Sciences (SPSS) version 20 was used for analysis.

Independent sample t-tests were used for continuous variables while chi-square tests were used for categorical variables for comparing results between participants with and without diabetes. Univariate and multivariate logistic regression were used to assess the association of risk factors among diabetic and non-diabetic adults in England. Within each age group, we computed adjusted odds ratios (AORs) for each risk factor to compare those with diabetes and with those without diabetes. The confounding risk factors were adjusted for age, sex, locality, ethnicity, qualification, survey year, cardiovascular disease, raised BP, dyslipidaemia, combined obesity, current smoker, and excessive drinker. Interaction effects between each variable and survey year was carried out individually in separate adjusted models to examine whether the effect of a variable on the risk of diabetes was changing over time, only significant interaction effects were included in the final model. *P*-value <0.05 was considered statistically significant in all tests used in this study.

Results

Participant characteristics

Table 1 shows the characteristics of participants included in this study, by age group and diabetes status. Of the 23,501

participants, 2,791 (11.9%) had diabetes. 5.3% in the young age group had diabetes, 18.1% in the middle-aged group, and 29.1% in the older age group. Prevalence of diabetes increased from 2003 to 2011 among young, middle-aged, and older adults. From 2011 to 2017 static or slight change was seen among young and middle-aged groups, while a significant decline in diabetes prevalence among older adults. However, prevalence remained higher in 2017 than in 2003 across each age group. Amongst the diabetic population, 12.9% of young adults, 18.3% of middle-aged, and 17.8% of older adults had undiagnosed diabetes.

CVD and its associated risk factors

The percentage of individuals reporting doctor-diagnosed CVD was significantly higher in men and women with diabetes across all age groups, increasing with age (Table 2). Raised measured BP was more prominent in those with diabetes, being significantly higher among young and middle-aged men than women. However, in older adults, BP was non-significantly higher among women than men. The prevalence of dyslipidaemia was higher in people with diabetes among each age group. Men had more dyslipidaemia than women, regardless of diabetes status and age group. Obesity, whether general or central, was significantly higher in people with diabetes irrespective of age and gender and was slightly higher among women than men in both people with and without diabetes. Current smokers were more prevalent in young men with diabetes and young women without diabetes, as compared with men and women in older age-groups. Excessive drinking was significantly lower in men with diabetes in both the young and middle age groups. Having one to two CVD risk factors was higher among people without diabetes in middle aged and older population, whilst having three or more risk factors was significantly higher in the diabetes group across age-groups and in young diabetes group.

Association of selected CVD risk factors

The prevalence of untreated hypertension (17.5%) was higher in people with diabetes among middle-aged adults and in people without diabetes among older adults (27.1%) (Table 3). TC/HDL ratio (≥6) was significantly higher among young adults with diabetes compared to middle-aged adults and older adults with and without diabetes. The percentage with untreated dyslipidaemia was significantly higher among young adults with diabetes. Untreated dyslipidaemia was more prominent among young with diabetes in comparison to without diabetes and middle-aged and older adults with or without diabetes. Lipid-lowering medication use increased with age, and was higher among participants with diabetes. Participants with diabetes were significantly more likely to be obese and have higher mean WC compared with those without diabetes, irrespective of age group and type of obesity.

Adjusted odd ratios of CVD risk factors

After adjustments for confounding variables, significant predictors of diabetes among young age group were CVD [AOR (95% CI)] [1.81(1.28-2.54)], raised BP [1.4(1.04-1.87], dyslipidaemia [3.72(2.25-6.14)], combined obesity [2.99(2.28-3.92)], and survey year 2006 [0.62(0.41-0.94)] compared with 2003. Moreover, it was found that the effect of dyslipidaemia in young adults on the risk of diabetes was greater in more recent years 2006 [3.87(1.98-7.54)], 2011 [3.04(1.52-6.08)] and 2017 [3.42(1.63-7.19)] as compared to 2003. Among middle age group, CVD [1.35(1.12-1.63)], raised BP [1.28(1.07-1.52)], combined obesity [3.29(2.69-4.02)] and survey years 2006 [1.25(1-1.57)] and 2011 [1.27(1-1.62)] were significant predictors of diabetes whereas in older population only dyslipidaemia [4.42(3.28-5.97)], combined obesity [1.87(1.39-2.52)] and survey year 2011 [1.41(0.97-2.06)] showed strong association with the risk of diabetes. In middle and older age group, no significant interactions were found between CVD risk factors and survey year on diabetes. Irrespective of age, smoking and excessive drinking did not show any association with diabetes. (Table 4)

Discussion

Overall increased prevalence of diabetes was seen from 2003 to 2017 in all age groups. Dyslipidaemia and combined obesity were the most strongly associated CVD risk factors with diabetes, irrespective of age. However, among young adults, history of CVD and hypertension were more strongly associated with diabetes than for middle aged and older adults. Moreover, the effects of dyslipidaemia on the risk of diabetes appeared to be greater in more recent years among young adults. Smoking and excessive drinking had weak or non-significant associations with diabetes in all age groups.

Diabetes is already a major public health concern but diabetes in young adults exposes these individuals to excess CVD risk from an early age. CVD risk factors are also often associated with T2DM in young adults than older people (Falkner et al. 1999). Rising prevalence of diabetes in younger adults was somewhat similar to the study by Bucholz et al (Bucholz et al. 2018). It presents a future population health burden affecting morbidity and mortality rates, loss of quality of life, and a burden on the healthcare system (Holmes et al. 2020). Our findings highlight the importance of CVD risk management in the younger age group as well as in middle-aged and older adults.

The CVD risk factors in young adulthood have a long life-course evolution (Hinton et al. 2020). Although

Table 1 General Characteristics and Anthropometric Measurements of Adults Aged 18 years and above, Health Survey for England (HSE) 2003, 2006, 2011, and 2017

Variables		Young age (18 - 54 years)		Middle age (55 - 74 years)		Older age (75 years or more)	
		With diabetes	Without diabetes	With diabetes	Without diabetes	With diabetes	Without diabetes
Total cases N (%)		707	12,654	1,433	6,467	651	1,589
Survey Years, N (%)	2003	184 (3.8%) *	4,682 (96.2%)	385 (14.2%) *	2,321 (85.8%)	165 (20.8%) *	629 (79.2%)
	2006	206 (4.8%) *	4,044 (95.2%)	408 (19.1%) *	1,731 (80.9%)	144 (34.6%) *	272 (65.4%)
	2011	175 (7.7%) *	2,095 (92.3%)	311 (21.3%) *	1,146 (78.7%)	184 (39.3%) *	284 (60.7%)
	2017	142 (7.2%) *	1,833 (92.8%)	329 (20.6%) *	1,269 (79.4%)	158 (28.1%) *	404 (71.9%)
Gender[a], % (95% CI)	Men	59.8 (56-63.4) *	50 (49.1-50.9)	59.5 (56.9-62)	47.1 (45.8-48.4)	45.6 (41.7-49.6)	42.4 (40-44.9)
	Women	40.2 (36.6-44) *	50 (49.1-50.9)	40.5 (38-43.1) *	52.9 (51.6-54.2)	54.4 (50.4-58.3)	57.6 (55.1-60)
Locality type[a], % (95% CI)	Urban	85.8 (82.8-88.2) *	80.9 (80.2-81.6)	77.5 (75.2-79.6) *	71.9 (70.7-73)	77.6 (74.2-80.7) *	73.3 (71.1-75.5)
	Rural	14.2 (11.8-17.2) *	19.1 (18.4-19.8)	22.5 (20.4-24.8) *	28.1 (27-29.3)	22.4 (19.3-25.8) *	26.7 (24.5-28.9)
Ethnic group[a], % (95% CI)	White	75.6 (72-78.9) *	89.9 (89.3-90.5)	88.8 (86.9-90.5) *	96.9 (96.4-97.3)	93.4 (91.1-95.2) *	98.3 (97.5-98.9)
	Black	3 (1.9-4.5) *	2.1 (1.8-2.4)	2.4 (1.7-3.4) *	0.7 (0.5-1)	1.7 (0.9-3.1) *	0.5 (0.3-1)
	Asian	18.8 (15.8-22.2) *	5.9 (5.5-6.4)	7.9 (6.5-9.6) *	1.9 (1.5-2.3)	3.5 (2.3-5.3) *	0.8 (0.5-1.5)
	Others	2.6 (1.6-4.3) *	2.1 (1.9-2.4)	0.9 (0.5-1.6) *	0.6 (0.4-0.8)	1.4 (0.7-2.8) *	0.3 (0.1-0.8)
Qualification[a], % (95% CI)	No qualification	23.9 (20.7-27.3) *	10.5 (9.9-11)	45.9 (43.3-48.6) *	32.6 (31.5-33.8)	65.9 (62-69.6) *	56.3 (53.8-58.7)
	Below degree qualification	58.1 (54.2-61.9) *	60.6 (59.7-61.5)	42.8 (40.2-45.4) *	50.1 (48.9-51.4)	27.9 (24.3-31.7) *	34.6 (32.3-37)
	Degree/NVQ4 and above	18.0 (15.2-21.2) *	28.9 (28.1-29.8)	11.3 (9.7-13.1) *	17.3 (16.3-18.3)	6.2 (4.6-8.3) *	9.1 (7.8-10.7)
Diabetes, % (95% CI)	Undiagnosed Diabetes	12.9 (10.6-15.5)	-	18.3 (16.4-20.4)	-	17.8 (15.1-21)	-
	Diagnosed Diabetes	87.1 (84.5-89.4)	-	81.7 (79.6-83.6)	-	82.2 (79-84.9)	-
BMI[a], % (95% CI)	Under-weight	0.3 (0.1-1.3) *	1.3 (1.1-1.5)	0.1 (0-0.5) *	0.7 (0.5-0.9)	0.3 (0.1-1.3) *	1.1 (0.7-1.9)
	Normal-weight	16.8 (13.8-20.3) *	39.9 (39-40.9)	11.2 (9.5-13.1) *	28.9 (27.7-30.1)	18.8 (15.5-22.8) *	30.0 (27.6-32.6)
	Over-weight	30.1 (26.4-34.2) *	37.7 (36.8-38.6)	34.6 (31.8-37.4) *	44.4 (43.1-45.7)	42.6 (38.1-47.3) *	45.5 (42.7-48.2)
	Obese	52.7 (48.5-57) *	21.1 (20.4-21.9)	54.2 (51.2-57.1) *	26.1 (24.9-27.2)	38.2 (33.7-42.9) *	23.4 (21.1-25.8)
Smoking[a], % (95% CI)	Current Smoker	27.9 (24.6-31.5)	27.3 (26.5-28.1)	16.6 (14.7-18.7) *	17.0 (16.0-17.9)	7.9 (6-10.3)	7.2 (6-8.5)
	Ex-smoker	31.7 (28.2-35.4)	31.4 (30.5-32.2)	51.9 (49.2-54.5) *	47.1 (45.9-48.4)	55 (51-58.9)	57.5 (55-60)
	Never smoked	40.4 (36.7-44.3)	41.3 (40.4-42.2)	31.5 (29.1-34.0) *	35.9 (34.7-37.1)	37.1 (33.3-41.1)	35.3 (33-37.7)
Drinking habit[a], % (95% CI)	Very frequent drinker	17.4 (14.6-20.6) *	32.0 (31.1-32.8)	26.3 (24-28.7) *	41.8 (40.6-43.1)	20 (17-23.3) *	32.9 (30.6-35.3)
	Occasional drinker	36.1 (32.5-39.9) *	47.0 (46-47.9)	29.7 (27.4-32.2) *	35.5 (34.3-36.7)	23.1 (20-26.6) *	30.3 (28-32.6)
	Rare/Non-drinker	46.5 (42.6-50.4) *	21.1 (20.3-21.8)	44 (41.4-46.6) *	22.7 (21.7-23.8)	56.9 (53-60.8) *	36.8 (34.4-39.2)
Excessive drinker [a], % (95% CI)	Yes	5.3 (3.8-7.3) *	8.8 (8.3-9.4)	1.4 (0.9-2.2) *	2.5 (2.1-2.9)	0 (0-0)	0.2 (0.1-0.6)
	No	94.7 (92.7-96.2) *	91.2 (90.6-91.7)	98.6 (97.8-99.1) *	97.5 (97.1-97.9)	100 (100-100)	99.8 (99.4-99.9)

Table 1 (continued)

Variables	Young age (18 - 54 years)		Middle age (55 - 74 years)		Older age (75 years or more)	
	With diabetes	Without diabetes	With diabetes	Without diabetes	With diabetes	Without diabetes
Waist to Hip Ratio [b], mean (95% CI)	0.94 (0.93-0.95) *	0.86 (0.85-0.86)	0.96 (0.96-0.97) *	0.89 (0.89-0.90)	0.93 (0.93-0.94) *	0.9 (0.9-0.9)
Systolic Blood Pressure (mmHg) [b], mean (95% CI)	127.85 (126.24-129.47) *	121.88 (121.59-122.17)	137.03 (135.81-138.26) *	133.28 (132.78-133.77)	137.29 (135.21-139.37) *	141.79 (140.65-142.93)
Diastolic Blood Pressure (mmHg)[b,] mean (95% CI)	77.19 (76.05-78.32) *	72.91 (72.68-73.13)	73.46 (72.73-74.19) *	75.57 (75.27-75.86)	66.51 (65.37-67.65) *	70.19 (69.59-70.79)

Of all data available, only those cases were selected aged 18 years and above, having complete data on age and diabetes status (either diagnosed by a doctor earlier or from HbA1c levels). Diabetes was classified as positive for those having a history of diagnosis by a doctor or having HbA1c >= 6.5%. BMI was categorized as: <18.5kg/m^2 = Underweight, 18.5 - 24.9 kg/m^2 Normal weight, 25.0 - 29.9 kg/m^2 Overweight and ≥30.0 kg/m^2 Obese. Drinking frequency was categorized into three categories: those consuming (i) on at least 3 days a week as a very frequent drinker, (ii) at least once a week or month as an Occasional drinker, and (iii) those who are non-drinker or had consumed only once or twice in past 12 months as Rare/Non-drinker. Excessive drinkers were those consuming more than 14 units in a week.

a Weight adjusted for non-response (interview-related variables)

b Weight adjusted for non-response (nurse-related variables)

c Weight adjusted for non-response (blood-related variables)

Data presented as valid percentage or mean with 95% CI in brackets.

Chi-square test was used for categorical data comparison while independent t-test was used for continuous data.

*P<0.05 indicates that people with diabetes significantly different from people without diabetes.

dyslipidaemia and raised BP were more prevalent in middle-aged and older adults as compared to young adults in our study. Cho et al., also observed worse dyslipidaemia parameters with older age in non-linear manner compared with young adults (Cho et al. 2020). However, after adjustments for confounding variables, adjusted odd ratios show that the effect of dyslipidaemia among young adults on the risk of diabetes was significant in more recent years as compared to 2003. Whereas, in middle and older age groups, no significant interaction was found between CVD risk factors and survey year on diabetes. Recently, it was reported that the increased levels of cholesterol among young adult life were associated with mortality by CVD in the middle age life (Iyengar et al. 2020). Deshmukh et al., reported that young adults with dyslipidaemia are more prone to develop CVDs risk factors (Deshmukh et al. 2019). A multicenter study in the United States and some others worldwide studies also reported the increased prevalence of dyslipidaemia in the paediatric diabetes population in recent decades (Kim et al. 2020). With high prevalence of dyslipidaemia in people with diabetes, multiple CVD risk factors among young adults are also found in our study similar to previous reported data. Our results are also consistent to a previous study reporting worse CVD risk profile, severe obesity, elevated lipids or hypertension in young adults with and without diabetes as compared to older adults (Christianson et al. 2006). High prevalence of untreated dyslipidaemia in the young age group with diabetes could be particularly due to stress, physical inactivity, low exercise, unhealthy eating, and/or diet deficient in polyunsaturated fatty acids in this well-developed country. Regardless of age, elevated cholesterol treatment was recommended in current clinical guidelines by the Association of American Diabetes (American Diabetes Association 2019). Further, untreated hypertension was more prevalent in middle-aged adults with diabetes and in older age adults without diabetes.

Although, three or more CVD risk factors were more common among people with diabetes, specifically in middle-aged and older age group. However, one to two CVD risk factors were commonly found in young adults with diabetes as compared to without diabetes. Previously, it was reported that people diagnosed diabetes at age 40 years could lose 6 to 7 years of life, while diabetes diagnosis at earlier than 40 years of age leads to increased risk of all-cause mortality by 1.2 times and risk of CVD mortality by 1.6 times (Gregg et al. 2014). We also found a high prevalence of doctor-diagnosed CVD in people with diabetes across all age groups indicating the importance of early diagnosis of CVD risk factors for the sake of complications in people with diabetes (Einarson et al. 2018).

There is limited evidence of behaviour change except for the reduction in smoking in patients with the diagnosis of T2DM (Hackett et al. 2018). A previous study also pointed out that young people are more likely than older adults to be smokers, obese, and to have a positive family history of diabetes (Rubin and Borden 2012). We also observed a high prevalence of active smokers and excessive drinking in younger adults regardless of diabetes

Table 2 CVD Risk Factors Among Adults Aged 18 years and above, Health Survey for England (HSE) 2003, 2006, 2011 and 2017, by Sex

Variables		Young age (18 - 54 years)		Middle age (55 - 74 years)		Older age (75 years or more)	
		With diabetes	Without diabetes	With diabetes	Without diabetes	With diabetes	Without diabetes
Total cases	N	707	12,654	1,433	6,467	651	1,589
Cardiovascular disease	N	706	12,646	1,362	6,460	612	1,584
	Men	17.7%*	6.4%	38.5%*	20.2%	53.2%*	34.3%
	Women	17.1%*	7.3%	32.9%*	15.4%	47.3%*	30.9%
Raised BP	N	404	10,380	941	5,641	428	1,426
	Men	29.5%*	17.3%	41.8%*	35.3%	40.3%	46.8%
	Women	19.3%*	8.9%	38.7%*	31.7%	43.3%	51.6%
Dyslipidaemia	N	418	12581	1,015	6,432	428	1,580
	Men	55.7%*	12.7%	71.6%*	28.2%	67.3%*	33.9%
	Women	50%*	3.3%	71.4%*	16.9%	65%*	26.8%
Combined Obesity	N	543	12,134	1,178	6,216	462	1,421
	Men	70.5%*	30.8%	76.8%*	44.9%	68.7%*	49.8%
	Women	78.8%*	38.3%	87.9%*	53.4%	82.4%*	62.1%
General Obesity	N	268	6,556	1,167	6,028	457	1,284
	Men	51.3%*	21.1%	52.5%*	25.4%	35.3%*	20.1%
	Women	56.0%*	22.1%	56.9%*	26.5%	41.1%*	25.9%
Central Obesity	N	477	12,533	1,063	6,382	448	1,538
	Men	62.4%*	26.5%	70.1%*	41.4%	61.3%*	43.9%
	Women	72.4%*	35.8%	85.6%*	50.9%	77.1%*	56.4%
Current smoker	N	706	12,648	1,431	6,467	648	1,588
	Men	33.1%	29.9%	18.9%	19.3%	7.2%	9.6%
	Women	22.4%	25%	13.7%	14.7%	8.5%*	5.3%
Excessive drinker	N	704	12,608	1,427	6,454	647	1,581
	Men	8.1%*	13.4%	2.6%*	4.8%	00%	0.4%
	Women	2.2%	3.5%	00%	0.5%	00%	00%
	N	707	12,654	1,433	6,467	651	1,589
No CVD risk factors	Men	19%*	33.7%	9.8%*	21.5%	12.7%	13.8%
	Women	20.4%*	41.2%	11.9%*	25.1%	14.5%	13.6%
1-2 CVD risk factors	Men	59.6%	57.7%	56.4%*	61.1%	58.2%*	66.8%
	Women	62.8%*	54.6%	57.7%*	63.8%	58.3%*	65.9%
≥3 CVD risk factors	Men	21.4%*	8.7%	33.9%*	17.4%	29.1%*	19.4%
	Women	16.7%*	4.2%	30.4%*	11.0%	27.2%*	20.5%

Diabetes was classified as positive for those having a history of diagnosis by a doctor or having HbA1c ≥ 6.5%. Cardiovascular disease: Considered to be positive if the person had a positive history of angina, heart attack, stroke, abnormal heart rhythm, heart murmur, or other heart condition. Raised BP: Those having SBP/DBP ≥ 140/90 mmHg. Dyslipidaemia: Having TC/HDL ≥ 6 or using lipid-lowering medicines. General obesity: Having BMI ≥ 30 kg/m^2. Central obesity: Having waist circumference >102 for men and >88 for women. Combined obesity: Classified as obese from either general or central obesity definition. Current smoker: Present smoker at the time of interview. Excessive drinker: Those intaking more than the prescribed limit of 14 units in a week.

Cardiovascular disease, Raised BP, Dyslipidaemia, Combined Obesity, Current Smoking, and Excessive drinking were taken as potential risk factors.

*$P<0.05$ indicates that people with diabetes were significantly different from people without diabetes.

status as compared to middle-aged and older adults. Our results support recent findings that young adults at age 18 years have highest levels of smoking initiation (Perry et al. 2018). However, alcohol drinking was more prevalent in people without diabetes as compared to people with diabetes, representing that people with diabetes are encouraged to be healthier once diagnosed. Alcohol and tobacco use plays an important role in sociodemographic patterns and should not be neglected in designing prevention and intervention programs for CVD. According to a Diabetes UK survey, many of the people with diabetes who smoke reported that they did not receive any medical advice or assistance to quit (Diabetes UK Care Survey 2014).

Table 3 Selected CVD Risk Factors Among Adults Aged 18 years and above, Health Survey for England (HSE) 2003, 2006, 2011, and 2017

Variables		Young age (18 - 54 years)		Middle age (55 - 74 years)		Older age (75 years or more)	
		With diabetes	Without diabetes	With diabetes	Without diabetes	With diabetes	Without diabetes
Hypertension	Medications for BP, % (95% CI)	33.5 (29.0-38.4)*	7.3 (6.6-8.0)	58.5 (55.4-61.6) *	33.8 (32.4-35.2)	62.8 (58.2-67.2) *	47.4 (44.7-50.0)
	Untreated hypertension, %(95%CI)	14.7 (11.5-18.7)*	11.1 (10.5-11.7)	17.5 (15.1-20.1) *	23.1 (22-24.2)	14.3 (11.3-18.1) *	27.1 (24.8-29.5)
Dyslipidaemia	Total Cholesterol (mmol/L) [c,] mean (95% CI)	5.06 (4.91-5.21) *	5.21(5.20-5.24)	4.86 (4.77-4.95) *	5.81 (5.78-5.84)	4.72 (4.57-4.86) *	5.46 (5.4-5.53)
	High Density Lipoprotein (mmol/L) [c], mean (95% CI)	1.27 (1.22-1.31) *	1.46(1.46-1.47)	1.27 (1.24-1.29) *	1.56 (1.55-1.57)	1.36 (1.31-1.4) *	1.58 (1.56-1.6)
	Non-HDL Cholesterol (mmol/L) [c], mean (95% CI)	3.8 (3.65-3.94)	3.75 (3.72-3.77)	3.59 (3.5-3.68) *	4.25 (4.22-4.28)	3.36 (3.22-3.5) *	3.88 (3.82-3.95)
	TC/HDL ratio, mean (95% CI)	4.27 (4.11-4.44) *	3.77(3.75-3.80)	4.04 (3.95-4.14) *	3.94 (3.91-3.97)	3.65 (3.53-3.78)	3.63 (3.58-3.69)
	TC/HDL ratio ≥ 6, % (95% CI)	12.4 (9.1-16.5) *	6.1(5.6-6.6)	7.4 (5.7-9.5)	5.8 (5.2-6.4)	3.9 (2.3-6.6)	3.2 (2.4-4.3)
	Lipid lowering drugs, % (95% CI)	42.6 (37.8-47.5) *	3.9 (3.4-4.4)	66.6 (63.6-69.5) *	24.7 (23.4-26)	59.6 (54.8-64.1) *	30.9 (28.4-33.4)
	Untreated dyslipidaemia, % (95% CI)	5.6 (3.6-8.5) *	2.8 (2.5-3.2)	3.2 (2.2-4.6) *	3.7 (3.3-4.2)	1.9 (1-3.8) *	2.7 (2-3.6)
Adiposity	Combined obesity, % (95% CI)	73.2 (69.1-76.9) *	33.7 (32.8-34.6)	81.4 (79-83.6) *	49.4 (48.1-50.7)	76.5 (72.3-80.1) *	57.2 (54.6-59.8)
	BMI, mean (95% CI)	31.37 (30.78-31.96) *	26.71 (26.61-26.8)	31.22 (30.9-31.53) *	27.68 (27.56-27.8)	29.29 (28.82-29.76) *	27.2 (26.97-27.44)
	General obesity, % (95% CI)	52.7 (48.5-57) *	21.1 (20.4-21.9)	54.2 (51.2-57.1) *	26.1 (24.9-27.2)	38.2 (33.7-42.9) *	23.4 (21.1-25.8)
	Waist circumference, mean (95% CI)	104.05 (102.37-105.73) *	89.9 (89.64-90.16)	106.99 (106.13-107.86) *	94.76 (94.43-95.09)	101.16 (99.96-102.37) *	94.73 (94.1-95.35)
	Central obesity, % (95% CI)	64.4 (59.4-69) *	29.7 (28.9-30.6)	76.4 (73.6-79) *	46.4 (45.2-47.7)	69.6 (65-73.8) *	51.8 (49.2-54.4)
HbA1c	HbA1c, mean (95% CI)	8.05 (7.82-8.28) *	5.24 (5.23-5.25)	7.48 (7.36-7.59) *	5.54 (5.53-5.55)	7.12 (6.98-7.26) *	5.65 (5.63-5.67)
	HbA1c ≥ 6.5 %, % (95% CI)	85.1 (80.4-88.9)	N/A	81.6 (78.6-84.3)	N/A	69.8 (79.7-100)	N/A
	HbA1c ≥ 7.0 %, % (95% CI)	64.7 (59.2-69.9)	N/A	53.8 (50.2-57.5)	N/A	40.9 (35.6-46.5)	N/A

Data presented as a valid percentage or mean with 95% CI in brackets

Untreated hypertension refers to those cases who were diagnosed hypertensive but were not taking medication for raised BP. Untreated dyslipidaemia refers to those cases who had a history of abnormal lipids levels or had TC/HDL ≥ 6 and were not taking any lipid-lowering medications.

*$P<0.05$ indicates that diabetes is significantly different from non-diabetes.

Table 4 Adjusted Odd Ratios of Associated CVD Risk Factors on the risk of Diabetes Among Adults in England, Health Survey for England (HSE) 2003, 2006, 2011 and 2017

	18-54 years		55-74 years		≥75 years	
Factors	AOR(95% CI)	*P*-value	AOR(95% CI)	*P*-value	AOR(95% CI)	*P*-value
CVD	1.81(1.28-2.54)	0.001	1.35(1.12-1.63)	0.002	1.28(0.96-1.7)	0.09
Raised BP	1.4(1.04-1.87)	0.026	1.28(1.07-1.52)	0.006	0.82(0.62-1.08)	0.166
Dyslipidemia	3.72(2.25-6.14)	<0.0001	6.4(5.32-7.69)	<0.0001	4.42(3.28-5.97)	<0.0001
Obesity	2.99(2.28-3.92)	<0.0001	3.29(2.69-4.02)	<0.0001	1.87(1.39-2.52)	<0.0001
Smoking	0.8(0.59-1.08)	0.142	1.14(0.9-1.44)	0.292	1.58(0.91-2.77)	0.107
Excessive drinking	1.07(0.65-1.78)	0.792	0.51(0.27-0.94)	0.032	0(0-0)	0.999
Survey 2006β	0.62(0.41-0.94)	0.025	1.25(1-1.57)	0.051	1.05(0.7-1.58)	0.797
Survey 2011β	1.12(0.72-1.74)	0.613	1.27(1-1.62)	0.055	1.41(0.97-2.06)	0.074
Survey 2017β	0.87(0.54-1.42)	0.581	1.17(0.92-1.49)	0.21	0.93(0.64-1.35)	0.69
Dyslipidemia*2006	3.87(1.98-7.54)	<0.0001	-	-	-	-
Dyslipidemia*2011	3.04(1.52-6.08)	0.002	-	-	-	-
Dyslipidemia*2017	3.42(1.63-7.19)	0.001	-	-	-	-

AOR: adjusted odd ratio

for age 18-54 years: model was adjusted for gender, ethnicity, locality type, qualification, survey year, cardiovascular disease, raised BP, dyslipidemia, combined obesity, current smoker, excessive drinker, and dyslipidemia*survey year.

for age >54 years models were adjusted for gender, ethnicity, locality type, qualification, survey year, cardiovascular disease, raised BP, dyslipidemia, combined obesity, current smoker, and excessive drinker.

[β]Reference category: survey 2003

P-value<0.05 considered to be statistically significant

Diabetes was classified as positive for those having a history of diagnosis by a doctor or having HbA1c ≥ 6.5%.

Cardiovascular disease: Considered to be positive if the person had a positive history of angina, heart attack, stroke, abnormal heart rhythm, heart murmur, or other heart condition. Raised BP: Those having SBP/DBP ≥ 140/90 mmHg. Dyslipidaemia: Having TC/HDL ≥ 6 or using lipid-lowering medicines.

Combined obesity: Classified as obese from either general or central obesity definition. Current smoker: Present smoker at the time of interview. Excessive drinker: Those intaking more than the prescribed limit of 14 units in a week

The CVD risk factors have also been reported in other large community-based surveys (Wu et al. 2018). Our results support Foy and colleagues showing that incidence of diabetes increases in people with smoking, had lower BMI, higher waist-to-hip ratio, provoke hyperglycemia, hyperinsulinemia, and elevated blood pressure (Foy et al. 2005). Poor diet is known to be an important CVD risk factor. The overall quality of diet has improved in England since the 1970s: for instance, fruits and vegetables availability has increased to the UK population by 60%, while intake of saturated fat and sugars has decreased considerably (Duthie et al. 2018). In the UK, a well-developed country, current management strategies targeting CVD risk profiles have been improved. To prevent this disease epidemic, early attention is still needed to target at early stages in young adults. Adoption of healthier lifestyles including low salt containing food, using more fruits and vegetables, increasing physical activity, promoting smoking cessation, control of BP and cholesterol levels even prior to medical interventions as well as using blood pressure-lowering and lipid-lowering therapy in diagnosed population deserves to be a top priority in reducing CVD events (Yang et al. 2020). Implementation of policy-level initiatives for healthy lifestyle modifications such as taxation on sugar-sweetened drinks or tobacco, health advertising, active transport options, and regular evaluation of interventions in local communities alongside active screening at the earliest stage for risk of disease will also aid to reduce the burden of CVD risk in the UK (Sacco et al. 2016).

Strengths and limitations

A strength of this study is the ability to estimate the real burden of major CVD risk factors among a nationally representative sample of adults in England, using objective biological measures. As physical activity was not included in HSE 2011, it could not be included in the analysis and is a limitation. The surveys were cross-sectional, and we were, therefore, unable to determine the direction of association, and ability to account for premature mortality which may have contributed to a survivorship bias among older adults, which is another limitation. However, that the prevalence of untreated dyslipidaemia was found to be higher among

young adults is a cause for concern. Due to the sample size and relatively small number of cases among 18- to 54-year-olds we were unable to assess the effects for younger age groups.

Conclusions

Overall, the level of diabetes was found to be increasing among young adults. Dyslipidemia and obesity are the most prominent CVD risk factors among people with diabetes, irrespective of age, though the effects of dyslipidemia being greater in more recent years among young adults. History of CVD and hypertension were also more strongly associated with diabetes among young adults than middle-aged and older adults. Therefore, specific targeted interventions are needed to prevent the sharp increase in the burden of CVD in the near future, appearing even at younger age, with a focus on improving dyslipidemia and lowering obesity.

Key points

- The prevalence of diabetes is higher is 2017 compared with 2003 in all age groups
- The AORs for history of CVD and Hypertension were more pronounced in young age groups and dyslipidaemia was the strongest risk factor.
- Dyslipidaemia and obesity are the most prominent CVD risk factors among people with diabetes, irrespective of age, though the effects of dyslipidaemia have become stronger in more recent years among younger age groups.

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Author contribution **Basit KA:** Conceived the idea of the study, conducted data analyses and prepared the manuscript

Fat NL: Advised on data analyses and contributed to subsequent revisions and approved the manuscript.

Gregg WE: Advised on data analyses and contributed to subsequent revisions and approved the manuscript.

Data availability The datasets supporting the conclusions of this article are available via the UK Data Service Archive, subject to their end user license agreement:

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Declarations

Ethical approval and consent to participate Ethical approval to conduct the HSE2017 survey was approved by the East of England research ethics committee (15/EE/0229). Ethical approval to conduct the 2011 surveys was obtained from the Oxford An Ethics Committee (2011:10/H0604/56). Ethical approval for the HSE surveys from 2006 and 2003 was obtained from the London MREC (2006: 05/MRe02/47). Sensitive information was removed and data were anonymised. For secondary analyses, further ethical approval was not needed.

Consent for publication Sensitive information was removed and data were anonymised in each dataset. For secondary analyses, further ethical approval was not needed.

Conflict of interest statement The authors declare that they have no conflict of interest.

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