Original article

Differences in ambulatory versus home blood pressure levels by ethnicity: Data from the United Kingdom and Japan

Short title: BP differences in the UK and Japan

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Abstract

This study tested the hypothesis that differences in ethnicity impact the level of agreement between ambulatory blood pressure (ABP) and home BP (HBP) levels. A retrospective analysis of cross-sectional data from the UK and Japan was performed. Participants underwent office BP, daytime ABP, and HBP measurements. The ABP–HBP difference was compared between ethnic groups by multiple linear regression analysis. Diagnostic disagreement was defined as a disparity between the hypertension diagnoses obtained using ABP and HBP, since both measures share common thresholds of 135/85 mmHg for hypertension. Definite diagnostic disagreement was assigned where such a difference exceeded ±5 mmHg for either systolic BP (SBP) or diastolic BP (DBP). A total of 1 408 participants (age 62.1±11.1 years, 48.6% males, 78.9% known hypertensive, White British 18.9%, South Asian 11.2%, African Caribbean 12.0%, Japanese 58.0%) were eligible. More Japanese participants showed higher ABP than HBP compared to White British: SBP +3.09 mmHg, 95% confidence interval (CI) +1.14, +5.04 mmHg; DBP +5.67 mmHg, 95%CI +4.51, +6.84 mmHg. More Japanese participants than African Caribbean participants exhibited diagnostic disagreement in SBP (33.2% vs. 20.7%, p=0.006). Furthermore, Japanese participants had a higher percentage of definite diagnostic disagreement in SBP compared to White British (9.3% vs. 4.5%, p=0.040) and African

Caribbean participants (9.3% vs. 3.0%, p=0.018). In conclusion, Japanese participants showed greater disparity between ABP and HBP compared to White British participants. Complementary use of ABP and HBP monitoring may be more beneficial for assessing cardiovascular disease risk in Japanese participants compared to other ethnic groups.

Introduction

Hypertension is the leading preventable risk factor for cardiovascular disease (CVD) morbidity and mortality worldwide.[1] Accurate assessment of blood pressure (BP) is essential to achieve optimal BP control and to judge the effectiveness of antihypertensive treatment. Ambulatory BP monitoring (ABPM) is the standard method for the diagnosis of hypertension,[2] while home BP monitoring (HBPM) is commonly used for long-term management of hypertension in clinical practice.[3]

There are considerable differences between ABPM and HBPM, including measurement schedule, environment, posture and reproducibility, and when the ambulatory BP (ABP) levels differ from the home BP (HBP) levels, it is often difficult to know which to use clinically. Moreover, white-coat hypertension and masked hypertension could be misdiagnosed if the BP values measured by these two types of out-of-office BP measurements were significantly different. Understanding the clinical characteristics of ABPM and HBPM, and the factors affecting the differences between ABP and HBP levels, is therefore useful in clinical practice.

Differences in health measures by ethnicity are seen clearly in the prevalence of hypertension and CVD outcomes in the UK population.[4] The prevalence of hypertension has been reported to vary between 8% and 39% among different ethnic groups.[5] The incidence of coronary heart disease (CHD) is higher among South Asians, while that of stroke is higher in the Black population compared to the White population.[6] In East Asians, stroke is more common than CHD.[7] Many factors, such as lifestyle, dietary habits, obesity, salt sensitivity, sympathetic nervous activity, socioeconomic status, psychosocial factors, and genetic heterogeneity could contribute to the differences in BP levels and CVD outcomes among ethnicities.[8-10] Therefore, it is important to understand whether any disparities in BP levels measured by different measurement modalities are also affected by ethnicity. The objective of this study was to test the hypothesis that differences in ethnicity are associated with differences between ABP and HBP measurements.

Materials and Methods

Study participants

This was a retrospective analysis of cross-sectional data from two datasets. The first dataset came from the Blood Pressure monitoring in different Ethnic Groups (BP-Eth) study (n=771), which was a primary care-based observational study conducted in Central England. Participants were recruited from 28 general practices from Central England between 2010 and 2012. Participants who were aged between 40 and 75 years and belonged to one of the three ethnic groups (White British, South Asian, and African-

Caribbean) were enrolled. Ethnicity was self-reported using the UK standard census questionnaire.[11] Details of the BP-Eth study rationale, design and procedures have been published previously.[12] The second dataset came from the Japan Morning Surge-Home Blood Pressure (J-HOP) study (n=4,310), which was a nationwide practice-based observational study conducted in Japan. Participants were recruited from 71 institutions (45 primary practices, 22 hospital-based outpatient clinics, and 4 specialized university hospitals) between 2005 and 2012. Participants with a history of CVD, risk factors for CVD, or both were enrolled. Details of the J-HOP study rationale, design and procedures have also been published previously.[13] In both studies, participants gave informed consent for their data to be used for research purposes.

Blood pressure measurements

Office BP measurement

In the BP-Eth study, three office BP (OBP) readings were taken at three different office visits by a researcher using standardized protocols[2] with a validated monitor (BPM-100; BpTRU Medical Devices, Dallas, TX).[14] In the J-HOP study, three OBP readings were taken on two different occasions by physicians or nurses using standardized protocols[3] at each of two office visits (HEM-5001; Omron Healthcare, Kyoto, Japan). The Omron

HEM-5001 BP device uses the same BP measurement algorithm as used in the validated HEM-737 BP device.[15] In the present analysis, we defined OBP as the mean of second and third readings on two different days (the third day OBPs were excluded in the BP-Eth study for comparability and the first values of BP measurement on each occasion were excluded in both study datasets).

Ambulatory BP measurement

ABPM was performed in an outpatient setting according to relevant clinical guidelines.[2] In the BP-Eth study, ABPs were measured at half–hourly intervals during the day (07:00–23:00) and hourly overnight (23:00–07:00) using a validated automatic device (Spacelabs 90217-1Q; Spacelabs Healthcare Inc., Snoqualmie, WA).[16] In the J-HOP study, ABPs were measured at half hourly intervals for 24 hours using a validated automatic device (TM-2421 or TM-2425; A&D, Tokyo).[17] Day and night periods were determined by participant self-report. In this study, we used daytime ABP levels for the analysis, since daytime ABP and HBP included only daytime measurements and they have the same BP threshold of 135/85 mmHg (systolic BP [SBP]/diastolic BP [DBP]) in the major international hypertension guidelines.[2,3,18] Eligible participants had at least 14 daytime ABP readings.[2]

Home BP measurement

Self-measured HBP was obtained according to the UK and Japanese BP guidelines.[2,3] In the BP-Eth study, HBP was measured twice each morning (06:00–12:00) and evening (18:00–24:00) for 1 week using a validated automatic device (Microlife WatchBP Home; Microlife AG, Widnau, Switzerland).[19] In the J-HOP study, HBP was measured three times each morning and evening for two weeks using the same validated automatic device as used for the OBP measurements (HEM-5001; Omron Healthcare).[15] All HBP readings taken with these two BP measurement devices were automatically stored in the devices themselves. In the present analysis, for the purpose of unifying the number of HBP measurements with the BP-Eth study, we excluded the third value at each BP measurement occasion and used BP values only in the first week of the J-HOP study. In both datasets, the first day of readings was excluded, and the mean of the remaining 2–7 days morning and evening readings was calculated.[20] Eligible participants had a minimum of 12 HBP readings over three days.[20]

In the BP-Eth study, the order of ABPM and HBPM was varied randomly so that approximately half of the participants used ABPM first and half used HBPM first. Both ABPM and HBPM were undertaken within 10 days. In the J-HOP study, the order of

ABPM and HBPM was selected by the participants. In the present study, only ABP and HBP measurements undertaken within a 28-day period were included.

Definitions

In the BP-Eth study, diagnosis of hypertension was based on a clinical code in the participant electronic health records. In the J-HOP study, hypertension was defined as an office SBP of ≥140 mmHg and/or office DBP of ≥90 mmHg, or current use of antihypertensive medication.

Diagnostic disagreement was defined as a disparity between the hypertension diagnoses obtained using ABP and HBP (i.e., [i] hypertensive ABP and controlled HBP, or [ii] controlled ABP and hypertensive HBP). Definite diagnostic disagreement was defined as diagnostic disagreement where both mean daytime ABP and mean HBP differed by ≥5 mmHg from their respective diagnostic thresholds (i.e., for SBP, a case with [i] ABP ≥140 mmHg and HBP ≤130 mmHg or [ii] ABP ≤130 mmHg and HBP ≥140 mmHg; for DBP, a case with [iii] ABP ≥90 mmHg and HBP ≤80 mmHg or [iv] ABP ≤90 mmHg and HBP ≥80 mmHg).

Statistical analysis

Descriptive statistics are presented as means and standard deviation (SD), and numbers (proportions). Characteristics of study participants were compared by one-way analysis of variance or chi-square test, and the Tukey–Kramer Honestly Significant Difference test was used for multiple comparisons. To investigate the agreement between daytime ABP and HBP, we created Bland–Altman plots, with narrower limits of agreement indicating better agreement between the two measurements. The Shapiro–Wilk test and calculation of skewness were used to check the normal distribution of the differences between daytime ABP and HBP. We performed multiple linear regression analyses to assess BP differences among ethnic groups using White British as a reference and to examine factors associated with ABP–HBP differences, after adjustment for age, sex, body mass index (BMI), smoking status, alcohol drinking, prevalence of hypertension, prevalence of dyslipidemia, prevalence of diabetes mellitus, prevalence of chronic kidney disease (CKD), history of CVD, and OBP values. These covariates were selected *a priori* because they have known correlations with BP and CVD risk and could potentially confound the association between these two variables.[21] Numbers (proportions) of participants with diagnostic disagreement and definite diagnostic disagreement were calculated for each ethnic group.

We also assessed differences between daytime ABP and morning HBP by ethnicity, and between daytime ABP and evening HBP, separately. In addition, ethnic differences in the disparity between OBP and morning HBP values, and the disparity between OBP and evening HBP values were assessed. This approach allowed us to assess differences by ethnicity in BP levels measured under standardized conditions and those measured in an environment where individual lifestyles might be reflected.

Based on evidence that BP fundamentally differs by age and gender,[18] we conducted post hoc stratified analyses by age (under 65 years old and over 65 years old) and gender in the multiple linear regression analyses evaluating ABP–HBP differences.

All statistical analyses were performed with R software, ver. 4.2.2 (The R Foundation for Statistical Computing, Vienna, Austria). Two-sided *p*-values <0.05 were defined as statistically significant.

Results

Of the 771 participants in the BP-Eth study, 179 participants were excluded due to insufficient data, leaving an eligible sample of 592 participants (266 White British, 157 South Asian, and 169 African Caribbean) (Supplementary Fig. S1). Of the 4 310 participants in the J-HOP study, 1 465 participants performed 24-hour ABPM. We excluded 58 participants with insufficient data as well as 591 participants for whom the temporal difference between ABPM and HBPM exceeded 28 days, leaving a total of 816 participants who were eligible from the J-HOP study (Supplementary Fig. S2). Among these 816 participants, 655 (80.3%) underwent HBPM before ABPM. The mean difference between the days on which ABPM and HBPM were started was 14.9±7.6 days. For the present analysis, a total of 1 408 participants (mean age 62.1±11.1 years, 48.6% males, 78.9% known hypertensive) across both studies were included.

Table 1 shows the characteristics of study participants. Japanese participants were older, had a lower BMI, a lower prevalence of alcohol intake, and a higher prevalence of hypertension and CKD compared to other ethnicity groups. South Asian and Japanese participants had a higher prevalence of diabetes mellitus compared to White British and African Caribbean participants.

Compared to White British, Japanese participants showed higher office SBP and daytime ABP and lower home DBP (Table 2). African Caribbean participants showed higher daytime ambulatory DBP and home DBP compared to White British participants, but those differences were not clinically significant. Home SBP and office DBP levels among all other ethnic groups were similar.

Figure 1 shows Bland–Altman plots presenting the difference between daytime ABP and HBP values, along with the plots of both means. DBP showed less variation than SBP. BP levels in other than Japanese participants were slightly higher for HBP than daytime ABP, while daytime ambulatory DBP was higher than home DBP in Japanese participants. Bland–Altman plots showed very wide 95% limits of agreement for all ethnic groups. Japanese participants showed an especially wider 95% limit of agreement in comparison to other ethnic groups, suggesting a lower measurement accuracy.

In regression coefficient plots, Japanese ethnicity was associated with higher daytime ABP than HBP when White British was set as a reference (Fig. 2). Alcohol intake was also associated with higher daytime ABP. Higher age and prevalence of CKD were associated with higher home SBP. Higher BMI and prevalence of dyslipidemia were associated with higher home DBP.

Comparing White British and Japanese participants, the differences seen between morning HBP and both office BP and daytime ABP were much smaller than the equivalent differences between evening HBP and office or ABP measurements (Supplementary Table S1).

Figure 3 shows the distribution of daytime ABP and HBP values. Across all ethnic groups, the proportions of participants with definite diagnostic disagreement were much lower than the proportions of those with diagnostic disagreement (Table 3), indicating that the majority of discrepancies between daytime ABP and HBP were observed close to the BP thresholds. Notably, Japanese participants showed a higher percentage of diagnostic disagreement in SBP compared to African Caribbean participants (33.2% vs. 20.7%, p=0.006). Moreover, Japanese participants demonstrated a higher percentage of definite diagnostic disagreement in SBP compared to White British (9.3% vs. 4.5%, p=0.040) and African Caribbean participants (9.3% vs. 3.0%, p=0.018) (Table 3).

In the age stratified analyses, there was a significant interaction between age group and Japanese ethnicity in the SBP difference between ABP and HBP measurements (p=0.006). Additionally, there was a significant interaction between gender and Japanese ethnicity in the DBP difference between ABP and HBP measurements (p<0.001) (Supplementary Fig. S3-S6).

Discussion

Main findings

In an observational study conducted in mixed settings of general practice and hospital-based populations, we evaluated OBP, daytime ABP and HBP to assess the ethnic differences in any disparities between out-of-office BP levels, using data from the UK and Japan. We demonstrated that Japanese participants had higher mean daytime ABP than mean HBP compared to White British participants. A key reason for this difference appeared to be the differences seen between the two populations in HBP measured in the evening, where HBP readings in the Japanese participants were lower. Moreover, Japanese participants showed a higher proportion of diagnostic discrepancy for hypertension between ABP and HBP compared to other ethnic groups. Complementary use of ABP and HBP monitoring may be more beneficial for assessing CVD risk in Japanese participants compared to other ethnic groups.

Comparison with previous literature

This is the first study to demonstrate that ethnic differences exist in the BP values obtained from daytime ABPM and HBPM. Although there was no significant difference in home SBP levels among the four each ethnic groups studied, Japanese participants showed higher daytime ABP levels compared to White British participants. Only a few studies have directly compared ABP and HBP values, and their results have been inconsistent. Stergiou et al. showed that there were no significant differences between daytime ABP and HBP in Greek untreated hypertensive patients (n=133, mean age 48.4±10.2 years, 54.9% male).[22] In a mixture of European treated and untreated hypertensive patients which included the current BP-Eth dataset (n=1 971, mean age 53.8±11.4 years, 52.6% male), daytime ambulatory SBP was slightly but significantly higher than home SBP by

1.4±10.8 mmHg. On the other hand, the TEST-BP trial, which was a randomized controlled trial conducted in the UK (n=80, mean age 74.1±10.3 years, 66.3% male, all with hypertension), showed that daytime ambulatory SBP values were consistently 6.6 mmHg and 7.1 mmHg lower than home SBP values in two sets of ABPM and HBPM conducted on two different occasions.[23] The Ohasama study demonstrated that daytime ambulatory SBP was 6–7 mmHg higher than home SBP (n=1 007, mean age 66.3±5.8 years, 32.6% male),[24] which supports the results seen in Japanese people in the present study. One possible mechanism that could explain the greater disparity between daytime ABP and daytime HBP in Japanese participants compared to White British participants is high-salt sensitivity: East Asian individuals are known to have a higher salt intake than West Europeans.[25] Chronic high salt intake may lead to increased sympathetic nervous activity, resulting in high BP levels during working hours.[26] This pathophysiology may explain why Japanese had a greater limit of agreement than other ethnic groups in the present Bland–Altman analysis (Fig. 1).

The different timing of evening HBP measurements may also affect the ethnic difference of daytime ABP and HBP levels. Unlike European hypertension guidelines, which do not specify the precise timing of evening BP measurement,[2,18] the Japanese hypertension guideline recommends that evening BP should be measured just before bedtime.[3] However, BPs measured at bedtime may be affected by various life style factors, such as bathing and alcohol consumption, resulting in lower evening BP levels compared to BPs measured before dinner.[27] This might explain our findings that the differences between OBP and evening HBP and between daytime ABP and evening HBP were much larger in Japanese participants compared to White British. Other possible confounders, such as job strain, psychological stress, sedentary lifestyle, temperature, and greater diurnal BP variability could also have contributed to the ethnic difference of daytime ABP and HBP levels.[28-31]

In the present study, Japanese participants showed lower home DBP levels compared to other ethnic groups. Some potential mechanisms could explain this phenomenon. First, Japanese participants of this study had a history of CVD or risk factors, or both, and might have had increased aortic stiffness. In addition, such a population might have had a higher proportion of participants with impaired cardiac function and, consequently, lower DBP levels. Secondly, a higher proportion of Japanese participants were hypertensive and used antihypertensive medications, which could have resulted in lower home DBP. Thirdly, the BP–lowering effects of bathing and alcohol consumption have been reported to last longer for DBP than for SBP in evening HBP measurements,[27] which might have resulted in lower home DBP compared to daytime ambulatory DBP.

In the present study, the participants reporting alcohol intake showed higher daytime ABP than HBP. This supports the thesis that alcohol consumption has biphasic effects on BP levels; i.e., an early acute depressor effect in the evening and a pressor effect in the daytime after its consumption.[32] In addition, drinking during the daytime may also have affected evening HBP levels. Our findings that older age and higher BMI were associated with greater ABP–HBP disparity were consistent with previously reported findings.[33]

Our findings that CKD was associated with greater ABP–HBP disparity was also in line with a previous study.[34] Evidence suggests that CKD patients tend to have elevated BP during nighttime and morning hours.[35] In this context, we should note that Japanese participants in our study exhibited higher morning home SBP than participants from other ethnic groups, which may have influenced the observed ABP–HBP differences.

Furthermore, autonomic dysfunction, which is commonly seen in CKD patients,[36] may have interacted with the BP–lowering effects induced by bathing, thereby affecting the evening BP reduction observed in the Japanese participants. The higher prevalence of CKD, along with significant BP variability,[37] could also explain why the Bland–Altman analysis showed a wider limit of agreement for the Japanese participants compared to other ethnic groups.

Our analysis revealed a significant interaction between Japanese ethnicity and the variables of age and gender in relation to ABP–HBP differences. Specifically, the systolic ABP–HBP differences were larger in Japanese participants under 65 years old compared to those over 65 years old. Additionally, the diastolic ABP–HBP differences were larger in Japanese male participants compared to Japanese female participants.

These results can be attributed to several factors. For participants under 65 years old, the findings of elevated ambulatory SBP compared to home SBP may be explained by greater physical activity and environmental stress during daily routines, which are captured more effectively by ABPM. In contrast, HBPM is typically performed in a more controlled and relaxed setting, likely leading to lower BP measurements. Younger adults are generally more active throughout the day, which could contribute to the higher ambulatory SBP observed.

For males, the findings of higher ambulatory DBP compared to home DBP could potentially be explained by differences in daily activity patterns or physiological responses during ABPM. While specific data on work-related stress or physical exertion by gender were not directly assessed in this study, prior research suggests that individual variations in stress response, activity levels, and autonomic regulation could influence ABP measurements.[38] The observed interaction effect between gender and the diastolic ABP–HBP differences may reflect underlying physiological or behavioral differences, the impact of which will require further investigation in future studies.

Strengths and limitations

Strengths of this study include the collections of daytime ABP and HBP data following standardized protocols from four ethnic groups. In addition, the out-of-office BP values assessed in this study were reliable as they were automatically stored in the memory of the device itself. However, there are some limitations. First, the number of participants in each ethnic group was small, which would affect the power to assess ethnic differences between ABP and HBP levels. Second, although all BP devices used in the present study had been previously validated and found to be accurate,[14-17,19] we could not eliminate the impact of the differences in BP measurement devices between the BP-Eth and J-HOP studies, which might have contributed to the variations in each BP parameter. Third, the definition of hypertension was different between the two studies. However, despite this difference in hypertension definitions, home SBP levels were similar among the four ethnic groups in our study. Fourth, the definitions of daytime were different between the two studies. The BP-Eth study might have included participants who had periods of sleep during the day, which could have affected ABP levels. Fifth, data regarding antihypertensive medication use among study participants were not available for this analysis. This limitation could affect the generalizability and validity of the findings. Additionally, data regarding the use of medications that may affect the efficacy of antihypertensive medications, such as glucocorticoids or non-steroidal anti-inflammatory drugs (NSAIDs),[18] were not collected. Sixth, we did not obtain information on CVD, such as heart failure or peripheral artery disease, which could potentially influence daily activity patterns.[39,40] Seventh, our analysis did not evaluate whether ethnic differences in social factors or those in intrinsic biological characteristics were more strongly related to the ethnic differences observed between ABP and HBP levels. Finally, we were unable to adjust for differences in socioeconomic status, access to healthcare, education, and lifestyle that might influence the difference between ABP and HBP levels,[10] as such information was not available in the database used in this study. Further studies incorporating comprehensive socioeconomic data are needed to better understand and interpret the differences observed across ethnic groups.

Conclusion

We demonstrated that Japanese participants showed greater disparity between ABP and HBP compared to White British participants in a clinical patient population. Complementary use of ABP and HBP monitoring may be more beneficial for assessing CVD risk in Japanese participants compared to other ethnic groups.

Summary Table

What is known about the topic

・The management of hypertension using out-of-office blood pressure (BP) monitoring, including ambulatory BP (ABP) monitoring and home BP (HBP) monitoring, is essential to achieve optimal BP control and to judge the effectiveness of antihypertensive treatment in clinical practice.

・There are ethnic differences in the prevalence and control of hypertension.

What this study adds

・Japanese participants showed greater disparity between ABP and HBP compared to White British participants.

・Japanese participants showed a higher proportion of discrepancy between ABP- and HBP-based diagnosis of hypertension compared to other ethnic groups.

Data Availability Statement

The datasets generated during and/or analysed during the current study are not publicly available due to privacy and confidentiality concerns but are available from the corresponding author on reasonable request.

References

1. Ettehad D, Emdin CA, Kiran A, Anderson SG, Callender T, Emberson J, et al. Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *Lancet.* 2016;387:957-967.

2. National Institute for Health and Care Excellence. Hypertension in adults: diagnosis and management. NICE guideline Published: 28 August 2019 Last updated: 21 November 2023. https://www.nice.org.uk/guidance/ng136. Accessed March 2024.

3. Umemura S, Arima H, Arima S, Asayama K, Dohi Y, Hirooka Y, et al. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH 2019). *Hypertens Res.* 2019;42:1235-1481.

4. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. *Lancet.* 2021;398:957-980.

5. NHS England. Health Survey England Additional Analyses, Ethnicity and Health, 2011-2019 Experimental statistics. https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-england-additional-analyses/ethnicity-and-health-2011-2019-experimental-statistics#. Accessed March 2024.

6. George J, Mathur R, Shah AD, Pujades-Rodriguez M, Denaxas S, Smeeth L, et al. Ethnicity and the first diagnosis of a wide range of cardiovascular diseases: Associations in a linked electronic health record cohort of 1 million patients. *PLoS One.* 2017;12:e0178945.

7. Kim AS, Cahill E, Cheng NT. Global stroke belt: geograohic variation in stroke burden worldwide. *Stroke.* 2015;46:3564-3570.

8. Steg PG, Bhatt DL, Wilson PW, D'Agostino R Sr, Ohman EM, Röther J, et al. One-year cardiovascular event rates in outpatients with atherothrombosis. *JAMA.* 2007;297:1197-1206.

9. Okada Y, Jarvis SS, Best SA, Edwards JG, Hendrix JM, Adams-Huet B, et al. Sympathetic neural and hemodynamic responses during cold pressor test in elderly Blacks and Whites. *Hypertension.* 2016;67:951-958.

10. van Laer SD, Snijder MB, Agyemang C, Peters RJ, van den Born BH. Ethnic differences in hypertension prevalence and contributing determinants - the HELIUS study. *Eur J Prev Cardiol.* 2018;25:1914-1922.

11. McKenzie K, Crowcroft N. Ethnicity, race, and culture: guidelines for research, audit, and publication. *BMJ.* 1996;312:1094.

12. Gill P, Haque MS, Martin U, Mant J, Mohammed MA, Heer G, et al. Measurement

of blood pressure for the diagnosis and management of hypertension in different ethnic groups: one size fits all. *BMC Cardiovasc Disord.* 2017;17:55.

13. Hoshide S, Yano Y, Haimoto H, Yamagiwa K, Uchiba K, Nagasaka S, et al. Morning and evening home blood pressure and risks of incident stroke and coronary artery disease in the Japanese general practice population: the Japan Morning Surge-Home Blood Pressure study. *Hypertension.* 2016;68:54-61.

14. Wright JM, Mattu GS, Perry Jr. TL, Gelferc ME, Strange KD, Zorn A, et al. Validation of a new algorithm for the BPM-100 electronic oscillometric office blood pressure monitor. *Blood Press Monit.* 2001;6:161-165.

15. Anwar YA, Giacco S, McCabe EJ, Tendler BE, White WB. Evaluation of the efficacy of the Omron HEM-737 IntelliSense device for use on adults according to the recommendations of the Association for the Advancement of Medical Instrumentation. *Blood Press Monit.* 1998;3:261-265.

16. Baumgart P, Kamp J. Accuracy of the SpaceLabs Medical 90217 ambulatory blood pressure monitor. *Blood Press Monit.* 1998;3:303-307.

17. Imai Y, Sasaki S, Minami N, Munakata M, Hashimoto J, Sakuma H, et al. The accuracy and performance of the A&D TM 2421, a new ambulatory blood pressure monitoring device based on the cuff-oscillometric method and the Korotkoff sound

technique. *Am J Hypertens.* 1992;5:719-726.

18. Mancia G, Kreutz R, Brunstrom M, Burnier M, Grassi G, Januszewicz A, et al. 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). *J Hypertens.* 2023;41:1874-2071.

19. Stergiou GS, Giovas PP, Gkinos CP, Patouras JD. Validation of the Microlife WatchBP Home device for self home blood pressure measurement according to the International Protocol. *Blood Press Monit.* 2007;12:185-188.

20. Kyriakoulis KG, Ntineri A, Niiranen TJ, Lindroos A, Jula A, Schwartz C, et al. Home blood pressure monitoring schedule: optimal and minimum based on 2122 individual participants' data. *J Hypertens.* 2022;40:1380-1387.

21. D'Agostino Sr RB, Vasan RS, Pencina MJ, Wolf PA, Cobain M, Massaro JM, et al. General cardiovascular risk profile for use in primary care: the Framingham Heart Study. *Circulation.* 2008;117:743-753.

22. Stergiou GS, Skeva II, Baibas NM, Kalkana CB, Roussias LG, Mountokalakis TD. Diagnosis of hypertension using home or ambulatory blood pressure monitoring: comparison with the conventional strategy based on repeated clinic blood pressure

measurements. *J Hypertens.* 2000;18:1745-1751.

23. Davison WJ, Myint PK, Clark AB, Potter JF. Blood pressure differences between home monitoring and daytime ambulatory values and their reproducibility in treated hypertensive stroke and TIA patients. *Am Heart J.* 2019;207:58-65.

24. Hara A, Tanaka K, Ohkubo T, Kondo T, Kikuya M, Metoki H, et al. Ambulatory versus home versus clinic blood pressure: the association with subclinical cerebrovascular diseases: the Ohasama Study. *Hypertension.* 2012;59:22-28.

25. Powles J, Fahimi S, Micha R, Khatibzadeh S, Shi P, Ezzati M, et al. Global, regional and national sodium intakes in 1990 and 2010: a systematic analysis of 24 h urinary sodium excretion and dietary surveys worldwide. *BMJ Open.* 2013;3:e003733.

26. Pickering TG. The effects of environmental and lifestyle factors on blood pressure and the intermediary role of the sympathetic nervous system. *J Hum Hypertens.* 1997;11 Supple 1:S9-S18.

27. Fujiwara T, Hoshide S, Nishizawa M, Matsuo T, Kario K. Difference in evening home blood pressure between before dinner and at bedtime in Japanese elderly hypertensive patients. *J Clin Hypertens (Greenwich).* 2017;19:731-739.

28. Saeki K, Obayashi K, Iwamoto J, Tone N, Okamoto N, Tomioka K, et al. Stronger association of indoor temperature than outdoor temperature with blood pressure in colder

months. *J Hypertens.* 2014;32:1582-1589.

29. Hattori T, Munakata M. Low job control is associated with higher diastolic blood pressure in men with mildly elevated blood pressure: the Rosai Karoshi study. *Ind Health.* 2015;53:480-488.

30. Kario K, Bhatt DL, Brar S, Bakris GL. Differences in dynamic diurnal blood pressure variability between Japanese and American treatment-resistant hypertensive populations. *Circ J.* 2017;81:1337-1345.

31. Tomitani N, Kanegae H, Kario K. The effect of psychological stress and physical activity on ambulatory blood pressure variability detected by a multisensor ambulatory blood pressure monitoring device. *Hypertens Res.* 2023;46:916-921.

32. Kawano Y. Physio-pathological effects of alcohol on the cardiovascular system: its role in hypertension and cardiovascular disease. *Hypertens Res.* 2010;33:181-191.

33. Ntineri A, Niiranen TJ, McManus RJ, Lindroos A, Jula A, Schwartz C, et al. Ambulatory versus home blood pressure monitoring: frequency and determinants of blood pressure difference and diagnostic disagreement. *J Hypertens.* 2019;37:1974-1981.

34. Andersen MJ, Khawandi W, Agarwal R. Home blood pressure monitoring in CKD. *Am J Kidney Dis.* 2005;45:994-1001.

35. Liu X, Li F, Zhang T, Zheng Z, Zhou H, Qin A, et al. The Association of Morning

Hypertension With Target Organ Damage in Patients With Chronic Kidney Disease and Hypertension. *Front Cardiovasc Med.* 2021;8:715491.

36. de Oliveira CA, de Brito Junior HL, Bastos MG, de Oliveira FG, Casali TG, Bignoto TC, et al. Depressed cardiac autonomic modulation in patients with chronic kidney disease. *J Bras Nefrol.* 2014;36:155-162.

37. Sarafidis PA, Ruilope LM, Loutradis C, Gorostidi M, de la Sierra A, de la Cruz JJ, et al. Blood pressure variability increases with advancing chronic kidney disease stage: a cross-sectional analysis of 16 546 hypertensive patients. *J Hypertens.* 2018;36:1076-1085.

38. Landsbergis PA, Dobson M, Koutsouras G, Schnall P. Job strain and ambulatory blood pressure: a meta-analysis and systematic review. *Am J Public Health.* 2013;103:e61-71.

39. Gorodeski EZ, Goyal P, Hummel SL, Krishnaswami A, Goodlin SJ, Hart LL, et al. Domain Management Approach to Heart Failure in the Geriatric Patient: Present and Future. *J Am Coll Cardiol.* 2018;71:1921-36.

40. Bonaca MP, Hamburg NM, Creager MA. Contemporary Medical Management of Peripheral Artery Disease. *Circ Res.* 2021;128:1868-84.

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Author Contributions

Conceptualization: TF, CK, RM.

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Ethical Approval

Ethical approval of the BP-Eth study has been obtained from the Black Country Research Ethics Committee: Ref 09/H1202/ 114. Ethical approval of the J-HOP study has been obtained from the Institutional Review Board of Jichi Medical School.

Competing Interests

The authors state that they have no potential competing interests for this work.

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Figure Legends

Fig. 1 Bland–Altman plots comparing daytime ambulatory blood pressure and home blood pressure values.

Data are expressed as the mean difference between daytime ambulatory BP and daytime home BP values ± 1.96 × SD. The mean difference and the upper and lower limit of agreement are shown as dashed lines, and their 95% confidence intervals are shown as dotted lines. BP indicates blood pressure; SD, standard deviation.

Fig. 2 Regression coefficient plot showing predictors of daytime ambulatory and home blood pressure difference.

This plot indicates the estimates for each effect in the model, with lines that indicate the width of the 95% confidence interval for the parameters. Variables whose confidence intervals intersect the reference line at 0 are not significant. BMI indicates body mass index; BP, blood pressure; CKD, chronic kidney disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Fig. 3 Scatter plots showing the distribution of daytime ambulatory blood pressure and home blood pressure values.

Daytime ambulatory BP and daytime home BP levels for each participant are plotted as gray or black circles. Black circles in gray zones indicate participants with definite diagnostic disagreement. The diagnostic thresholds of daytime ambulatory BP and home BP are shown as dashed lines at 135 mmHg for systolic BP and at 85 mmHg for diastolic BP, respectively. ABP indicates ambulatory blood pressure; BP, blood pressure; HBP, home blood pressure.

Table 1. Characteristics of the study population (n=1,408).

	White British (n=266)	South Asian (n=157)	African Caribbean (n=169)	Japanese (n=816)
Descriptive variables				
Age, years	62.2±8.6	57.5±9.3*	56.9±9.6*	64.0±11.9†,‡
Male, n (%)	133 (50.0)	90 (57.3)	66 (39.1)†	395 (48.4)
Body mass index, kg/m^2	29.8±5.5	28.3±4.0*	30.7±6.0†	24.5±3.6*,†,‡
Smoking, n (%)	46 (17.3)	6 (3.8)*	24 (14.2)†	104 (12.7)†
Alcohol intake, n (%)	164 (61.7)	40 (25.5)*	69 (40.8)*,†	171 (21.0)*,‡
Hypertension, n (%)	162 (60.9)	95 (60.5)	111 (65.7)	743 (91.1)*,†,‡
Dyslipidemia, n (%)	93 (35.0)	65 (41.4)	41 (24.3)†	264 (32.4)
Diabetes mellitus, n (%)	29 (10.9)	41 (26.1)*	26 (15.4)	229 (28.1)*,‡
Chronic kidney disease, n (%)	19 (7.1)	5 (3.2)	19 (11.2)	198 (24.3)*,†,‡
History of CVD, n (%)	55 (20.7)	23 (14.6)	16 (9.5)*	127 (15.6)
Blood pressure parameters, mmHg				
Office SBP	129.3±16.1	125.7±14.8	128.9±14.8	138.8±16.0*,†,‡
Office DBP	79.0±9.5	79.5±8.2	82.1±9.0*	79.7±11.2‡
Daytime ambulatory SBP	132.6±14.0	130.2±14.7	132.6±14.3	135.6±13.8*,†,‡
Daytime ambulatory DBP	78.3±9.0	79.9±8.7	81.6±9.1*	80.4±10.0*
Morning-evening mean home SBP	134.2±12.8	132.0±13.2	134.1±12.9	135.3±14.0†
Morning-evening mean home DBP	79.9±8.8	81.7±7.5	83.6±8.5*	76.1±10.0*,†,‡
Morning home SBP	135.2±14.0	131.2±13.4*	134.9±14.0	141.1±15.9*,†,‡
Morning home DBP	81.0±9.6	81.8±7.7	84.7±8.9*,†	80.0±10.9‡
Evening home SBP	134.2±13.3	133.3±14.0	134.4±13.1	132.5±15.8
Evening home DBP	79.1±8.6	82.2±7.9*	83.0±8.9*	73.4±10.5*,†,‡

Data are expressed as means±SD or number (percentage). Characteristics of study participants were compared by one-way analysis of variance or chi-square test. To compare characteristics among the four ethnic groups, we used the Tukey–Kramer Honestly Significant Difference (HSD) test for multiple comparisons. CVD indicates cardiovascular disease; DBP, diastolic blood pressure; SBP, systolic blood pressure. Statistical significance was defined as $P<0.05$. *$P<0.05$ vs. White British; †$P<0.05$ vs. South Asian; ‡$P<0.05$ vs. African Caribbean.

Table 2. Differences in blood pressure values of each ethnic group against those of White British participants.

	White British (n=266)	South Asian (n=157)	African Caribbean (n=169)	Japanese (n=816)
Systolic blood pressure, mmHg				
Office SBP				
Model 1	0 (reference)	–2.59 (–5.71 to 0.54)	0.29 (–2.76 to 3.34)	10.47 (8.09 to 12.85)‡
Model 2	0 (reference)	–1.92 (–5.13 to 1.30)	–0.16 (–3.20 to 2.88)	8.65 (5.96 to 11.34)‡
Daytime ambulatory SBP				
Model 1	0 (reference)	–2.53 (–5.31 to 0.25)	–0.45 (–3.16 to 2.27)	4.26 (2.15 to 6.38)‡
Model 2	0 (reference)	–1.90 (–4.78 to 0.98)	–0.76 (–3.48 to 1.96)	3.13 (0.73 to 5.54)*
Home SBP				
Model 1	0 (reference)	–0.82 (–3.47 to 1.84)	0.98 (–1.62 to 3.57)	2.67 (0.65 to 4.69)†
Model 2	0 (reference)	–0.97 (–3.71 to 1.76)	0.13 (–2.46 to 2.71)	– 0.07 (–2.35 to 2.22)
Diastolic blood pressure, mmHg				
Office DBP				
Model 1	0 (reference)	–1.27 (–3.15 to 0.61)	1.25 (–0.58 to 3.09)	1.95 (0.52 to 3.38)†
Model 2	0 (reference)	–0.65 (–2.58 to 1.27)	1.11 (–0.71 to 2.93)	1.54 (–0.07 to 3.15)
Daytime ambulatory DBP				
Model 1	0 (reference)	–0.36 (–2.10 to 1.38)	2.04 (0.34 to 3.74)*	2.27 (0.95 to 3.60)‡
Model 2	0 (reference)	0.56 (–1.24 to 2.35)	1.92 (0.22 to 3.61)*	2.09 (0.58 to 3.59)†
Home DBP				
Model 1	0 (reference)	0.37 (–1.35 to 2.08)	2.32 (0.65 to 4.00)†	–2.45 (–3.75 to –1.14)‡
Model 2	0 (reference)	0.53 (–1.25 to 2.30)	1.90 (0.23 to 3.58)*	–3.60 (–5.08 to –2.11)‡

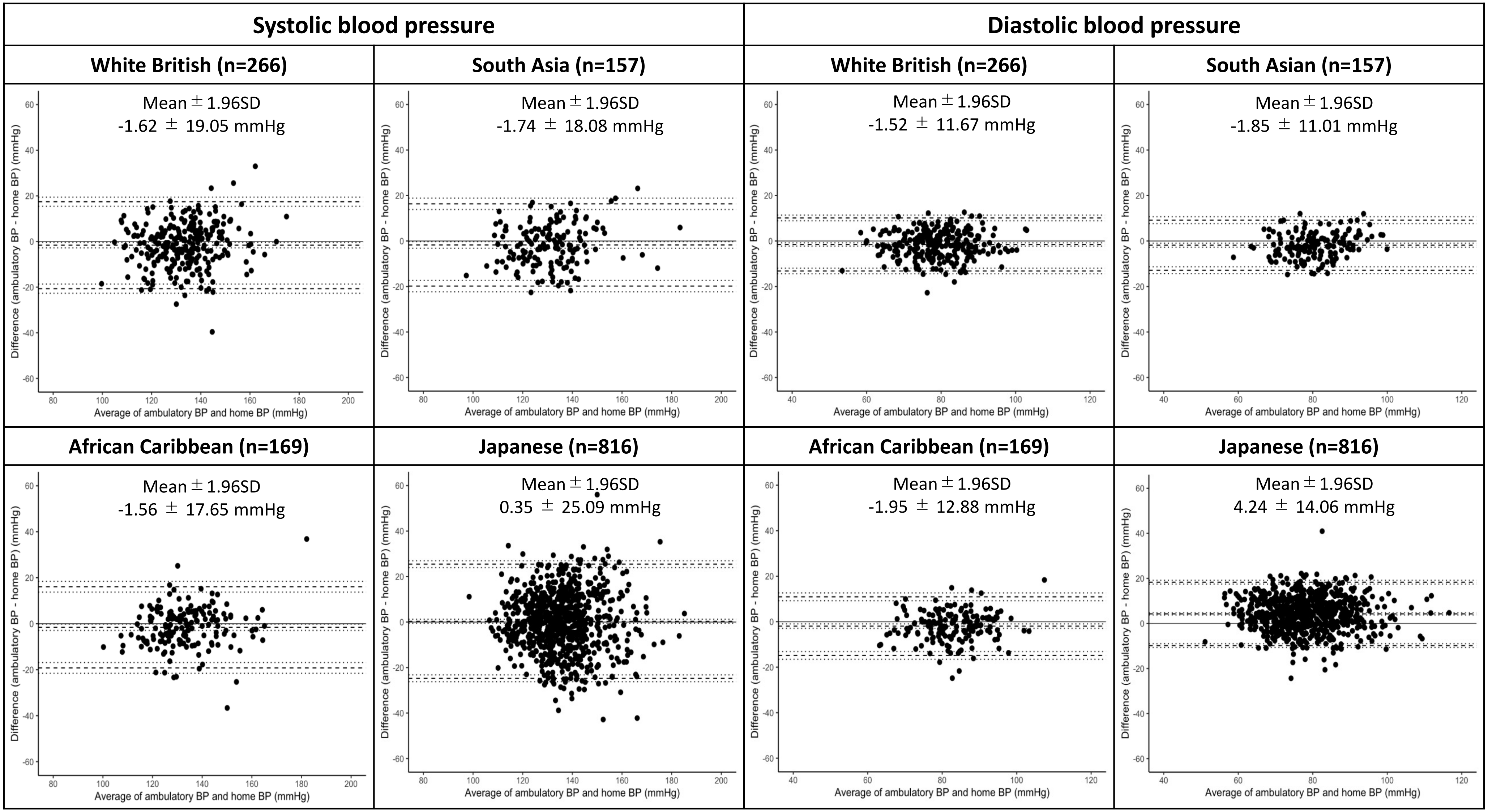
Linear regression analysis was used to assess differences in blood pressure values for each ethnic group against the values in White British participants. Regression coefficients (95% confidence intervals) are presented for each model. The morning-evening mean blood pressure value was used for home blood pressure. Model 1 was adjusted for age, sex, and BMI. Model 2 was adjusted for age, sex, BMI, smoking status, alcohol intake, prevalence of hypertension, prevalence of dyslipidemia, prevalence of diabetes mellitus, prevalence of chronic kidney disease, and history of CVD. BMI indicates body mass index; CVD, cardiovascular disease; DBP, diastolic blood pressure; SBP, systolic blood pressure. Statistical significance was defined as

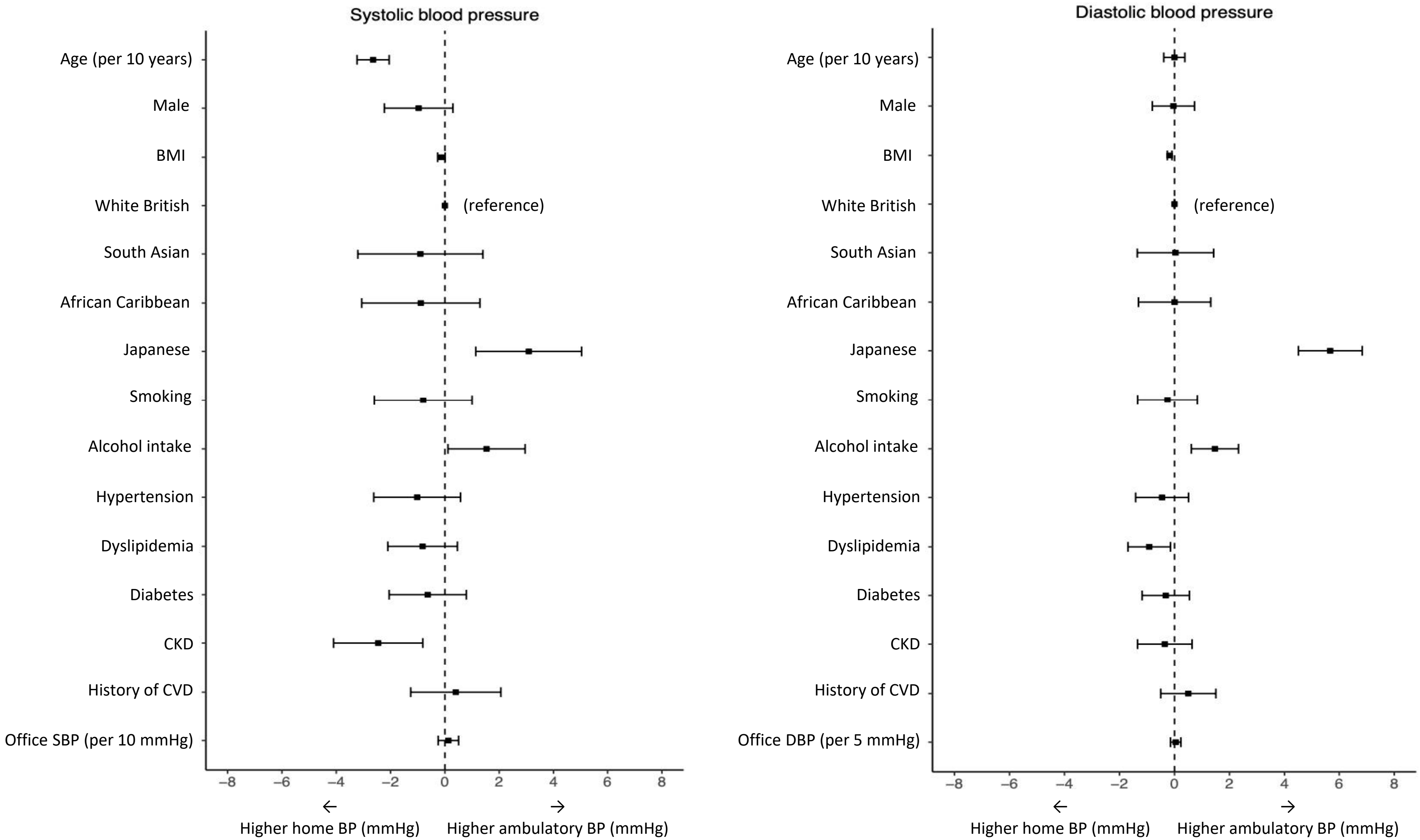
$P<0.05$. * $P<0.05$, † $P<0.01$, ‡ $P<0.001$, all vs. White British.

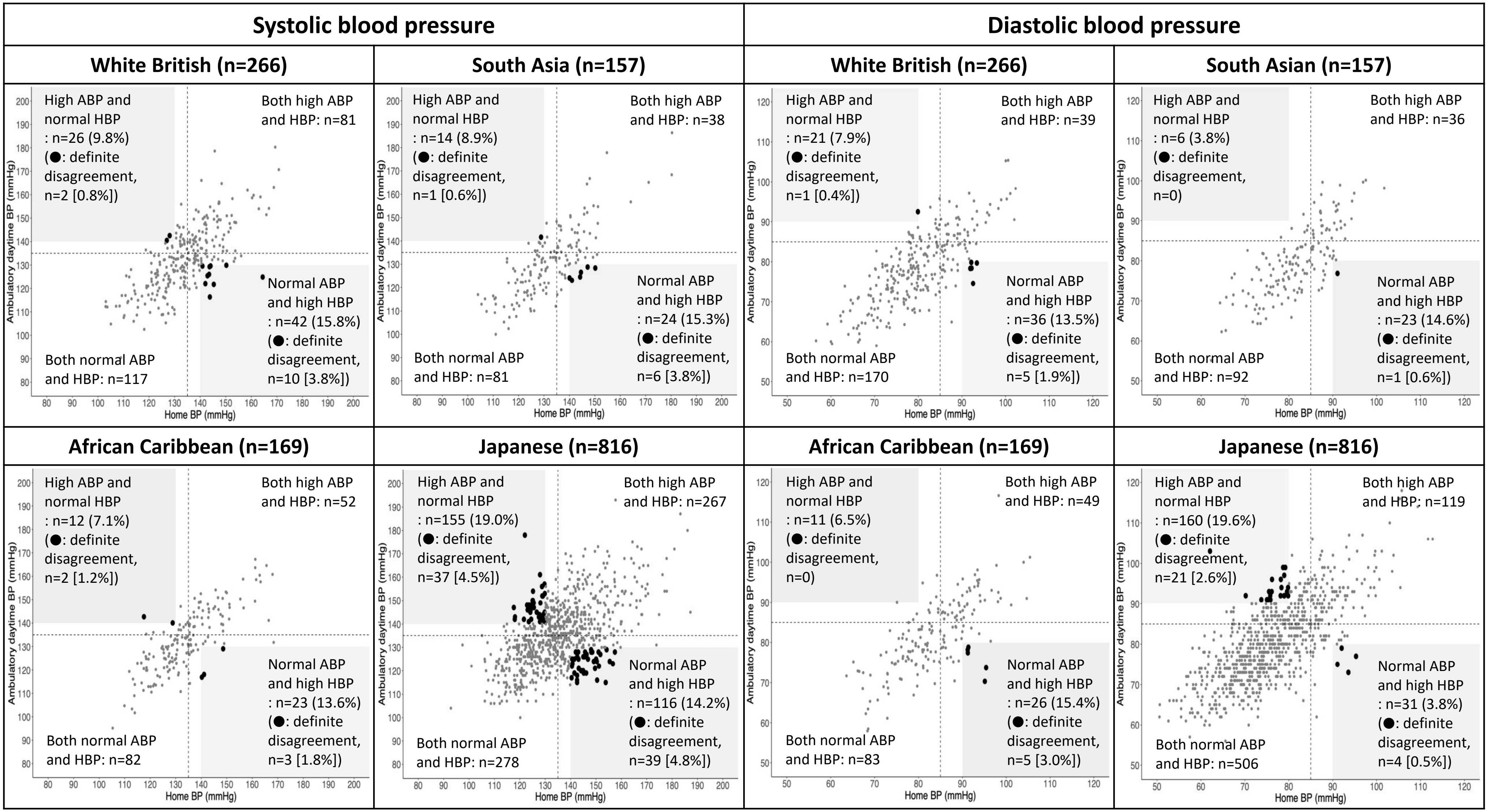
Table 3. Case exhibiting diagnostic disagreement in each ethnic group.

	White British (n=266)	South Asian (n=157)	African Caribbean (n=169)	Japanese (n=816)	*P* value
SBP, diagnostic disagreement					
	68 (25.6)	38 (24.2)	35 (20.7)	271 (33.2)[‡]	0.001
SBP, definite diagnostic disagreement					
	12 (4.5)	7 (4.5)	5 (3.0)	76 (9.3)[*,‡]	0.002
DBP, diagnostic disagreement					
	57 (21.4)	29 (18.5)	37 (21.9)	191 (23.4)	0.565
DBP, definite diagnostic disagreement					
	6 (2.3)	1 (0.6)	5 (3.0)	25 (3.1)	0.354

Data are expressed as number (percentage). Definite diagnostic disagreement was defined as diagnostic disagreement excluding cases with daytime ambulatory BP and/or home BP differing by ≤5 mmHg from their diagnostic thresholds (135 mmHg for SBP and 85 mmHg for DBP). The percentages of participants who showed diagnostic disagreement and definite diagnostic disagreement were compared by chi-square test. To compare differences among the four ethnic groups, we used the Tukey-Kramer Honestly Significant Difference (HSD) test for multiple comparisons. BP indicates blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure. Statistical significance was defined as $P<0.05$. [*]$P<0.05$ vs. White British; [†]$P<0.05$ vs. South Asian; [‡]$P<0.05$ vs. African Caribbean.


Systolic blood pressure
Diastolic blood pressure
White British (n=266)
South Asia (n=157)
White British (n=266)
South Asian (n=157)
Mean ± 1.96SD
-1.62 ± 19.05 mmHg
Mean ± 1.96SD
-1.74 ± 18.08 mmHg
Mean ± 1.96SD
-1.52 ± 11.67 mmHg
Mean ± 1.96SD
-1.85 ± 11.01 mmHg
African Caribbean (n=169)
Japanese (n=816)
African Caribbean (n=169)
Japanese (n=816)
Mean ± 1.96SD
-1.56 ± 17.65 mmHg
Mean ± 1.96SD
0.35 ± 25.09 mmHg
Mean ± 1.96SD
-1.95 ± 12.88 mmHg
Mean ± 1.96SD
4.24 ± 14.06 mmHg
Difference (ambulatory BP - home BP) (mmHg)
Average of ambulatory BP and home BP (mmHg)


Systolic blood pressure
Age (per 10 years)
Male
BMI
White British
(reference)
South Asian
African Caribbean
Japanese
Smoking
Alcohol intake
Hypertension
Dyslipidemia
Diabetes
CKD
History of CVD
Office SBP (per 10 mmHg)
−8
−6
−4
−2
0
2
4
6
8
Higher home BP (mmHg)
Higher ambulatory BP (mmHg)
Diastolic blood pressure
Age (per 10 years)
Male
BMI
White British
(reference)
South Asian
African Caribbean
Japanese
Smoking
Alcohol intake
Hypertension
Dyslipidemia
Diabetes
CKD
History of CVD
Office DBP (per 5 mmHg)
−8
−6
−4
−2
0
2
4
6
8
Higher home BP (mmHg)
Higher ambulatory BP (mmHg)



Systolic blood pressure
Diastolic blood pressure
White British (n=266)
High ABP and normal HBP : n=26 (9.8%) (●: definite disagreement, n=2 [0.8%])
Both high ABP and HBP: n=81
Normal ABP and high HBP : n=42 (15.8%) (●: definite disagreement, n=10 [3.8%])
Both normal ABP and HBP: n=117
South Asia (n=157)
High ABP and normal HBP : n=14 (8.9%) (●: definite disagreement, n=1 [0.6%])
Both high ABP and HBP: n=38
Normal ABP and high HBP : n=24 (15.3%) (●: definite disagreement, n=6 [3.8%])
Both normal ABP and HBP: n=81
White British (n=266)
High ABP and normal HBP : n=21 (7.9%) (●: definite disagreement, n=1 [0.4%])
Both high ABP and HBP: n=39
Normal ABP and high HBP : n=36 (13.5%) (●: definite disagreement, n=5 [1.9%])
Both normal ABP and HBP: n=170
South Asian (n=157)
High ABP and normal HBP : n=6 (3.8%) (●: definite disagreement, n=0)
Both high ABP and HBP: n=36
Normal ABP and high HBP : n=23 (14.6%) (●: definite disagreement, n=1 [0.6%])
Both normal ABP and HBP: n=92
African Caribbean (n=169)
High ABP and normal HBP : n=12 (7.1%) (●: definite disagreement, n=2 [1.2%])
Both high ABP and HBP: n=52
Normal ABP and high HBP : n=23 (13.6%) (●: definite disagreement, n=3 [1.8%])
Both normal ABP and HBP: n=82
Japanese (n=816)
High ABP and normal HBP : n=155 (19.0%) (●: definite disagreement, n=37 [4.5%])
Both high ABP and HBP: n=267
Normal ABP and high HBP : n=116 (14.2%) (●: definite disagreement, n=39 [4.8%])
Both normal ABP and HBP: n=278
African Caribbean (n=169)
High ABP and normal HBP : n=11 (6.5%) (●: definite disagreement, n=0)
Both high ABP and HBP: n=49
Normal ABP and high HBP : n=26 (15.4%) (●: definite disagreement, n=5 [3.0%])
Both normal ABP and HBP: n=83
Japanese (n=816)
High ABP and normal HBP : n=160 (19.6%) (●: definite disagreement, n=21 [2.6%])
Both high ABP and HBP: n=119
Normal ABP and high HBP : n=31 (3.8%) (●: definite disagreement, n=4 [0.5%])
Both normal ABP and HBP: n=506
Ambulatory daytime BP (mmHg)
Home BP (mmHg)