May Measurement Month 2019

The Global Blood Pressure Screening Campaign of the International Society of Hypertension

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See Editorial, pp 318–320

Abstract—Elevated blood pressure remains the single biggest risk factor contributing to the global burden of disease and mortality. May Measurement Month is an annual global screening campaign aiming to improve awareness of blood pressure at the individual and population level. Adults (≥18 years) recruited through opportunistic sampling were screened at sites in 92 countries during May 2019. Ideally, 3 blood pressure readings were measured for each participant, and data on lifestyle factors and comorbidities were collected. Hypertension was defined as a systolic blood pressure ≥140 mm Hg, or a diastolic blood pressure ≥90 mm Hg (mean of the second and third readings) or taking antihypertensive medication. When necessary, multiple imputation was used to estimate participants' mean blood pressure. Mixed-effects models were used to evaluate associations between blood pressure and participant characteristics. Of 1 508 130 screenees 482 273 (32.0%) had never had a blood pressure measurement before and 513 337 (34.0%) had hypertension, of whom 58.7% were aware, and 54.7% were on antihypertensive medication. Of those on medication, 57.8% were controlled to <140/90 mm Hg, and 28.9% to <130/80 mm Hg. Of all those with hypertension, 31.7% were controlled to <140/90 mm Hg, and 350 825 (23.3%) participants had untreated or inadequately treated hypertension. Of those taking antihypertensive medication, half were taking only a single drug, and 25% reported using aspirin inappropriately. This survey is the largest ever synchronized and standardized contemporary compilation of global blood pressure data. This campaign is

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needed as a temporary substitute for systematic blood pressure screening in many countries worldwide. (***Hypertension*. 2020;76:333-341. DOI: 10.1161/HYPERTENSIONAHA.120.14874.)** • **Data Supplement**

Key Words: adults ■ awareness ■ blood pressure ■ hypertension ■ risk factor ■ screening ■ treatment

Raised blood pressure (BP) remains the biggest single risk factor contributing to the global burden of disease and to global mortality,[1] with an estimate of 10.4 million deaths attributed to raised BP in 2017. This estimate rose from 9.4 million deaths in 2015 reflecting a growing and aging global population.[2] One study which included data on 57 840 hypertensive adults from 17 countries, reported that less than half of those screened who were hypertensive were aware of their condition.[3] A more recent compilation of representative samples screened in the last decade from 12 high-income countries[4] showed about 72% of adults (aged 40–79 years) were aware of their condition. By contrast, data from 44 low and middle-income countries showed only 39.2% of those with hypertension had been diagnosed and only 10.3% had their BPs controlled.[5]

Because of the critical importance of measuring BP to diagnose and, therefore, manage hypertension, a campaign to raise BP awareness, May Measurement Month (MMM), was initiated by the International Society of Hypertension. During May of 2017 and May 2018, over 1.2 and 1.5 million adults, respectively, were screened and in those 2 campaigns combined, over 550 000 adults with untreated or inadequately treated hypertension were identified.[6,7] In light of the clear inadequacies of BP screening and management facilities around the world, MMM provides an inexpensive and pragmatic temporary solution to identifying individuals in need of improved hypertension care, whilst also raising awareness of the importance of BP measurement at the population level. Ultimately, the data generated are intended to inform and persuade governments and health policymakers to improve BP screening and management facilities and thereby reduce the enormous global health burden caused by raised BP.[1]

Methods

Further details of statistical analyses, including imputation and regression do-files, are available from the authors on request.

Study Design

MMM is a cross-sectional survey of any adults (≥18 years) who wished to have their BPs measured at any of the MMM screening sites. These sites were set up by volunteer investigators who followed a common protocol (available on the MMM website: www.maymeasure.com). Ideally, by design, the survey sought out those who had not had their BP measured for at least a year, but no adults were excluded from the study.

Over 100 countries were contacted, mainly via those who had acted as national leaders in MMM17 and MMM18 but also via national societies of hypertension and related conditions. One or more national leaders were appointed in each country and asked to obtain ethical clearance for the study in their country (if required) and to set up a network of volunteer investigators who would, in turn, arrange for as many local MMM screening sites as possible within their country.

Training materials, critically including standardized BP measurement techniques and campaign promotional materials were made available via the MMM website. The campaign was promoted in a wide variety of ways around the world, but usually involved television, radio, the media, and social media and centrally via the International Society of Hypertension and the World Hypertension League. BP machines were made available by the International Society of Hypertension to those sites where insufficient machines were available, thanks to a donation of 20 000 machines in 2017 by OMRON Healthcare (Kyoto, Japan). Those presenting for BP measurement, who gave informed consent to participate, provided data collected on a simple questionnaire, including demography and medical history (See Data Supplement) and where facilities allowed, weight and height were measured and recorded. Where this was not feasible, weight and height were estimated. Body mass index (BMI) was calculated according to the standard definition as the weight in kilograms divided by the square of the height in meters and categorized into underweight (BMI under 18.5 kg/m^2), healthy weight (BMI, 18.5–24.9 kg/m^2), overweight (BMI, 25.0–29.9 kg/m^2), and obese (BMI, ≥30.0 kg/m^2). Written instructions and videos on recommended BP recording techniques are on https://maymeasure.com/get-involved/mmm-toolkits/ and https://maymeasure.com/get-involved/videos/, respectively. In summary, it involved 3 sitting measurements taken at 1-minute intervals after the participant had been seated for 5 minutes, whereas pulse rates were either measured by the BP device or if not, manually between BP readings. Data were entered via a bespoke mobile application available in 8 languages. Where for investigator preference or logistical reasons this application was not used, data were entered on preprepared paper forms and later transferred to spreadsheets or the mobile application.

Hypertension was defined primarily as a systolic BP ≥140 mm Hg or a diastolic BP ≥90 mm Hg [8,9] using the mean of the second and third BP readings or being on treatment with antihypertensive medication(s). Hypertension based on the definition used in the most recent US guidelines[10] (≥130/80 mm Hg) was also evaluated.

Among those receiving antihypertensive medication, controlled BP was primarily defined as a systolic BP of <140 mm Hg and a diastolic BP <90 mm Hg. The proportion on treatment who had BPs <130/80 mm Hg in keeping with currently recommended BP targets[8,10] was also calculated. Treatment resistance was defined as an individual taking 3 medications with an uncontrolled BP or on ≥4 medications. Participants with untreated or uncontrolled hypertension using the primary definitions above were supplied with an evidence-based summary of diet and lifestyle modification advice to lower BP (see Top Ten Tips in the Data Supplement). Advice on further follow-up of their BP and its management, tailored to local conditions and the level of BP, was also provided by the local MMM investigators.

Data Handling and Statistical Analyses

Submitted data were cleaned centrally according to prespecified cleaning criteria including reference ranges for continuous variables (see Data Cleaning Rules in the Data Supplement). Countries submitting fewer than ten screenees were excluded, along with any participant without at least one valid systolic and diastolic BP.

Data were managed using Jupyter Notebook version 6.0.1 and analyzed using Stata version 16.0 (StataCorp 2019). Geographic regions were defined using the United Nations classification with minor modifications to match previous MMM regional analyses and create groupings of comparable size.[11] Data on country income were sourced from the World Bank, based on 2018 estimates of Gross National Income per capita.[12] For age and sex standardization, the World Health

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Organization–derived single-age world-standard population was used, according to the Surveillance, Epidemiology, and End Results (SEER) group, and assuming an equal ratio of females to males.[13]

For those participants missing either the second or third BP measurement (or both), multiple imputation using chained equations was used to estimate the missing mean reading, to provide better comparison across all participants. This assumed missingness was Missing-at-Random and therefore dependent on the observed data only. Two separate imputation models were run: the first, complete imputation model, imputed the missing systolic, and diastolic BP value for only those individuals with fully recorded data on age, sex, ethnicity, use of antihypertensive medication, and where sex was not recorded as other. Also included were all variables included in the subsequent analyses, following guidance from White et al.[14] Variables which were used to compute the variables within the analysis models (such as the individual BP readings used to calculate the mean reading) were also included, following the just another variable approach.[15]

To handle cases missing the second or third BP measurement (or both) and ≥1 of age, sex, ethnicity, or use of antihypertensive medication, a second, reduced imputation model was run, imputing the missing systolic and diastolic BP values based only on the available BP readings. Imputed results from the 2 models were combined, with the imputations from the reduced imputation model used only where the values could not be imputed by the complete imputation model. A total of 25 imputations were created, corresponding to the percentage of missing data in the mean BP readings and aiming for a Monte Carlo error of the estimates at under 10%.[15] A full description of the imputation models and sensitivity analyses can be found in the Data Supplement.

Analysis of measures of association used only those individuals with complete data on age, sex, ethnicity, and use of antihypertensive medication, and imputations performed under the complete imputation model. Linear mixed-effects models were run separately for systolic and diastolic BP, assuming a random intercept model to account for country-level clustering effects. It was decided a priori to adjust for age, sex, and antihypertensive medication, along with an interaction between age and sex, given the known strong effects of these variables on BP. Age, as a continuous variable, was incorporated into models as a restricted cubic spline with 5 knots to allow for flexibility in its relationship with BP.

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Results

Study Participants

Data on 1 521 974 participants were submitted from 92 countries during MMM 2019. After data cleaning, and excluding participants who did not have at least one valid BP reading (see appendix), 1 508 130 participants were included in the study. Of these, 15.8% were submitted via the mobile application. Recording of key demographic factors was improved from the previous year, with 1.0% of participants missing data on age and 0.4% missing data on sex.

Of all screenees, 482 273 (32.0%: 28.4% of women and 35.9% of men) reported never having had a BP measurement taken before. There was moderate negative correlation between the proportion of participants never having had a BP measured within each country and gross national income (r=−0.32, P=0.002).

The majority of screening took place in hospitals or clinics (36.0%), with 25.7% in outdoor public areas, 9.1% in indoor public areas, 8.2% in the workplace, and 3.4% in pharmacies (with 17.6% unrecorded or recorded as other). Of all screenees, 304 101 (20.2%) had participated in either MMM 2017 or MMM 2018 (or both).

There was a wide geographic spread of participants, with the majority screened in South Asia (31.3%), followed by East Asia (18.6%) and the Americas (17.4%; Table 1). Across 7 geographic regions, the distribution of age and sex of screenees varied significantly. The highest mean age (51.2 years) was found in Europe and the lowest mean age (40.8 years) in Sub-Saharan Africa. In Europe, 61.3% of those screened were women, while in South Asia, 43.0% were women. Significant differences were also seen in the proportions of participants on antihypertensive medication, with 30.0% on treatment in South-East Asia and Australasia and only 9.6% on treatment in Sub-Saharan Africa (Table 1 and Table S2 in the Data Supplement).

Globally, 280 958 (18.6%) participants were taking antihypertensive medication, and of the 203 719 with a recorded number of medication classes, 53.1% were taking a single medication, and 33.3%, 9.5%, and 3.2% were taking 2, 3, and 4, respectively. Only 0.9% were taking ≥5 antihypertensive drugs.

The characteristics for all 1 508 130 participants globally are given in Table S3. Of all participants, 88.6% had a documented ethnicity of whom the majority reported their ethnicity as South Asian (33.7%) or East Asian (18.9%). Of all screenees, 116 369 (7.7%) reported having diabetes mellitus (either type I or type II), 55 189 (3.7%) a history of myocardial infarction, 36 667 (2.4%) a history of stroke, 184 225 (12.2%) were current smokers, and 82 726 (5.5%) reported drinking alcohol at least once per week. Among women, 17 762 (2.3%) were pregnant at the time of screening, whereas 19 120 (2.5%) reported a history of hypertension in a previous pregnancy. The mean BMI was 25.0 kg/m^2 (SD 5.3) in women and 25.1 kg/m^2 (SD 4.7) in men. 197 021 (25.4%) women and 214 395 (29.5%) men were overweight, and 104 690 (13.5%) women and 89 170 (12.3%) men were obese.

BP Readings

Based on the inclusion criteria, all participants had at least one BP reading and 1 133 008 (75.1%) had all 3 BP readings recorded with a further 119 669 (13.2%) having at least two readings. Analysis of only those with all three readings showed that BP fell, on average, by 3.1/1.8 mmHg, from a mean of 126.0/78.9 mmHg for the first reading to a mean of 122.9/77.1 mmHg for the third reading, whereas the corresponding proportion with hypertension fell from 37.6% to 33.6%. The mean of the second and third readings identified the lowest proportion of participants with hypertension (33.5%), compared with any single or combination of measures despite a higher average BP (123.8/77.7 mmHg) compared to the mean of the third reading (see Table S4).

Table 1. Total Participants and Distribution of Age, Sex, and Use of Antihypertensive Medication, Worldwide and by Region

Region	Total Participants	Female		Male		On Antihypertensive Medication
		Total	Mean Age, y	Total	Mean Age, y	
South Asia	471 302 (31.3%)	202 379 (43.0%)	42.2	267 590 (56.9%)	43.2	59 514 (12.6%)
East Asia	280 863 (18.6%)	148 843 (53.3%)	49.2	130 618 (46.7%)	50.0	47 060 (16.8%)
Americas	261 676 (17.4%)	156 615 (60.0%)	49.2	104 368 (40.0%)	50.0	75 056 (28.7%)
Sub-Saharan Africa	177 692 (11.8%)	92 921 (52.5%)	40.8	84 100 (47.5%)	40.8	17 114 (9.6%)
Southeast Asia and Australasia	121 767 (8.1%)	66 886 (55.1%)	45.1	54 493 (44.9%)	45.3	36 546 (30.0%)
Europe	107 608 (7.1%)	65 008 (61.3%)	50.5	41 079 (38.7%)	52.2	30 171 (28.0%)
Northern Africa and Middle East	87 222 (5.8%)	42 787 (49.2%)	41.8	44 103 (50.7%)	43.5	15 497 (17.8%)
Worldwide	1 508 130	775 439 (51.6%)	45.7	726 351 (48.4%)	45.8	280 958 (18.6%)

Four hundred and ten participants with sex recorded as other and 5930 participants with sex unknown not shown in the table.

Further analyses make use of the mean of the second and third BP reading for each participant, as the most conservative estimate. Where either, or both of the second and third BP readings were missing, multiple imputation using chained equations was performed to estimate the missing mean reading based on observed data. Measurements for a total of 372 120 participants were imputed—imputations for 201 810 participants from the complete imputation model and imputations for 170 310 participants from the reduced imputation model.

Worldwide, the mean BP (based on 1 136 010 individuals with the second and third BP reading available) was 123.7/77.7 mm Hg before imputation and, following imputation, of all 1 508 130 participants, was 124.1/77.7 mm Hg. The mean systolic and diastolic BPs, worldwide and by region, are displayed in Table S8, before and after standardization for age and sex. After imputation, and standardizing for age and sex, in those not taking antihypertensive medication, the mean BP was 121.6/76.7 mm Hg and in those taking antihypertensive medication was 130.8/81.7 mm Hg.

Participants With Hypertension

Following imputation, of all 1 508 130 participants, 513 337 (34.0%) had hypertension (Table 2). Of those with hypertension, 58.7% were aware of their diagnosis, and 54.7% were on antihypertensive medication. Of the 280 958 participants on medication, 162 512 (57.8%) had a BP controlled to <140/90 mm Hg and 28.9% controlled to <130/80 mm Hg. Of all hypertensive participants, 31.7% were controlled to <140/90 mm Hg and 15.8% to <130/80 mm Hg.

Of those participants not taking antihypertensive medication, 232 379 (18.9%) were found to have hypertension. In total, 350 825 (23.3%) participants were found to have untreated or inadequately treated hypertension. Of these, 47.9% had a BP in the range 140/90 to 149/94 mm Hg, and 25.5% had a BP in the range 150/95 to 159/99 mm Hg (Table S5). 6.6% of participants with hypertension, 6.6% had a BP over 180/110 mm Hg.

Using the lower threshold of systolic BP ≥130 mm Hg or diastolic BP ≥ 80 mm Hg (or in those on antihypertensive medication) to diagnose hypertension, 775 068 (51.4%) of screenees were identified as hypertensive.

Sensitivity analyses were performed comparing results from the complete case analysis to the analyses using imputations from the reduced imputation model, complete imputation model, and the combined imputation model, which are shown in Tables S6 and S7. The estimates from each model were similar, with the global proportion with hypertension, and raised BP stratified by medication use within a 1.0% absolute range. In the complete case analysis, the proportion of participants with hypertension was 33.5% out of a total of 1 136 010. The corresponding proportions from the reduced imputation and complete imputation models were 34.1% and

Table 2. Participant Numbers and Proportions With Hypertension, Proportions Aware, Treated, and Controlled, Worldwide and by Region

Region	Number With Hypertension	Proportion With Hypertension	Proportion of Hypertensives Aware	Proportion of Hypertensives on Medication	Proportion of Those on Medication With Controlled BP	Proportion of All Hypertensives Controlled
South Asia	138 236	29.3%	46.2%	43.1%	55.6%	23.9%
East Asia	86 020	30.6%	57.9%	54.7%	63.1%	34.5%
Americas	107 752	41.2%	73.0%	69.7%	61.2%	42.6%
Sub-Saharan Africa	49 616	27.9%	42.7%	34.5%	49.3%	17.0%
South-east Asia and Australasia	58 156	47.8%	65.5%	62.8%	59.6%	37.4%
Europe	46 881	43.6%	71.5%	64.4%	47.9%	30.8%
Northern Africa and Middle East	26 677	30.6%	61.6%	58.1%	58.9%	34.2%
Worldwide	513 337	34.0%	58.7%	54.7%	57.8%	31.7%

BP indicates blood pressure.

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33.1%, respectively, compared with 34.0% in the combined imputation model.

After standardization for age and sex, the proportion with hypertension worldwide reduced slightly to 32.5%, with absolute reductions in the proportion with hypertension of >5% in East Asia, the Americas, and Europe and an increase in the proportion with hypertension in Sub-Saharan Africa, South Asia, and Northern Africa, and the Middle East. The proportions of hypertensive awareness, and proportions with raised BP stratified by antihypertensive medication use, following standardization, are given in Table 3.

Medication Use

In participants taking a single antihypertensive medication, 39.3% were uncontrolled, and in those taking 2 drug classes, 44.8% were uncontrolled. Proportions with uncontrolled BP were similar in those on 3 (47.9%), 4 (48.0%) or ≥5 (44.5%) medications (Table S9). In total, 17 532 participants were defined as treatment-resistant, which is 8.6% of the hypertensive population included in the study for whom data on the number of medications were available.

Of the 209 048 participants taking antihypertensive medication for whom concomitant use of a statin was recorded, 76 480 (36.5%) were on a statin, of whom 14 013 (18.3%) had a previous myocardial infarction or stroke. Of the 207 220 participants taking antihypertensive medication for whom the concomitant use of aspirin was documented, 67 149 (32.4%) were taking aspirin, of whom only 14 871 (22.1%) reported a history of myocardial infarction or stroke. Of the 52 278 hypertensive patients not taking aspirin for secondary prevention, 18 131 (34.7%) had a BP ≥ 150/90 mm Hg.

Measures of Association

Based on linear mixed models, mean systolic BP displayed a roughly linear increase with age in both men and women who were not using antihypertensive medication (Figure S1). In contrast, mean diastolic BP showed an inverted U-shaped curve, with BP peaking at 50 to 55 years and then gradually decreasing. Systolic BP was higher in males compared to females until the age of about 80 years, after which the mean systolic was higher in females. Similarly, diastolic BP was higher in males until 80 years, after which there were no significant differences between the sexes. Increasing heart rate showed a strong linear association with increasing diastolic BP, but a weaker, less clear relationship was apparent with systolic BP (Figure S2 and Table S10).

Of all risk factors analyzed, reported use of antihypertensive medication and a previous diagnosis of hypertension were the strongest predictors of higher levels of systolic and diastolic BP. After adjusting for age and sex, participants taking antihypertensive medication had a higher mean systolic BP (8.8 mm Hg higher, $P<0.001$) and higher diastolic BP (3.7 mm Hg higher, $P<0.001$) compared with those not taking medication (Figure 1 and Table S11). After adjusting for age, sex, and antihypertensive medication use, those with known hypertension had a significantly higher mean systolic (8.0 mm Hg higher, $P<0.001$) and diastolic BP (4.5 mm Hg higher, $P<0.001$) compared with those without known hypertension.

Women who reported a history of previous hypertension in pregnancy had significantly higher systolic (3.6 mm Hg, $P<0.001$) and diastolic (2.6 mm Hg, $P<0.001$) BPs compared with women with no previous history of hypertension in pregnancy (Figure 2 and Table S12). Adjusting for BMI in addition to age, sex and antihypertensive medication use had no impact on the association between BP and previous hypertension in pregnancy.

BMI was also strongly linked to both systolic and diastolic BP, with a linear increase in both with increasing BMI category. The difference in mean systolic and diastolic BP in those participants with a BMI in the obese range, compared with those of healthy weight was 4.6 mm Hg and 3.1 mm Hg, respectively (Figure 3 and Appendix Table S13).

Several smaller but significant differences in systolic and diastolic BP were observed in association with several conditions or risk factors. For example, participants with diabetes had significantly higher systolic BPs, but significantly lower diastolic BPs, whereas those with a history of myocardial infarction or stroke had lower systolic and diastolic BPs (Figure 1 and Table S11).

Table 3. Proportions With Hypertension, of Those Taking/Not Taking Antihypertensive Medication, After Imputation and Standardization for Age and Sex According to the WHO World-Standard Population

Standardized for Age and Sex					
Region	Proportion With Hypertension	Proportion With Hypertension	Proportion of Hypertensives Aware	Proportion of Those Not on Antihypertensive Medication With Hypertension	Proportion of Those on Antihypertensive Medication With Uncontrolled BP
South Asia	29.3%	31.1%	40.8%	19.3%	41.3%
East Asia	30.6%	24.8%	59.0%	14.8%	33.4%
Americas	41.2%	35.5%	73.4%	17.3%	35.2%
Sub-Saharan Africa	27.9%	31.2%	32.9%	21.9%	44.9%
South-east Asia and Australasia	47.8%	46.1%	66.5%	25.2%	36.8%
Europe	43.6%	36.2%	69.6%	19.9%	43.4%
Northern Africa and Middle East	30.6%	31.4%	54.8%	16.2%	34.9%
Worldwide	34.0%	32.5%	55.7%	18.6%	38.3%

WHO indicates World Health Organization.

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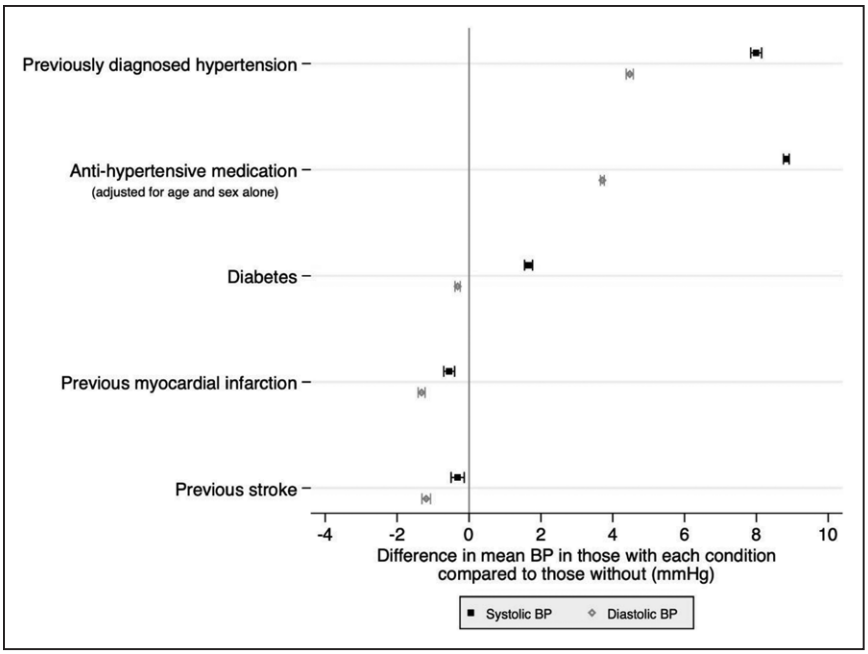


Figure 1. Difference in mean systolic and diastolic blood pressure (BP; with 95% CI) in those with each condition compared to those without, from linear mixed models adjusted for age, sex, and antihypertensive medication.

In addition, a significant dose-dependent increase in both systolic and diastolic BP was seen in alcohol drinkers compared with nondrinkers, after adjusting for age, sex, and antihypertensive medication use (Figure 2 and Table S12). Participants who currently smoked, and those fasting during the period of MMM had a small, but statistically significant increase in both systolic and diastolic BP. Adjusting for BMI in addition had no significant impact on the association between BP and smoking. Conversely, women who were pregnant had significantly lower systolic and diastolic BPs than those who were not.

On average, BPs measured in pharmacies were higher than in any other setting, whereas those measured in indoor public areas were the lowest (Figure S3 and Table S14). Small variations in mean BPs taken on different days of the week were apparent but were of limited, if any, clinical significance (Figure S4 and Table S15).

Discussion

MMM 2019 expanded on the preceding 2 campaigns, including over 1.5 million participants from 92 countries. The campaign reached significant numbers of new participants, with 1.2 million never having participated in a previous campaign and almost half a million never having had their BP measured before. Over half a million screenees met the criteria for hypertension based on a cutoff of 140/90 mm Hg or being on treatment for hypertension, and over half of all those screened were classified as hypertensive using the lower threshold of 130/80 mm Hg. Furthermore, over one-third of a million participants were found to have either untreated or inadequately treated hypertension. When using the lower BP target of <130/80 mm Hg as the definition of control, which more accurately reflects current guideline recommendations,[8,10] the proportion controlled globally was particularly low at 15.8%.

The proportion of screenees classified as hypertensive in MMM is susceptible to spurious elevation due to a combination of selection bias (those worried about their BP presenting for measurement) and basing the diagnosis on only one set of 3 readings, which is by no means ideal and not in keeping with recommendations for diagnosis at the individual level.[8–10]

Although the screening was volunteer-based and opportunistic with the propensity to ascertainment bias, it is striking that almost one-third of all screenees reported never having had their BPs measured previously. This proportion was higher in men (35.9%) than women (28.4%), which may reflect the routine BP measurement in women associated with oral contraceptive use and pregnancy.

In 2019, the number of medication classes taken by those participants on antihypertensive medication was recorded for the first time. Of those taking medication, more than half were only on a single agent, a further third were taking 2 medications, and only 13.6% were taking ≥3 medications. Almost 4 in 10 of those on a single drug were uncontrolled, suggesting a significant enhanced treatment potential through the use of additional agents. These findings add support to the increasing recommendation to initiate drug treatment with 2 agents.[8,10] The concomitant use of aspirin by one-third of those on antihypertensive medication is at odds with current recommendations[16] in that many such users did not report established cardiovascular disease and many also had inadequately controlled BP.

Despite not being designed to provide nationally representative samples, and including different screening sites in different countries, each year the global findings are remarkably consistent with previous estimates from MMM.[6,7] The overall proportions with hypertension in 2017 and 2018 were, respectively, 34.9% and 33.4%, compared with 34.0% in 2019. Rates of awareness amongst hypertensives were 58.7% in 2019, compared with 59.5% in 2018, whereas the proportion treated was 54.7% in 2019 compared with 55.3% in 2018. The proportion of all hypertensives controlled to <140/90 mm Hg was 31.7% in 2019, marginally lower than in 2018 (33.2%).

Although most major guidelines recommend the use of ambulatory or home BP measurement in the diagnosis of hypertension,[8–10] such an approach was not feasible in this study

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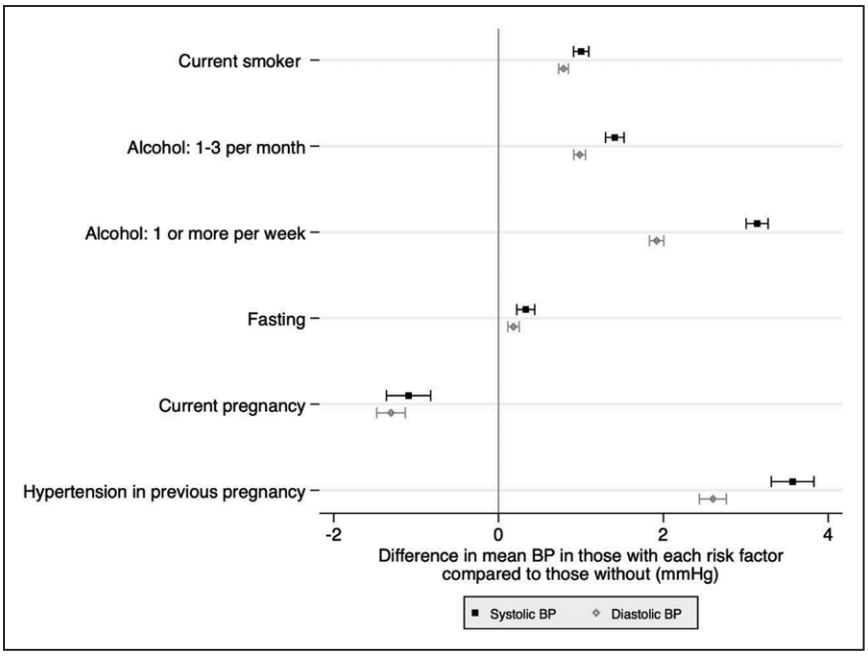


Figure 2. Difference in mean systolic and diastolic blood pressure (BP; with 95% CI) in those with each risk factor compared to those without, from linear mixed models adjusted for age, sex and antihypertensive medication (current pregnancy and hypertension in previous pregnancy adjusted for age and antihypertensive medication alone).

due to the cost and logistics involved, and so diagnosis was based on a single set of clinic readings. Our results suggest that if clinic readings are used, the mean of the second and third of 3 readings results in the most conservative estimate of hypertension, which again is consistent with the results of previous campaigns.[6,7]

Although these reported estimates of parameters of hypertension management are not population-based, adjusted measures of association within the MMM cohort are less subject to selection bias and remain valid.[17] Compared with previous years, a similar pattern of the difference in mean BP with age and sex was seen. Participants with diabetes mellitus had on average higher systolic and diastolic BPs, but those with a history of myocardial infarction or stroke had, surprisingly, lower BPs, after adjusting for age, sex, and antihypertensive medication use. The lower BPs in those with a history of myocardial infarction may reflect the routine use of cardioprotective agents such as ACE (angiotensin-converting enzyme)-inhibitors and beta-blockers in that setting irrespective of the presence of raised BP. Alternatively, both in those with a history of myocardial infarction or stroke, the lower BPs may reflect stricter BP management in these groups, in turn, reflecting greater interaction with healthcare professionals.

Strong positive associations were seen between BP and risk factors, such as increasing BMI and increasing alcohol intake, and as found in previous years, pregnant women had lower systolic and diastolic BPs. Women with a previous history of hypertension in pregnancy had significantly higher mean BPs compared with women without previous hypertension in

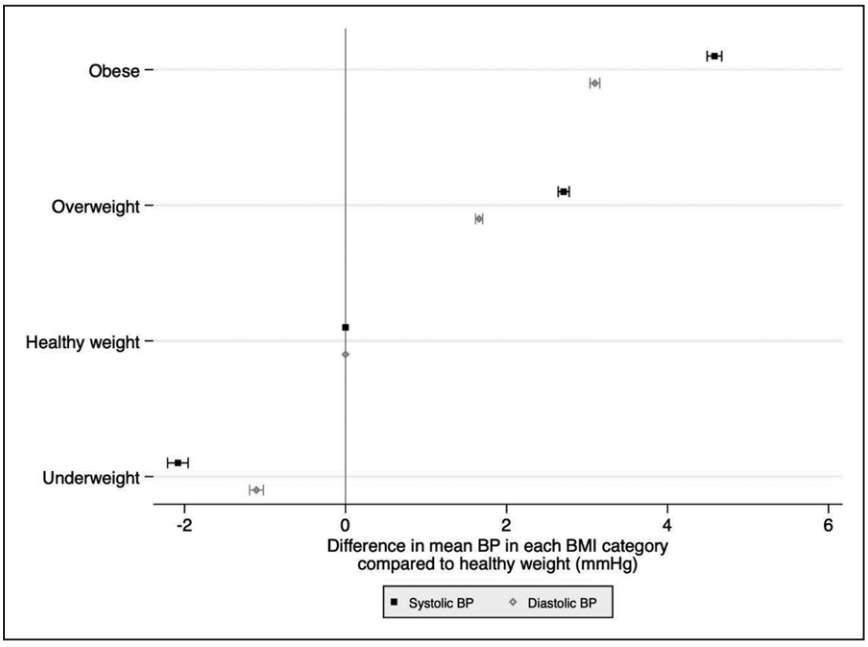


Figure 3. Difference in mean systolic and diastolic blood pressure (BP; with 95% CI) in those in each body mass index (BMI) category compared to healthy weight, from linear mixed models adjusted for age, sex, and antihypertensive medication.

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pregnancy. This difference was unaffected by adjustment for BMI, implying that raised BMI was not a common explanatory etiological mechanism. Higher rates of hypertension and cardiovascular disease are established in women with a history of hypertensive pregnancy disorders,[18] and hence women who experience pregnancy-associated hypertension may benefit from more regular BP checks in ensuing years.

Much of the costs of the MMM campaign are borne by the generous support from local benefactors and thousands of volunteers around the world, but the central coordination remains relatively inexpensive and equates to a cost of 0.65 USD per case of untreated or inadequately treated hypertension detected.

Limitations

As an opportunistic study aimed primarily at raising awareness, the results of MMM should be viewed in the context of its limitations. Study participants were self-selected through convenience sampling, and hence recruitment is unlikely to generate representative samples of the population due to selection bias. Hence, prevalence at a global, regional, or national level should not be inferred. However, the overall study aim was to raise awareness of the importance of BP measurement and so investigators were not encouraged by design to seek representative samples. Nevertheless, although the aim was to target those who had not had a BP measured in the last 12 months, no one was excluded on this basis.

Similarly, differences in the estimates between countries and regions should be interpreted cautiously, due to differential characteristics of those screened. Standardization of estimates according to the World Health Organization world age-standard population can reduce differential distributions of age and sex, but selection differences will remain. Likewise, although standardization improves direct comparability across regions, it does not ensure that the proportions of hypertensives estimated are any more representative at the regional level, as the regional distribution of age will not match the world-standard population.

Although the protocol was unified across all screening sites, and efforts were made to train volunteers in the measurement and recording of BPs, due to the scale of the study, inconsistencies in measurement may have arisen within and between sites. Data were not fully recorded for all individuals, and 13 844 (0.9%) of submitted participants were excluded due to data quality. However, all included participants had at least one BP measurement and 99.0% and 99.6% had age and sex recorded, respectively.

The protocol specified that 3 BP measurements be taken for each participant, but in around one-quarter of cases, this was not the case, reflecting local logistical challenges or participant preference. Our findings showed significant differences in the mean BPs between the first, second, and third readings, which had the potential to bias the results in favor of a higher proportion with hypertension in those with only one or two readings. However, by using multiple imputation, we were able to provide a more reliable estimate of what the mean reading would have been, reducing any bias. Sensitivity analyses showed the results were robust to different imputation models, with only small differences in the proportions with hypertension. These data serve to inform optimal BP screening particularly in the less-than-ideal but all-too-common situation in which diagnosis and treatment initiation are based on a single clinic visit.

Despite lacking a population-based representative design, the estimates at the global level have been remarkably consistent across MMM campaigns and are in line with other published estimates of hypertension prevalence. Furthermore, the results of MMM provide real-world estimates of the numbers of individuals with hypertension that could be detected through an opportunistic campaign, which may make the estimates more applicable to the potential impact of screening in settings where systematic population-based screening is not feasible.

Due to the cross-sectional design of the study, outcomes in participants found to have raised BP cannot be evaluated. However, those found to have high BP were provided with lifestyle and dietary advice, and advice to seek further medical assessment based on locally available facilities. This approach mirrors precisely the intervention used in a recent community-based BP screening program of older adults in China which, using regression discontinuity analysis, resulted in a 6.3 mm Hg reduction in systolic BP after 2 years.[19] If similar BP-lowering was associated with the MMM campaign intervention huge benefits in terms of cardiovascular disease prevention would accrue.[20]

Advantages

The MMM19 campaign includes contemporary data from over 1.5 million adults from 92 countries that were collated in a synchronized survey following a common protocol. Over 350 000 individuals were detected with untreated or inadequately treated hypertension and advised on nonpharmacological management and further follow-up. Meanwhile utilizing multimedia promotion campaigns the importance of raised BP was enhanced at the population level.

Although systematic screening is still a distant prospect for many nations in the world, we think that the MMM campaign should continue annually to raise awareness at the individual and population level of this treatable condition which currently leads to approximately 28 000 deaths per day.[1]

Perspectives

MMM has included over 4.2 million screenings across the first 3 annual campaigns and grown each year in terms of number of countries involved and total participants.[6,7] The detection of over 900 000 adults with untreated or inadequately treated hypertension during these 3 years, attests to the benefits of such opportunistic screening. As a condition for which lifestyle changes can have major benefits, and effective treatments are relatively cheap and accessible, the finding that fewer than a third of participants with hypertension were controlled must motivate efforts to better detect and manage raised BP. MMM continues to supply an inexpensive means of raising BP awareness at the individual and population level around the world.

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Novelty and Significance

What Is New?

- One-third of over 1.5 million adults who volunteered for blood pressure (BP) measurement in 92 countries, had never had it measured before.
- Over 500 000 were found to have hypertension; half of these were on treatment, of whom half were only on one drug.
- Less than one in six hypertensives adults were controlled to current BP targets.
- Aspirin was being used inappropriately by 25% of those on treatment for BP.

What Is Relevant?

- This huge global survey confirms very poor levels of detection, treatment, and control of raised BP but excess use of aspirin.

Summary

To reduce the huge disease burden due to raised BP worldwide, it is critical to urgently enhance current BP screening and effective hypertension management.