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Hypertension prevalence, coding and control in an urban primary care setting in the UK between 2014 and 2021

--Manuscript Draft--

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Corresponding Author:	Karol Basta Lambeth Council UNITED KINGDOM
Corresponding Author's Institution:	Lambeth Council
First Author:	Karol Basta
Order of Authors:	Karol Basta
	Lesedi Ledwaba-Chapman
	Hiten Dodhia
	Mark Ashworth
	David Whitney
	Kathryn Dalrymple
	Yanzhong Wang
Abstract:	Objective: Hypertension is a leading preventable cause of mortality, yet high rates of undiagnosed and uncontrolled hypertension continue. The burden falls most heavily on some ethnic minorities and the socially deprived, with the COVID-19 pandemic having further widened inequalities. We sought to determine the prevalence and predictors of unmeasured blood pressure (BP), uncoded elevated BP, and uncontrolled hypertension in primary care across 2014-2021. Methods: A population-based cohort study using data from all 41 general practices in a socioeconomically diverse inner-city borough. BP measurements, sociodemographic, lifestyle and clinical factors were extracted from anonymised primary care data. Hypertension and BP control were defined using NICE guidelines. Associations between patient characteristics and hypertension outcomes were identified using logistical regression modelling. Results: Of 549,082 patients, 39.5% had unmeasured BP; predictors included male sex (AOR 2.40, 95% CI 2.26-2.43) and registration in the pandemic years. Of 71,970 adults with elevated BP, 36.0% were uncoded; predictors included obesity (AOR 2.51, 95% CI 2.42-2.60) and increasing age. Of 44,648 adults on the hypertension register, 46.8% had uncontrolled hypertension; predictors included black ethnicity compared to white (AOR 1.54, 95%CI 1.41-1.68) and cardiovascular co-morbidities (AOR 1.23, 95% CI 1.21-1.25). Social deprivation was only weakly or not significantly associated with hypertension outcomes. Conclusion: The burden of uncoded elevated BP and uncontrolled hypertension is high. Obesity and male sex were associated with uncoded elevated BP and uncontrolled hypertension. Black ethnicity was associated with uncontrolled hypertension. Initiatives are needed to optimise hypertension coding and control, with an emphasis on specific population subgroups.

Dr Karol Basta
Lambeth Council
6 Brixton Hill
London
SW2 1EG
karol.basta1@nhs.net

Professor Anthony M. Heagerty
Editor-in-chief
Journal of Hypertension

22nd December 2022

Dear Professor Heagerty,

We wish to submit an original research article entitled “Prevalence and predictors of undiagnosed and uncontrolled hypertension in a UK Urban Setting” for consideration by the Journal of Hypertension.

We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

We conducted a population-based cohort study using real world data from all 41 general practices in a socioeconomically diverse inner-city borough. We found 40% of 549,082 adult patients registered across 2014-21, had no recorded blood pressure reading. Predictors included male sex, recorded obesity and last registration year in 2021 and 2020 compared to 2014. Of 71,970 adults with hypertension, a third (36%) had undiagnosed hypertension. Predictors included male sex, recorded obesity and increasing age. Of 44,648 adults with known hypertension, nearly half (47%) were uncontrolled according to latest NICE guideline thresholds. Predictors included male sex, recorded obesity, African, Caribbean, or mixed ethnic groups compared to White ethnic group, increasing age, cardiovascular co-morbidities, and prescription of 2 or 3 hypotensive medications compared to none or one. Health inequalities in hypertension outcomes have been demonstrated, associated with sex, age and ethnicity, but only weakly or not significantly associated with social deprivation.

We believe this study is appropriate for publication by the Journal of Hypertension. It is the only UK study examining the interplay of the COVID-19 pandemic with sociodemographic, lifestyle and clinical factors on hypertension diagnosis and management. The early detection and treatment of hypertension has been identified as key to saving lives lost to cardiovascular disease in the 2019 NHS Long Term Plan. Our findings can be used to identify and target individuals who are at high risk for unmeasured blood pressure, undiagnosed and uncontrolled hypertension.

We have no conflicts of interest to disclose.

All authors have approved the manuscript and agree with its submission to the Journal of Hypertension.

Please address all correspondence concerning this manuscript to me at karol.basta1@nhs.net.

Thank you for your consideration of this manuscript.

Sincerely,

Dr Karol Basta
Public Health Registrar
Lambeth Council
6 Brixton Hill
London
SW2 1EG
karol.basta1@nhs.net

Abbreviation list

- BP, Blood Pressure
- UK, United Kingdom
- GP, General Practice
- NICE, National Institute for Health and Care Excellence
- NHS, National Health Service
- LR, Logistic Regression
- IMD, Index of Multiple Deprivation
- BMI, Body Mass Index
- AOR, Adjusted Odds Ratio
- CI, Confidence Interval
- HTN, Hypertension
- Ref, Reference Category
- Tmt, Treatment
- QOF, Quality and Outcomes Framework
- US, United States

TITLE PAGE

Full title: Hypertension prevalence, coding and control in an urban primary care setting in the UK between 2014 and 2021

Running head: hypertension coding and control

Authors

- Dr Karol BASTA (karol.basta1@nhs.net), Public Health Speciality Registrar, Lambeth Council Public Health, Civic Centre, 6 Brixton Hill, London, UK SW2 1EG
- Lesedi LEDWABA-CHAPMAN (lesedi_jethro.ledwaba-chapman@kcl.ac.uk), Researcher in Medical Statistics, King's College London, Population Health Sciences, Addison House, Guy's Campus 4th Floor, London, UK SE1 1UL
- Dr Hiten DODHIA (hdodhia@lambeth.gov.uk), Consultant in Public Health, Lambeth Council Public Health, Civic Centre, 6 Brixton Hill, London, UK SW2 1EG
- Professor Mark ASHWORTH (mark.ashworth@kcl.ac.uk), Professor of Primary Care, King's College London, School of Life Course and Population Sciences, 3rd Floor, Addison House, Guy's Campus, London, UK SE1 1UL
- David WHITNEY (david.whitney@selondonics.nhs.uk), Data Architect and Analyst, King's College London, Guy's Campus, London, UK, SE1 1UL
- Dr Kathryn DALRYMPLE (kathryn.dalrymple@kcl.ac.uk), Researcher in Medical Statistics, King's College London, Population Health Sciences, Addison House, Guy's Campus 4th Floor, London, UK SE1 1UL
- Dr Yanzhong WANG (yanzhong.wang@kcl.ac.uk), Reader in Medical Statistics, King's College London, Population Health Sciences, Addison House, Guy's Campus, 4th Floor, London, UK SE1 1UL

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Corresponding author: Dr Karol BASTA (*karol.basta1@nhs.net*, mobile - 07577836884), Public Health Speciality Registrar, Lambeth Council Public Health, Civic Centre, 6 Brixton Hill, London, UK SW2 1EG

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ABSTRACT

Objective: Hypertension is a leading preventable cause of mortality, yet high rates of undiagnosed and uncontrolled hypertension continue. The burden falls most heavily on some ethnic minorities and the socially deprived, with the COVID-19 pandemic having further widened inequalities. We sought to determine the prevalence and predictors of unmeasured blood pressure (BP), uncoded elevated BP, and uncontrolled hypertension in primary care across 2014-2021.

Methods: A population-based cohort study using data from all 41 general practices in a socioeconomically diverse inner-city borough. BP measurements, sociodemographic, lifestyle and clinical factors were extracted from anonymised primary care data. Hypertension and BP control were defined using NICE guidelines. Associations between patient characteristics and hypertension outcomes were identified using logistical regression modelling.

Results: Of 549,082 patients, 39.5% had unmeasured BP; predictors included male sex (AOR 2.40, 95% CI 2.26-2.43) and registration in the pandemic years. Of 71,970 adults with elevated BP, 36.0% were uncoded; predictors included obesity (AOR 2.51, 95% CI 2.42-2.60) and increasing age. Of 44,648 adults on the hypertension register, 46.8% had uncontrolled hypertension; predictors included black ethnicity compared to white (AOR 1.54, 95%CI 1.41-1.68) and cardiovascular co-morbidities (AOR 1.23, 95% CI 1.21-1.25). Social deprivation was only weakly or not significantly associated with hypertension outcomes.

Conclusion: The burden of uncoded elevated BP and uncontrolled hypertension is high. Obesity and male sex were associated with uncoded elevated BP and uncontrolled hypertension. Black ethnicity was associated with uncontrolled hypertension. Initiatives

are needed to optimise hypertension coding and control, with an emphasis on specific population subgroups.

KEYWORDS

- Hypertension
- Blood pressure
- Missed diagnosis
- Cardiovascular risk factors
- Primary care
- Lifestyle factors
- Socioeconomic factors
- Socioeconomic disparities
- Ethnicity
- Healthcare disparities

INTRODUCTION

Hypertension has traditionally been coined a “silent killer” - mostly diagnosed in asymptomatic individuals (1) whilst long recognised as a leading cause of mortality worldwide (2) (3). Yet, even modest reductions in blood pressure (BP) can substantially reduce the risk of cardiovascular and cerebrovascular sequalae (4) (5).

Hypertension is relatively easy and affordable to diagnose and treat in primary care. However, a study reported in the Lancet of 12 high income countries, including the UK, found that improvements in hypertension control has mostly plateaued since the advent of readily available hypotensives in the 1980s and 1990s. This is attributed to the high rates of undiagnosed and untreated hypertension (6).

The Quality and Outcomes Framework (QOF) in the UK incentivises maintaining a hypertension register, a structured list of patients with coded hypertension in their electronic health record (EHR) (7). A systematic review of 72 randomised controlled trials found that implementation and accurate maintenance of a hypertension registry is the most effective intervention to significantly optimise hypertension treatment in primary care settings (8). However, under-coding of hypertension in electronic medical records has previously been reported (9).

In the UK the burden of hypertension and its associated complications of cardiovascular, cerebrovascular and renal disease falls most heavily on the socially deprived and some ethnic minority groups (10) (11). The COVID-19 pandemic has disrupted healthcare use (12), worsened health outcomes and widened health inequalities (13) (14) (15).

Understanding the interplay of sociodemographic factors and the impact of the pandemic on hypertension coding and management is therefore pertinent, especially given the necessity of early diagnosis and management to prevent end organ complications.

Thus, in a multi-ethnic UK urban setting, we aimed to determine the prevalence and sociodemographic, lifestyle and clinical factors associated with unmeasured, uncoded elevated BP, and uncontrolled hypertension across a 7-year period, from 2014-2021.

METHODS

Study design and population

Anonymized patient level data was extracted from Lambeth DataNet on the 1st of October 2022, for the study period January 2014-December 2021. Lambeth DataNet is a database holding routinely collected primary care data, for all 41 general practices (GP) within Lambeth – an ethnically diverse inner London borough. UK NICE guidelines differ in those aged 80 years and above compared to those aged 18-79, so inclusion was restricted to patients registered at GP practices aged 18-79 years.

Study sample

2303 patients had requested an 'informed dissent' code for data sharing and so information was not extracted for these patients, this meant there were 2,517,303 total data entries extracted across the years 2014-2021. Entries were removed if they had invalid or unknown pseudonymised NHS identity numbers, date of birth or age (see Figure 1, Supplemental Digital Content 1). This left a total of 2,502,164 data entries for analysis corresponding to 549,082 patients. Where patient entries had characteristics missing, the last recorded value for the patient was used if available, otherwise entries were removed (see Figures 2-4 of Supplemental Digital Content 1).

Hypertension outcome measures

Patients were classified as having an "unmeasured BP" if they did not have a valid BP measurement (defined as valid if there was both a systolic and diastolic value) recorded at any time point in the electronic health record. Patients were classified with "uncoded

elevated BP" if their most recent recorded annual mean BP exceeded 140/90 and if they were not on the hypertension register (not coded as hypertensive). "Uncontrolled hypertension" was defined as a BP above NICE guideline treatment targets, which varied according to co-morbidities; the threshold was 140/90 for most patients but was 135/85 for those with Type 1 diabetes and 130/80 for those with Stroke or Transient Ischemic Attack.

Statistical Analysis

Associations between patient characteristics and unmeasured BP, uncoded elevated BP and uncontrolled hypertension were identified by logistic regression (LR), using fixed and mixed effects models. Patient characteristics were included as fixed effects. The random effect was a random intercept for each patient. For the fixed effects models, the most recent registration year during the time period for each patient was used and models were fitted on three different cohorts based on when a patient was last registered: 2014-2021, 2018-2019, and 2020-2021. These cohorts were chosen to give an indication of pre-pandemic and early pandemic time periods. For the mixed effects models, each year the patient was registered during the period was included.

Fixed effects LR was used for the unmeasured BP and uncoded elevated BP analyses as so few components of the data changed across the years rendering the data unsuitable for mixed effects models. For uncontrolled hypertension, patients changed their control status across the years, so a mixed effects model was used.

The fixed effects models adjusted for: registration year, age, sex, deprivation measured using the Index of Multiple Deprivation (IMD) 2019 (16) quintile, ethnicity, alcohol consumption, smoking status, body mass index (BMI), and cardiovascular comorbidities. The mixed effects models adjusted for the same variables with the addition of the number of anti-hypertensive medications prescribed corresponding to the NICE treatment stage (17).

Adjusted odds ratios (AOR) were reported with 95% confidence intervals (CIs). Statistical significance was defined at P<0.05. All analysis were performed using Rv4.1.3. The fixed effects models were fitted using the “stats” package and the mixed effects models were fit using the “lme4” package.

Sensitivity Analysis

For uncontrolled hypertension a mixed effects LR model was used. Some of the mixed model results differed from previous research findings, so the analysis was repeated using a fixed-effects model.

Ethical approval

All data were extracted under the terms of a signed data sharing agreement with each practice and with project-specific approval following submission of a data privacy impact assessment, approved by Lambeth Clinical Commissioning Group on 2 November 2017. Separate ethical committee approval was not required (Health Research Authority, personal correspondence, 29 September 2017) since all data were fully anonymised for the purposes of research access, and all patient identifiable data had been removed.

RESULTS

The total sample included 549,083 individuals registered at a GP from 2014-21, as shown in Figure 1 (see also Figure 1 of Supplemental Digital Content 2)**.** Those in the most deprived 2 IMD quintiles made up most of the sample (68%) as did those under 44 years of age (70.8%) as shown in Table 1. 60.5% of the total sample had a valid BP reading, 42% of which had more than one BP reading recorded within a single year. 71,970 adults had an elevated BP, of which 36.0% had uncoded elevated BP. 44,648 adults were on the hypertension register and had a valid BP reading, of whom 46.8% had uncontrolled hypertension.

Predictors of unmeasured blood pressure

Baseline characteristics of those with a valid blood pressure reading are shown in Table 1 of Supplemental Digital Content 2. Fixed effects LR is shown in Figure 2 (see also Table 2 of Supplemental Digital Content 2)**.** Compared to patients registered in 2014, those registered in 2020-2021 were over twice as likely to have unmeasured BP. Compared to patients aged 45-54, younger patients had a significantly higher likelihood of unmeasured BP, with the 35-44 age group having the highest likelihood (AOR 1.74, 95% CI 1.70-1.78). Males were more likely than females to have unmeasured BP (AOR 2.4, 95% CI 2.36-2.43). There was little variation by ethnic group or IMD. Presence of each cardiovascular comorbidity decreased likelihood by 74% (AOR 0.26, 95% CI 0.25-026). Obese patients were less likely than healthy weight patients to have an unmeasured BP (AOR 0.55, 95% CI 0.54-0.56). Patients had a higher likelihood of an unmeasured BP if they were missing information on ethnicity (AOR 1.36, 95% CI 1.33-1.40), and cardiovascular risk factors such as alcohol use (AOR 1.18, 95% CI 1.17-1.20), smoking (AOR 1.85, 95% CI 1.77-1.94) or BMI (AOR 2.87, 95% CI 2.79-2.95).

Predictors of uncoded elevated BP

Baseline characteristics of those with a valid blood pressure reading are shown in Table 3 of Supplemental Digital Content 2. A fixed effects LR model was fitted on three different cohorts based on year of registration. Predictors of uncoded elevated BP were very similar in all cohorts. The 2014-2021 results are shown in Figure 3, and the other cohort results are shown in Tables 4-6 and Figures 2-3 of Supplemental Digital Content 2. In the 2014-21 cohort, compared to patients registered in 2014, those in 2020 were more likely (AOR 1.12, 95%CI 1.06-1.18) to have uncoded elevated BP and those in 2021 were less likely (AOR 0.66, 95% CI 0.62-0.70).

In all cohorts compared to patients aged 18-24, older age groups were associated with a higher likelihood of uncoded elevated BP, with the 35-44, 45-54, and 65-74 age groups having the highest likelihood. In all cohorts, males were more likely than females to have uncoded elevated BP; in the 2014-2021 cohort they were twice as likely (AOR 1.98 95% CI 1.92-2.03). In all cohorts, including the 2014-21 cohort, patients had a higher likelihood of uncoded elevated BP if they had cardiovascular risk factors, such as obesity (AOR 2.51, 95% CI 2.42-2.60). There was little variation by ethnic group or IMD in any cohort.

Predictors of uncontrolled hypertension

Baseline characteristics of patients on the hypertension register are shown in Table 7 of Supplemental Digital Content 2. Mixed effects LR is shown in Figure 4 (see also Table 8 of Supplemental Digital Content 2)**.** Those registered between 2015-2018 were significantly more likely to have uncontrolled hypertension than those registered in 2014 and those registered between 2020-2021 were significantly less likely. Compared to patients aged 75-80, those aged 18-65 were significantly more likely to have uncontrolled hypertension, with the 35-44 age group having the highest likelihood (AOR 1.65, 95%CI 1.5401.77). Males were more likely than females to have uncontrolled hypertension (AOR 1.36, 95% CI 1.31-1.41).

There was no significant variation according to IMD quintiles. Patients identified as African, Caribbean, Other Black, or who had a missing ethnicity record were at least 40% more likely than White British patients to have uncontrolled hypertension. The Asian ethnic group was the only group that was significantly less likely (AOR 0.85, 95%CI 0.79-0.91).

Patients had a higher likelihood of uncontrolled hypertension if they had cardiovascular risk factors. Compared to patients on one medication, patients on two medications (AOR

1.19, 95% CI 1.14-1.24) or three medications (AOR 1.14, 95 CI 1.09-1.19) were more likely to have uncontrolled hypertension.

A sensitivity analysis with fixed effect LR showed very similar results (see Table 9 and Figure 4 of Supplemental Digital Content 2), with one exception: there was no longer any significant difference in uncontrolled hypertension rates between Asian and White British patients (AOR 1.02, 95% CI 0.94-1.10).

DISCUSSION

Summary of main findings

In a multi-ethnic population in South London based on primary care data from almost 550,000 adult patients registered over a seven year period, 40% had no record of a BP reading. Of those with elevated blood pressure readings, a third were uncoded and half of those with diagnosed hypertension were uncontrolled. Patients registered in the pandemic years, 2020 and 2021, were more than twice as likely to have unmeasured BP compared to those registered in 2014 but were less likely to have uncontrolled hypertension.

Age and male sex were strongly associated with the three main outcomes of our study. After adjustment for other demographic and lifestyle factors, social deprivation was either not significantly or only weakly associated with any of the hypertension outcome measures. Ethnicity was only minimally associated with unmeasured BP or uncoded elevated BP. However, those in Black, mixed or unknown ethnic groups were at least 40% more likely than White British patients to have uncontrolled hypertension.

Those with concurrent cardiovascular risk factors had an increased association of uncoded elevated BP and uncontrolled hypertension. Cardiovascular co-morbidities were associated with a decreased odds of unmeasured BP and uncoded elevated BP but increased odds of uncontrolled hypertension. Increasing the NICE treatment step in

hypotensive medications was associated with an increased odds of uncontrolled hypertension.

Strengths and limitations

This study included a large sample size of patients, data observations and years of patient registration. Registration at GP practices in the UK is universally encouraged, free and not dependant on pre-existing co-morbidities. This minimises the risk of selection bias compared to previous studies that have used survey data (18) (19) to explore hypertension outcome measures.

In Lambeth 42.9% of people are from Black, Asian and minority ethnic communities (20) and deprivation rates are higher compared to the rest of the England (16). This provides large sample variability and allows socioeconomic inequalities to be assessed. However, our results from one defined geographical area may not be generalisable to other parts of the UK. Lambeth is a densely populated borough (21) with a young and mobile population - the average age is almost 5 years younger than the mean for England (22) and it has higher rates of internal and international migration compared to the rest of London and England (23). High population turnover means that a proportion of people may be registered at Lambeth GP practices but may be living elsewhere, so we may have overestimated unmeasured BP rates. This may be especially relevant in the pandemic lock down years when many people temporarily left London increasing internal migration and in the post Brexit era which has increased international migration.

A strength of this study is the inclusion of all major cardiovascular co-morbidities that are common in clinical practice. Vascular events such as aortic aneurysms, aortic dissection, and atherosclerotic disease in the gut and lower extremities were not included. However, whilst it is true that these vascular events are important when considering hypertension coding and control, they affect very few numbers in the Lambeth population (24). The

frequency of new patients being coded as hypertensive over time was not examined, neither was the number of prescriptions for existing hypertension cases. This could be a limitation of our study, as these factors could provide evidence on the possible impact of uncoded elevated BP in this population.

In the pandemic there was a suspension of the Quality and Outcomes Framework (QOF) (25) which incentivises BP recording, and we found a subsequent decrease in the number of recorded BP measurements per patient. It is therefore possible that some hypertensive patients registered in the pandemic years had unrecorded, uncontrolled BP. Furthermore, those who continued to have BP readings recorded in the pandemic may have been more motivated and health conscious skewing the results. We were unable to ascertain if a BP measurement was taken at home, in the clinic or by ambulatory measurement so it is also possible that during the pandemic more BP measurements were taken at home with a reduced effect of white coat hypertension confounding the results. Taken together, these pandemic effects are likely to have resulted in underestimates of the rates of uncontrolled BP in our study findings.

This study used the average BP readings for an individual taken from across the year to screen for uncoded elevated BP. A limitation of our study is that only 42% of the study population had more than one BP reading recorded within a single year. Although BP readings at a single time point may not provide a definitive diagnosis of hypertension according to NICE guidelines (17), they can still provide important insights into the prevalence and risk factors associated with undiagnosed hypertension at a population level. This approach has been used in other large-scale analysis of uncoded and undiagnosed hypertension (26) (27). In this study we have opted for a more conservative approach by labelling individuals with high BP, who are not on the hypertension register, as having “uncoded elevated BP.” However, according to the Health Survey for England criteria they would have been classified as those with “undiagnosed hypertension.”

Comparison with existing literature

The prevalence of uncontrolled hypertension (46.8%) in our study is largely consistent with other UK based studies (19) (28) and in other high income countries worldwide (29) (30). The COVID-19 pandemic has been shown to have reduced diagnostic procedures relating to hypertension such as ambulatory BP monitoring (31), as well as reducing the number of BP measurements taken in those with hypertension (32). Our study adds information on patients who registered with their general practice during the pandemic years who were found to be less likely to have a recorded BP reading. Studies on hypertension control in the pandemic have shown conflicting results; two US studies showed worsening control (32) (33), a study in Italy showed improved control (34) and a study in Brazil found no change (35). The differences may be due to differing health care systems, and our study gives a UK perspective.

Lower rates of unmeasured BP in women may be partially explained by the necessity of screening for hypertension prior to starting oral contraceptives and at pregnancy (36). However male sex was also strongly associated with uncoded elevated BP and uncontrolled hypertension, as found in other studies (19) (37). Men have different health seeking behaviour compared to women, for example men have fewer primary care consultation rates in the UK and this difference is only partially accounted for by consultations due to reproductive reasons (38). It is possible therefore that due to overall higher consultation rates in women, there are more opportunities for GP's to measure BP, discuss BP readings and take more frequent steps to code, monitor and control hypertension.

Previous studies have shown that lifestyle modification in the middle-aged population is key to healthy aging and reducing the risk of cardiovascular disease (39), providing an onus to target this age group which was found to be at a greater risk of unmeasured BP, uncoded elevated BP, and uncontrolled hypertension. Furthermore, the prevalence of

young strokes has been shown to be increasing (40) increasing the importance of hypertension detection and control in the middle-aged.

Uncontrolled hypertension was associated with younger age in this study. This may be due to differences in medication adherence, as previous research has shown that younger patients have lower rates of medications adherence for long term conditions including hypertension (41) (42) (43). Additionally, the proportion of hypertension classified as secondary hypertension, which can be more challenging to manage, has been found to be higher in younger patients compared to older patients (44) (45). This may further contribute to the observed association between younger age and uncontrolled hypertension in this study.

Our study found that Black ethnicity remains associated with uncontrolled hypertension (19) (28) (46) but did not affect the coding of elevated BP (47) (48). This may be explained by lower BP monitoring post diagnosis and lower antihypertensive intensification rates in those of Black ethnicity compared to European ethnicities found in a recent UK retrospective cohort study (49). Our study further adds to the literature by showing Black ethnicity did not affect the frequency of BP measurement.

A Welsh cohort study showed deprivation measured at the geographical level was not associated with the initiation of anti-hypertensives (50), whilst an analysis of the Health Survey for England data found no income-based inequalities in the diagnosis of hypertension (27). A study using the UK Biobank found increased deprivation measured by the Townsend deprivation index increased odds of hypertension control. However, this same study found individual characteristics associated with lower socioeconomic standing such as low income, low education and less professionalised occupations decreased the odds of hypertension control (19). Social deprivation measured at the geographical level, may be biased by the ecological fallacy (51), which would be expected to lead to an underestimate of the effect of deprivation on individual level

hypertension outcomes. Geographical measures of deprivation such as the IMD-2019, have been widely used and validated (52). However, new approaches could be considered to capture real time information on the social determinants of health at an individual level, for example through recording this data in the electronic health record during clinical encounters (53).

Conclusions

It is known that uncontrolled hypertension causes high morbidity and mortality. Across a 7-year period, 2014-21, in a socioeconomically diverse inner-city setting, a third (36.0%) of those with elevated blood pressure were uncoded, and half (46.8%) of those with diagnosed hypertension were uncontrolled. Health inequalities in hypertension outcomes have been shown to be present, associated with sex, age and some ethnicities, but only weakly or not significantly associated with social deprivation. Research is needed to identify possible barriers for specific population groups to understand the reasons for discrepancies. For example, are there associations with health literacy, medication adherence, exercise, nutritional habits, healthcare utilisation or hypertension type and stage.

Given the high rates of unmeasured, uncoded elevated BP, and uncontrolled hypertension, universal interventions to address these outcomes are needed. However, interventions must be evaluated in diverse groups to ensure inequalities aren't widened. Inequalities have been found affecting those already at a higher risk of cardiovascular mortality such as those with cardiovascular risk factors. Inequalities have also been found affecting those who may be at a stage when interventions may yield the highest benefit, such as the middle-aged population. Therefore, targeted interventions for these specific groups may be especially pertinent.

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Each author has confirmed compliance with the journal's requirements for authorship.

The authors have declared no conflicts of interest.

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INDIVIDUAL TABLES AND CAPTIONS

Table 1: Patient characteristics of the total sample (n = 549,082).

Characteristics	Categories	% (n)
Last registration year at a Lambeth general practice	2014-15	10.6 (58383)
	2016-17	9.7 (53407)
	2018-19	10.7 (58770)
	2020-21	68.9 (378522)
Age group	18-24	10.4 (57180)
	25-34	38.4 (210846)
	35-44	22.0 (120549)
	45-54	13.0 (71631)
	55-64	9.0 (49551)
	65-74	4.6 (25258)
	75-80	2.6 (14067)
Sex	Female	51.1 (280718)
	Male	48.9 (268364)
IMD quintile	5, Least deprived	4.2 (22839)
	4	4.2 (23101)
	3	23.5 (128888)
	2	37.1 (203586)
	1, Most deprived	30.9 (169849)

	Missing	0.1 (819)
Ethnicity	British	32.7 (179515)
	Other White	25.8 (141407)
	African	8.1 (44206)
	Caribbean	4.7 (26017)
	Other Black	2.5 (13506)
	Asian	6.9 (37917)
	Mixed	4.6 (25459)
	Other	3.4 (18868)
	Unknown	<0.1 (242)
	Not stated, or refused	1.7 (9434)
	Missing	9.6 (52511)
Alcohol intake (units/week)	0-14	39.4 (216240)
	>14	6.6 (36029)
	Missing	54.1 (296813)
Smoking status	Non-smoker	58.7 (322466)
	Current smoker	17.9 (98456)
	Ex-smoker	15.7 (86102)
	Missing	7.7 (42058)
BMI	<18.5	3.0 (16277)
	18.5-24.9	42.1 (230966)
	25-29.9	22.6 (124117)
	≥30	13.0 (71387)
	Missing	19.4 (106335)
Cardiovascular co-morbidities*, n	0	93.5 (513254)
	1	2.2 (11920)
	2+	4.4 (23908)

*Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease.

Abbreviations: IMD = Index of Multiple Deprivation; BMI = Body Mass Index

LIST OF SUPPLEMENTAL DIGITAL CONTENT

- Supplemental Digital Content 1. doc
- Supplemental Digital Content 2. doc

FIGURE 1: Summary of total sample

Abbreviations: BP = Blood pressure, HTN = hypertension

FIGURE 2: Characteristics associated with unmeasured BP; odds ratios calculated using a fixed effects logistical regression model (n = 548,263).

Covariates are listed on the left and their AORs (presented as: AOR (95% CI)) are listed on the right, reference categories are in brackets after each variable. Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease. Abbreviations: Ref = Reference category; IMD = Index of Multiple Deprivation; BMI = Body Mass Index.

FIGURE 3: Characteristics associated with uncoded elevated BP in the 2014-2021 Cohort; odds ratios calculated using a fixed effects logistical regression model (n = 331,812).

Covariates are listed on the left and their AORs (presented as: AOR (95% CI)) are listed on the right, reference categories are in brackets after each variable

Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease

Abbreviations: Ref = Reference category; IMD = Index of Multiple Deprivation; BMI = Body Mass Index.

FIGURE 4: Characteristics associated with uncontrolled hypertension from 2014-2021; odds ratios calculated using a mixed effects logistical regression model (n = 199,660 from 44,617 patients).

Covariates are listed on the left and their AORs (presented as: AOR (95% CI)) are listed on the right, reference categories are in brackets after each variable

Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease

The NICE treatment step corresponds to the number of hypotensive medications

Abbreviations: Ref = Reference category; IMD = Index of Multiple Deprivation; BMI = Body Mass Index; tmt = treatment.

Figure 1

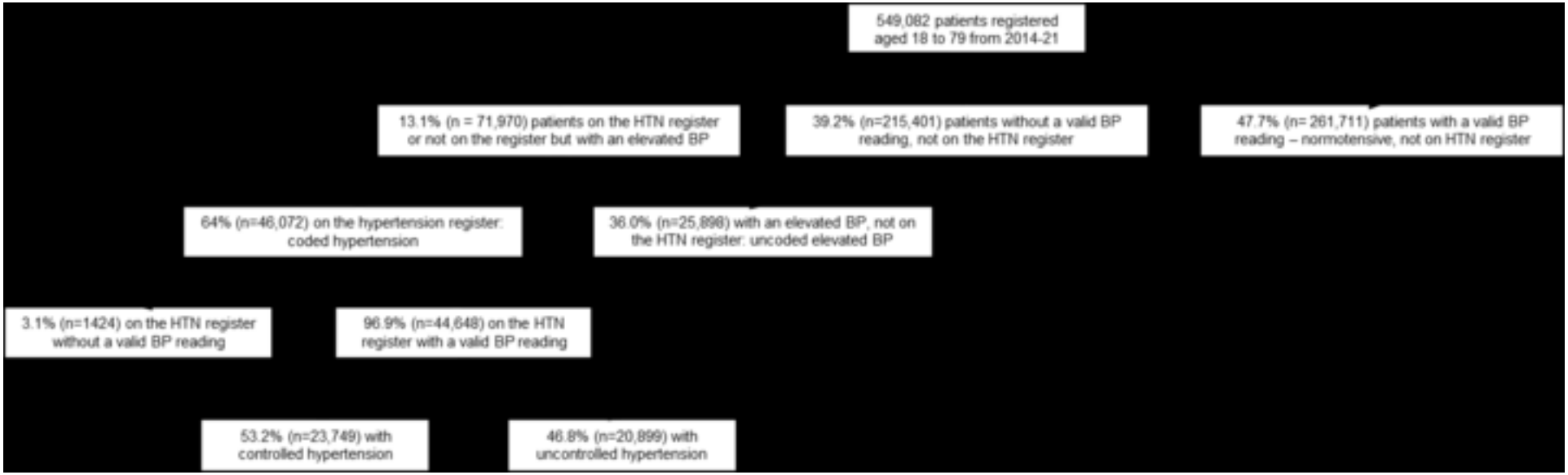


Figure 2

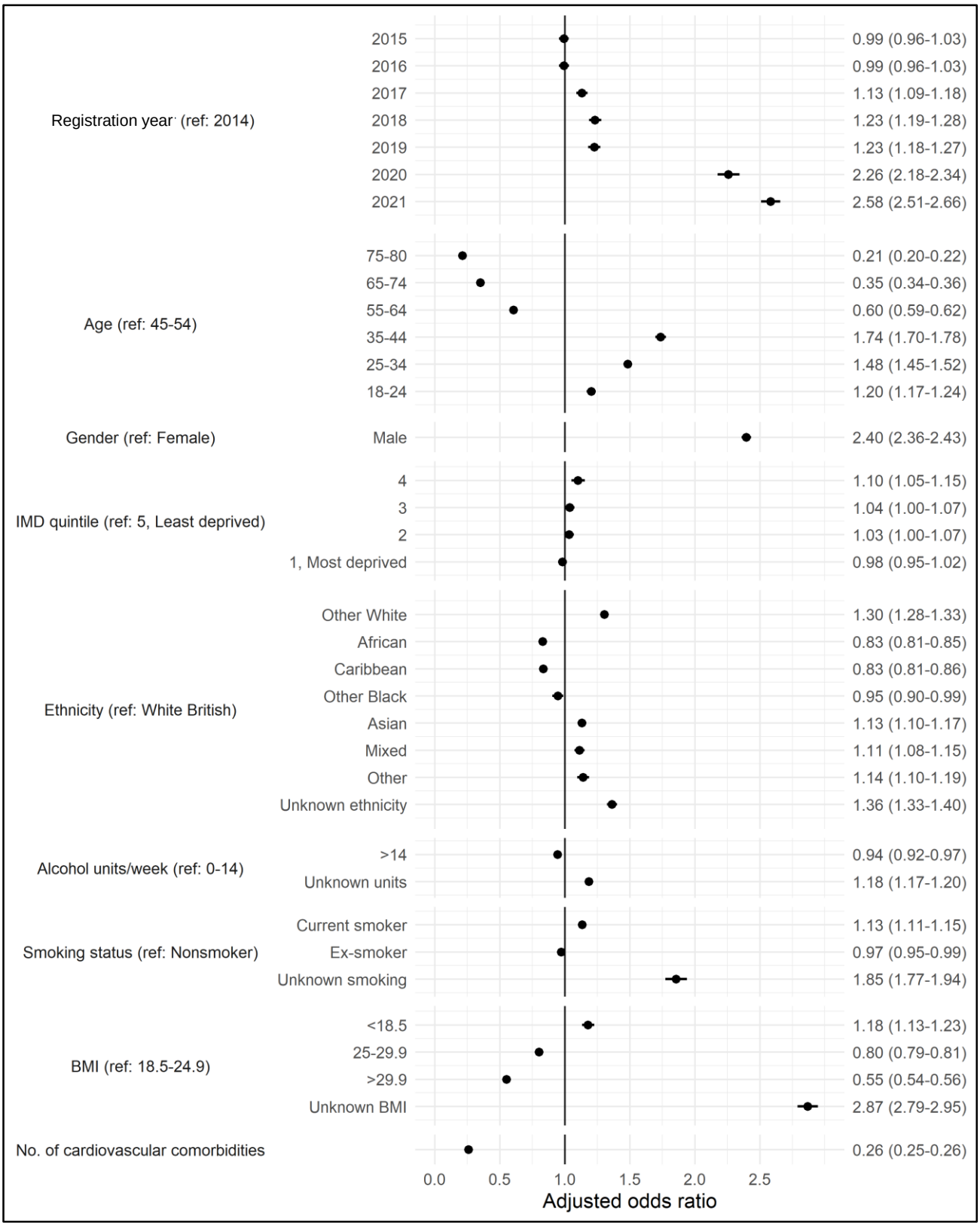

Registration year (ref: 2014)
2015
2016
2017
2018
2019
2020
2021
0.99 (0.96-1.03)
0.99 (0.96-1.03)
1.13 (1.09-1.18)
1.23 (1.19-1.28)
1.23 (1.18-1.27)
2.26 (2.18-2.34)
2.58 (2.51-2.66)
Age (ref: 45-54)
75-80
65-74
55-64
35-44
25-34
18-24
0.21 (0.20-0.22)
0.35 (0.34-0.36)
0.60 (0.59-0.62)
1.74 (1.70-1.78)
1.48 (1.45-1.52)
1.20 (1.17-1.24)
Gender (ref: Female)
Male
2.40 (2.36-2.43)
IMD quintile (ref: 5, Least deprived)
4
3
2
1, Most deprived
1.10 (1.05-1.15)
1.04 (1.00-1.07)
1.03 (1.00-1.07)
0.98 (0.95-1.02)
Ethnicity (ref: White British)
Other White
African
Caribbean
Other Black
Asian
Mixed
Other
Unknown ethnicity
1.30 (1.28-1.33)
0.83 (0.81-0.85)
0.83 (0.81-0.86)
0.95 (0.90-0.99)
1.13 (1.10-1.17)
1.11 (1.08-1.15)
1.14 (1.10-1.19)
1.36 (1.33-1.40)
Alcohol units/week (ref: 0-14)
>14
Unknown units
0.94 (0.92-0.97)
1.18 (1.17-1.20)
Smoking status (ref: Nonsmoker)
Current smoker
Ex-smoker
Unknown smoking
1.13 (1.11-1.15)
0.97 (0.95-0.99)
1.85 (1.77-1.94)
BMI (ref: 18.5-24.9)
<18.5
25-29.9
>29.9
Unknown BMI
1.18 (1.13-1.23)
0.80 (0.79-0.81)
0.55 (0.54-0.56)
2.87 (2.79-2.95)
No. of cardiovascular comorbidities
0.26 (0.25-0.26)
0.0
0.5
1.0
1.5
2.0
2.5
Adjusted odds ratio

FIGURE 2: Characteristics associated with unmeasured BP; odds ratios calculated using a fixed effects logistical regression model (n = 548,263).

Covariates are listed on the left and their AORs (presented as: AOR (95% CI)) are listed on the right, reference categories are in brackets after each variable. Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease. Abbreviations: Ref = Reference category; IMD = Index of Multiple Deprivation; BMI = Body Mass Index.

Figure 3

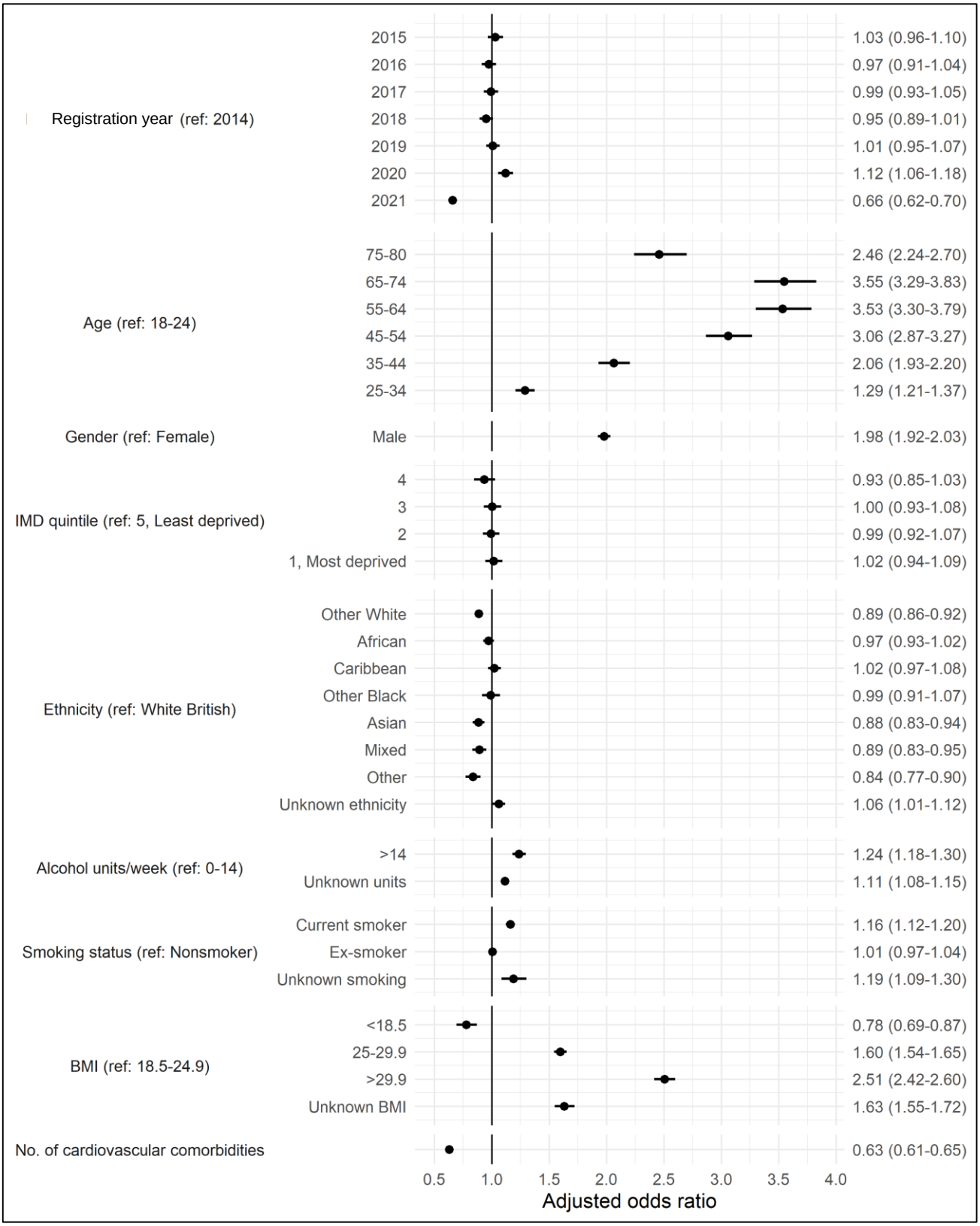

Registration year (ref: 2014)
2015
2016
2017
2018
2019
2020
2021
1.03 (0.96-1.10)
0.97 (0.91-1.04)
0.99 (0.93-1.05)
0.95 (0.89-1.01)
1.01 (0.95-1.07)
1.12 (1.06-1.18)
0.66 (0.62-0.70)
Age (ref: 18-24)
75-80
65-74
55-64
45-54
35-44
25-34
2.46 (2.24-2.70)
3.55 (3.29-3.83)
3.53 (3.30-3.79)
3.06 (2.87-3.27)
2.06 (1.93-2.20)
1.29 (1.21-1.37)
Gender (ref: Female)
Male
1.98 (1.92-2.03)
IMD quintile (ref: 5, Least deprived)
4
3
2
1, Most deprived
0.93 (0.85-1.03)
1.00 (0.93-1.08)
0.99 (0.92-1.07)
1.02 (0.94-1.09)
Ethnicity (ref: White British)
Other White
African
Caribbean
Other Black
Asian
Mixed
Other
Unknown ethnicity
0.89 (0.86-0.92)
0.97 (0.93-1.02)
1.02 (0.97-1.08)
0.99 (0.91-1.07)
0.88 (0.83-0.94)
0.89 (0.83-0.95)
0.84 (0.77-0.90)
1.06 (1.01-1.12)
Alcohol units/week (ref: 0-14)
>14
Unknown units
1.24 (1.18-1.30)
1.11 (1.08-1.15)
Smoking status (ref: Nonsmoker)
Current smoker
Ex-smoker
Unknown smoking
1.16 (1.12-1.20)
1.01 (0.97-1.04)
1.19 (1.09-1.30)
BMI (ref: 18.5-24.9)
<18.5
25-29.9
>29.9
Unknown BMI
0.78 (0.69-0.87)
1.60 (1.54-1.65)
2.51 (2.42-2.60)
1.63 (1.55-1.72)
No. of cardiovascular comorbidities
0.63 (0.61-0.65)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Adjusted odds ratio

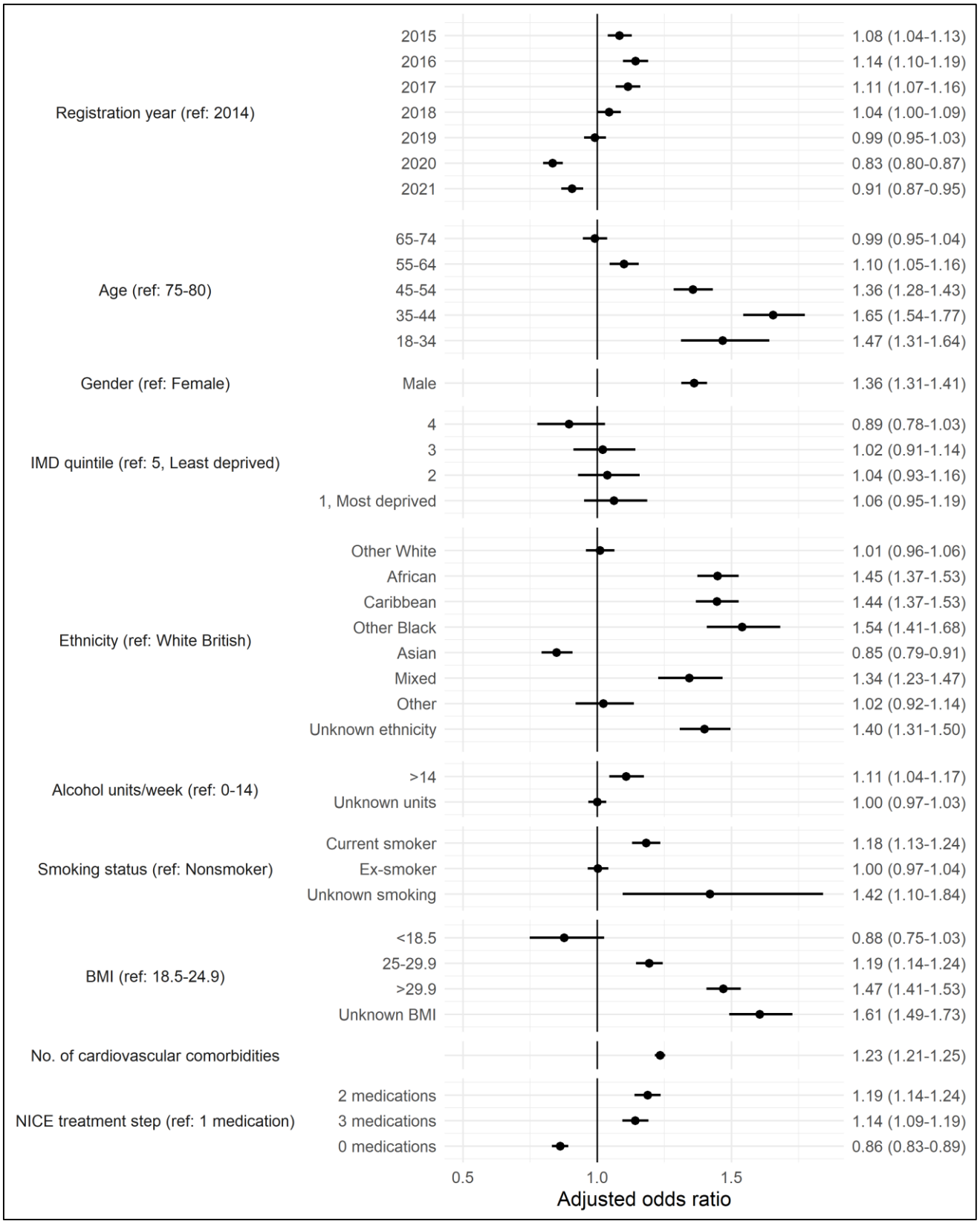
FIGURE 3: Characteristics associated with uncoded elevated blood pressure in the 2014-2021 Cohort; odds ratios calculated using a fixed effects logistical regression model (n = 331,812).

Covariates are listed on the left and their AORs (presented as: AOR (95% CI)) are listed on the right, reference categories are in brackets after each variable

Cardiovascular co-morbidities = Type 1 and Type 2 diabetes, stroke, transient ischemic attack, chronic kidney disease and coronary heart disease

Abbreviations: Ref = Reference category; IMD = Index of Multiple Deprivation; BMI = Body Mass Index.

Figure 4


Registration year (ref: 2014)
2015
2016
2017
2018
2019
2020
2021
1.08 (1.04-1.13)
1.14 (1.10-1.19)
1.11 (1.07-1.16)
1.04 (1.00-1.09)
0.99 (0.95-1.03)
0.83 (0.80-0.87)
0.91 (0.87-0.95)
Age (ref: 75-80)
65-74
55-64
45-54
35-44
18-34
0.99 (0.95-1.04)
1.10 (1.05-1.16)
1.36 (1.28-1.43)
1.65 (1.54-1.77)
1.47 (1.31-1.64)
Gender (ref: Female)
Male
1.36 (1.31-1.41)
IMD quintile (ref: 5, Least deprived)
4
3
2
1, Most deprived
0.89 (0.78-1.03)
1.02 (0.91-1.14)
1.04 (0.93-1.16)
1.06 (0.95-1.19)
Ethnicity (ref: White British)
Other White
African
Caribbean
Other Black
Asian
Mixed
Other
Unknown ethnicity
1.01 (0.96-1.06)
1.45 (1.37-1.53)
1.44 (1.37-1.53)
1.54 (1.41-1.68)
0.85 (0.79-0.91)
1.34 (1.23-1.47)
1.02 (0.92-1.14)
1.40 (1.31-1.50)
Alcohol units/week (ref: 0-14)
>14
Unknown units
1.11 (1.04-1.17)
1.00 (0.97-1.03)
Smoking status (ref: Nonsmoker)
Current smoker
Ex-smoker
Unknown smoking
1.18 (1.13-1.24)
1.00 (0.97-1.04)
1.42 (1.10-1.84)
BMI (ref: 18.5-24.9)
<18.5
25-29.9
>29.9
Unknown BMI
0.88 (0.75-1.03)
1.19 (1.14-1.24)
1.47 (1.41-1.53)
1.61 (1.49-1.73)
No. of cardiovascular comorbidities
1.23 (1.21-1.25)
NICE treatment step (ref: 1 medication)
2 medications
3 medications
0 medications
1.19 (1.14-1.24)
1.14 (1.09-1.19)
0.86 (0.83-0.89)
0.5
1.0
1.5
Adjusted odds ratio

Reviewer Comments:

Reviewer #2: Comments

In the revised manuscript, the authors have addressed the concerns of the reviewers. Nonetheless, there are a couple of residual issues for this reviewer. First, the comment on page 12, last line, stating the cardiovascular co-morbidities 'affect very few numbers in the Lambeth population', is surprising, given its multi-ethnic composition that includes minorities where the prevalence of diabetes is excessively high. Since diabetes is a component of cardiovascular co-morbidities, the 6.6% prevalence rate of all cardiovascular co-morbidities in the total sample (Table 1) suggests that the prevalence rate of diabetes in the Lambeth population is inexplicably lower than the prevalence of diabetes in the UK population overall, estimated to be 1 in 14 people (7.1%). On the other hand, in Supplement TABLE 7: Baseline characteristics of those on the hypertension register (n = 46,072), 44.2% or 20,364 individuals had 1 or more cardiovascular comorbidity, which would be in keeping with other data showing a one (1) in three (3) prevalence of diabetes in hypertensive populations.

Author response:

Thank you for your feedback. The below is taken from page 12 in the original manuscript:

“A strength of this study is the inclusion of all major cardiovascular co-morbidities that are common in clinical practice. Vascular events such as aortic aneurysms, aortic dissection, and atherosclerotic disease in the gut and lower extremities were not included. However, whilst it is true that these co-morbidities are important when considering hypertension coding and control, they affect very few numbers in the Lambeth population (24).”

We would like to clarify that when we stated that certain co-morbidities "affect very few numbers in the Lambeth population," we were specifically referring to the vascular events mentioned immediately before that statement: namely, aortic aneurysms, aortic dissection, and atherosclerotic disease in the gut and lower extremities. We did not intend to suggest that other cardiovascular co-morbidities, such as diabetes, affect only a small number of individuals in this population.

We understand this wording may be misleading and so to ensure clarity and prevent any further misinterpretation, we have now rephrased this portion of our manuscript as follows:

“A strength of this study is the inclusion of all major cardiovascular co-morbidities that are common in clinical practice. Vascular events such as aortic aneurysms, aortic dissection, and atherosclerotic disease in the gut and lower extremities were not included. However, whilst it is true that these **vascular events** are important when considering hypertension coding and control, they affect very few numbers in the Lambeth population (24).”

Second, there is no mention in Results and Conclusion sections of the Abstract about social deprivation or COVID-19 pandemic, even though both are highlighted in Objective section. The omission is striking and detracts from the originality of the manuscript.

Author response: Thank you for your feedback we have now updated the abstract to highlight findings regarding social deprivation and the pandemic.

Reviewer #3: The reviewer believes that the authors have adequately responded to the reviewer's comments.

Author response: Thank you for your feedback.