May Measurement Month 2017: an analysis of blood pressure screening results worldwide

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Summary

Background Increased blood pressure is the biggest contributor to the global burden of disease and mortality. Data suggest that less than half of the population with hypertension is aware of it. May Measurement Month was initiated to raise awareness of the importance of blood pressure and as a pragmatic interim solution to the shortfall in screening programmes.

Methods This cross-sectional survey included volunteer adults (≥18 years) who ideally had not had their blood pressures measured in the past year. Each participant had their blood pressure measured three times and received a a questionnaire about demographic, lifestyle, and environmental factors. The primary objective was to raise awareness of blood pressure, measured by number of countries involved, number of people screened, and number of people who have untreated or inadequately treated hypertension (defined as systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg, or both, or on the basis of receiving antihypertensive medication). Multiple imputation was used to estimate the mean of the second and third blood pressure readings if these were not recorded. Measures of association were analysed using linear mixed models.

Findings Data were collected from 1 201 570 individuals in 80 countries. After imputation, of the 1 128 635 individuals for whom a mean of the second and third readings was available, 393 924 (34·9%) individuals had hypertension. 153 905 (17·3%) of 888 616 individuals who were not receiving antihypertensive treatment were hypertensive, and 105 456 (46·3%) of the 227 721 individuals receiving treatment did not have controlled blood pressure. Significant differences in adjusted blood pressures and hypertension prevalence were apparent between regions. Adjusted blood pressure was higher in association with antihypertensive medication, diabetes, cerebrovascular disease, smoking, and alcohol consumption. Blood pressure was higher when measured on the right arm than on the left arm, and blood pressure was highest on Saturdays.

Interpretation Inexpensive global screening of blood pressure is achievable using volunteers and convenience sampling. Pending the set-up of systematic surveillance systems worldwide, MMM will be repeated annually to raise awareness of blood pressure.

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Introduction

Raised blood pressure continues to be the biggest contributor to the global burden of disease[1,2] and to global mortality, leading to 10·5 million deaths each year.[1,2] This situation is expected to worsen in the coming decades as the global population increases and ages.[1,3]

Despite the existence of several major drug classes that are effective at lowering blood pressure and reducing the associated risk of adverse cardiovascular events,[4] only a small minority of patients with hypertension have their blood pressures controlled to hitherto generally accepted targets (<140 mm Hg systolic blood pressure and <90 mm Hg diastolic blood pressure).[5–7] This is mainly because most people with hypertension are not treated, which is largely due to the low levels of awareness and screening for increased blood pressure.[5–7]

The World Heart Federation[8] and the *Lancet* Commission on Hypertension[9] highlighted the importance of improving awareness of increased blood pressure as a crucial action that is needed to address the associated health burden.

Measurement of blood pressure is a cheap, simple, and non-invasive technique to detect hypertension and, assuming effective therapy is supplied, leads to highly cost-effective protection against death and disability,[4,9] which otherwise usually arises from myocardial infarction, cerebrovascular disease, and renal failure.

In high-income countries such as the UK[10] and Canada,[11] where relatively high rates of awareness of hypertension prevail,[6] routine blood pressure surveillance

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Research in context

Evidence before this study

Increased blood pressure is the biggest cause of global mortality and disease burden despite the existence of effective treatments. The identification of hypertension remains a major challenge, with effective blood pressure surveillance systems unavailable in most countries of the world.

Added value of this study

May Measurement Month (MMM) 2017 is the largest ever synchronised, standardised multinational screening campaign of any cardiovascular risk factor. Data on the blood pressures of more than 1·2 million individuals from 80 countries are presented, with three measurements for two-thirds of participants. MMM was the largest ever blood pressure survey in more than 34 countries. 153 905 (17·3%) of 888 616 participants not receiving antihypertensive treatment had high blood pressure. 105 456 (46·3%) of the 227 721 participants receiving treatment did not have controlled blood pressure. The scale of this survey permits the exploration of potential associations between blood pressure levels and other participant characteristics and environmental factors, including day of the week.

Implications of all the available evidence

Volunteer screening with convenience sampling can be cost-effective and can be used to identify large numbers of individuals who could benefit from treatment or enhanced treatment. MMM will be repeated annually for the purposes of screening and boosting awareness of raised blood pressure until systematic blood pressure screening systems are established.

is implemented as part of routine health services[12] or occupational services (or both), but very often through opportunistic screening.[13]

By contrast, access to free or cheap health care is not available via the workplace or health-care system in most countries. Routine blood pressure screening is therefore not usually available, and awareness of hypertension is low.[5–9,12,13] Unfortunately, introduction of systematic blood pressure surveillance systems needs substantial funding and governmental support and is unlikely to happen in the near future. Meanwhile, with more than 10 million people dying from increased blood pressure each year,[2] urgent action is required. As a pragmatic and rapid approach to addressing the problem of insufficient awareness of hypertension, we expanded World Hypertension Day to become May Measurement Month (MMM)[14]—a month of standardised global blood pressure measurement and data collection.

Methods

Study design

See Online for appendix

The MMM cross-sectional survey was set up between October, 2016, and April, 2017, and more than 100 countries worldwide were approached. A detailed protocol to be used by all countries was developed by the International Society of Hypertension (ISH) and distributed to all participating countries. Communication and distribution of the protocol, essential training material, videos, and marketing information were shared using the bespoke MMM website. In each country, one or more national leaders were identified and made responsible for obtaining ethical clearance for the survey, if required, and for recruiting volunteer staff to set up screening sites. Sites were set up in a wide range of locations, including pharmacies, supermarkets, places of worship, shopping malls, sports grounds, schools, and existing clinics in primary and secondary care facilities. Target participants were volunteer adults (≥18 years) who ideally had not had their blood pressures measured in the previous year. The campaign was promoted internationally by the ISH and the World Hypertension League and locally by celebrity and government endorsements, on television and radio, and through the media and social media.

For **MMM** see http://www.maymeasure.com and http://www.whleague.org/index.php/2014-07-09-22-47-11/may-measurement-month-2017

Volunteer staff were trained to measure blood pressure via video recordings housed on the MMM website. Recommendations for standard methods included three seated recordings taken on the left arm (preferably) or right arm (where using the left arm was impractical) with 1 min intervals between readings when the pulse rate was recorded. Omron Healthcare donated 20 000 blood pressure devices, of which more than 10 000 were distributed to sites as required. At least 40% of blood pressures were measured by Omron devices. Staff were recommended to use automated blood pressure devices, but training on both automated and manual sphygmomanometers were provided because equipment varied at different sites.

A questionnaire was used to collect a limited amount of additional data from each participant (appendix), and these data were entered, where internet was accessible, onto a study-specific mobile application produced in six languages. Alternatively, data were entered on paper forms and later transferred to spreadsheets.

Blood pressure was calculated from the mean of the second and third readings, and hypertension was defined as a systolic blood pressure of at least 140 mm Hg or a diastolic blood pressure of at least 90 mm Hg (or both). Participants receiving antihypertensive treatment were also assumed to have hypertension. Among those on treatment, controlled blood pressure was defined as a blood pressure of less than 140/90 mm Hg. Participants found to have blood pressures in the hypertensive range were provided, as a minimum, with printed evidence-based dietary and lifestyle advice designed to lower blood pressure (the Top Ten Tips are listed in the appendix). Advice for fur-ther follow-up tailored to locally available facilities was also provided.

Data handling and statistical analysis

Data cleaning was done either locally or centrally depending on local capacity. Data cleaning rules (appendix) and cut-off ranges were devised and provided to all sites.

Submitted data from 80 participating countries were collated centrally and analysed using Stata version 14.2. Countries providing ten participants or less were excluded post-hoc because of concerns with the origins and validity of these data. Data from 190 955 individuals from India could not be provided at an individual level for regulatory reasons and instead were analysed locally. These results were submitted centrally and incorporated where possible using weighted averages. Global data were subdivided by seven UN geographical regions with some modifications.[15] Information on country income was sourced from the World Bank classification of economies (as of June, 2017).[16]

Ideally, three blood pressures were recorded and crude analyses were done using the mean of the second and third blood pressure readings, where available. Using only those individuals with all three readings, we compared mean blood pressures and the proportion of participants with hypertension using different combinations of the three readings.

To provide a comparable blood pressure reading for all individuals, multiple imputation was used to estimate the average of the second and third readings where either reading was not documented. Six separate models were run on a single reading (three each for systolic and diastolic blood pressures), using either the first, second, or third reading as predictors. Both systolic and diastolic components were included within the imputation models. Age (as a restricted cubic spline with five knots) and sex were included, along with an interaction term. Region was included as a determinant of missingness (appendix p 13).

Mean blood pressures were standardised for age and sex according to the WHO world age-standard population along with an assumed sex ratio of 1:1.[17,18] Linear mixed models were run separately for systolic and diastolic blood pressures, allowing for random effects of country to account for clustering. In all models, the association of blood pressure was adjusted for age and sex (with an interaction term) and antihypertensive medication. A multivariable model measuring the association of national income strata with blood pressure included all potential predictors in the model.

Full details of the statistical analysis are provided in the appendix.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The first and corresponding authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

97 countries participated in MMM, but 17 countries were excluded from the analysis because they had data for less than ten participants. A complete list of countries by region can be found in the appendix (p 9). Data from 1 201 570 participants were cleaned, collated centrally, and analysed. Only about 8% of data were collected onto the bespoke mobile application. Because data collection was incomplete for some of the variables in the study questionnaire, numbers used in different analyses vary.

The numbers of participants included in the database were stratified across seven regions, and mean ages and distribution between men and women were calculated (table 1). The percentages of participants from high-income, upper-middle income, lower-middle income, and low-income countries were 9·6%, 20·0%, 68·8%, and 1·6% respectively.

More women than men were screened in all regions except in the south Asian, northern African, and Middle Eastern regions. Mean ages ranged from 37·4 years in northern Africa and the Middle East to 55·0 years in east Asia. 24·2% of participants were taking antihypertensive medications, and this proportion varied at a regional level, from 3·3% in northern Africa and the Middle East, to 56·8% in east Asia (table 1).

Of 1 201 570 screenees, 103 201 (8·6%) participants reported having type 2 diabetes, 37 758 (3·1%) reported a history of myocardial infarction, and 21 980 (1·8%) reported a history of stroke. 138 798 (11·6%) respondents reported smoking, 90 469 (7·5%) reported alcohol consumption once or more per week, and more than 7000 women (1·1% of female respondents) reported being pregnant. The mean body-mass index (BMI) of respondents was 24·6 kg/m² (SD 4·5; appendix p 11).

Of 818 353 respondents with three blood pressures readings, blood pressures decreased on average by 2·9/1·5 mm Hg between the first and third readings (table 2). Likewise, the proportion of participants with

	Mean age (SD), years	Women	Men	Participants receiving antihypertensive treatment
Southeast Asia and Australasia	42·8 (15·9)	218 155 (61·1%)	138 832 (38·9%)	78 973 (22·5%)
South Asia	39·9 (14·7)	118 707 (45·5%)	142 030 (54·5%)	27 691 (15·5%)
East Asia	55·0 (16·6)	95 836 (53·6%)	82 813 (46·4%)	44 843 (56·8%)
Sub-Saharan Africa	39·0 (14·7)	68 046 (54·2%)	57 591 (45·8%)	12 109 (9·6%)
Europe	52·2 (16·9)	64 566 (59·5%)	43 858 (40·5%)	42 354 (43·5%)
Americas	48·7 (17·8)	64 268 (60·3%)	42 351 (39·7%)	32 307 (30·6%)
Northern Africa and Middle East	37·4 (15·1)	19 747 (37·5%)	32 976 (62·5%)	1742 (3·3%)
Worldwide	44·9 (16·9)	649 325 (54·6%)	540 451 (45·4%)	240 019 (24·2%)

Data are n (%), unless stated otherwise. Percentages given exclude those where sex or treatment are unrecorded (appendix p11).

Table 1: **Worldwide and regional distributions of age, sex, and antihypertensive medication**

	Reading 1	Reading 2	Reading 3	Mean of readings 1 and 2	Mean of readings 2 and 3
Mean systolic blood pressure, mm Hg	126·5	124·7	123·6	125·8	124·3
Mean diastolic blood pressure, mm Hg	79·4	78·5	77·9	79·1	78·4
Proportion with hypertension	331 293 (40·5%)	310 021 (37·9%)	299 536 (36·6%)	305 914 (37·4%)	290 921 (35·5%)

Data are based on readings from 818 353 measurements with all three readings.

Table 2: **Differences in mean blood pressure and number of participants with hypertension, by reading**

	Participants with hypertension*	Participants with hypertension and not receiving treatment	Participants receiving treatment but with uncontrolled blood pressure
Southeast Asia and Australasia	121 502 (34·1%)	42 529 (15·3%)	34 183 (45·0%)
South Asia	62 560 (31·1%)	34 869 (20·1%)	9177 (44·1%)
East Asia	61 897 (34·5%)	17 054 (12·7%)	16 125 (36·2%)
Sub-Saharan Africa	35 585 (28·3%)	23 476 (20·6%)	6601 (55·9%)
Europe	59 767 (55·0%)	17 413 (26·3%)	26 756 (63·6%)
Americas	42 693 (41·0%)	10 386 (14·4%)	11 859 (38·6%)
Northern Africa and Middle East	9921 (18·8%)	8179 (16·0%)	754 (43·7%)
Worldwide	393 924/1 128 635 (34·9%)	153 905/888 616 (17·3%)	105 456/227 721 (46·3%)

Data are n (%) or n/N (%). The denominators include those individuals with a mean of the second and third blood pressure readings after imputation. *The total number with hypertension includes an additional 12 298 individuals taking antihypertensive medication for whom an imputed mean reading was not available. An expanded table with all denominators is provided in the appendix (p 14).

Table 3: **Total number of participants with hypertension, with and without treatment, for each region after imputation**

	Mean blood pressure, mm Hg*	Proportion of participants with hypertension (standardised by age and sex standardised)*	Proportion of participants with uncontrolled blood pressure in those on treatment (standardised by age and sex)
Southeast Asia and Australasia	118·6/77·3	17·1%	39·8%
South Asia	122·5/78·2	18·5%	41·5%
East Asia	120·0/75·0	9·6%	31·9%
Sub-Saharan Africa	124·7/78·3	24·9%	51·0%
Europe	124·1/77·5	21·0%	48·7%
Americas	119·5/74·5	13·5%	32·4%
Northern Africa and Middle East	120·5/76·3	15·8%	37·6%
Worldwide	120·6/76·8	16·5%	38·9%

*Excluding participants receiving antihypertensive treatment.

Table 4: **Mean blood pressure and percentage of participants with hypertension (in untreated and treated populations) after imputation and standardisation for age and sex distributions**

hypertension decreased on subsequent readings, with a 3·9% difference in the prevalence of hypertension between the first and third readings. The mean of the second and third readings, which was used in subsequent analyses, generated the lowest prevalence.

In a simple regression model of the mean of the second and third readings against the first reading, the R^2 value was 0·83 for systolic blood pressure and 0·74 for diastolic blood pressure, implying that a large proportion of the variation in the mean was explained by a single blood pressure measurement.

Multiple imputation was used to impute the mean of the second and third readings based on any single reading reported. 20 imputation sets were created, with a total of 293 819 readings imputed. Plots of residuals against fitted values from subsequent analyses showed no significant differences between imputation sets.

After imputation, of the 1 128 635 individuals for whom a mean of the second and third readings was available or known to be on antihypertensive treatment, 393 924 (34·9%) participants were hypertensive (table 3). Excluding participants taking antihypertensive medication, 153 905 (17·3%) of 888 616 participants with hypertension were not receiving treatment. Among participants who were receiving treatment for hypertension, 105 456 (46·3%) of 227 721 participants receiving treatment for hypertension had uncontrolled blood pressure.

The differential distribution in age and sex in the seven regions shows the need for standardisation to make comparisons between regions. This is exemplified by the difference in ranking of regions on the basis of proportion of populations with hypertension and uncontrolled, treated hypertension (table 3; table 4). The age-standardised and sex-standardised mean blood pressures were calculated by region along with the standardised proportion of untreated participants with hypertension, and the proportion of participants receiving treatment but with uncontrolled hypertension (table 4). We found a strong correlation between mean blood pressure and proportion of respondents with hypertension (0·80 for systolic blood pressure; 0·86 for diastolic blood pressure). Mean systolic and diastolic pressures and the proportion of participants with hypertension were highest in sub-Saharan Africa. Mean systolic blood pressure was lowest in southeast Asia and Australasia, whereas mean diastolic blood pressure was lowest in the Americas. The crude measurements, along with the age-standardised and sex-standardised blood pressures before imputation are shown in the appendix (p 14).

Based on a linear mixed model, the global association between age and sex with systolic blood pressures in people who were not receiving antihypertensive treatment showed a linear increase, with the mean blood pressure in women exceeding the mean blood pressure in men at 80 years of age. For diastolic blood pressure,

the relationship shows an inverted U shape, with highest levels at age 50–55 years, and with blood pressure in women lower than in men until aged 80 years (figure 1).

After adjustment for age and sex (allowing for an interaction), significantly higher systolic and diastolic blood pressures were apparent in people receiving antihypertensive treatment (figure 2). Adjusting for age, sex, and antihypertensive treatment, systolic and diastolic blood pressures were significantly higher in those with a previous history of stroke, and systolic blood pressure was significantly higher in people with diabetes (figure 2). Smoking, alcohol intake (figure 2), and increasing BMI (figure 3) were also associated with significant increases in both systolic and diastolic blood pressures. The association with smoking was unaffected by further adjustment for BMI. By contrast, blood pressure readings in pregnant women, in people with a previous history of myocardial infarction, and those measured on the left arm were significantly lower than readings from the comparator groups (ie, non-pregnant, no history of previous myocardial infarction, and readings on the right arm, respectively; figure 2). Coefficients for the regression analyses are shown in the appendix (pp 15–17).

After adjusting for age, sex and antihypertensive medication, systolic and diastolic blood pressures varied significantly by day of the week (figure 4), with the highest systolic blood pressures recorded on Saturdays and the lowest systolic blood pressures measured on Tuesdays. Adjusting further for levels of alcohol consumption did not significantly alter the results (not shown).

Relatively modest differences in systolic and diastolic blood pressures were apparent across the four strata of national incomes. After multivariable adjustment for other participant characteristics (age, sex, treatment, BMI, ethnicity, diabetes, previous myocardial infarction or stroke, alcohol intake, smoking habit, measurement arm, and day of the week), and using mean blood pressure in lower-middle-income countries as the referent group, only diastolic blood pressures were significantly different (lower) in upper-middle-income countries, with a trend towards higher systolic and diastolic blood pressures in low-income countries (figure 5).

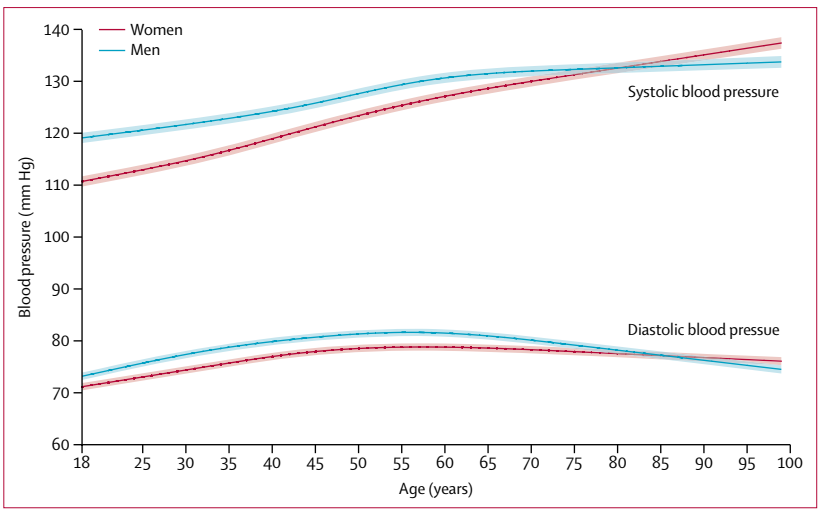

Figure 1: **Change in blood pressure with age and sex from linear mixed model, excluding individuals receiving treatment**

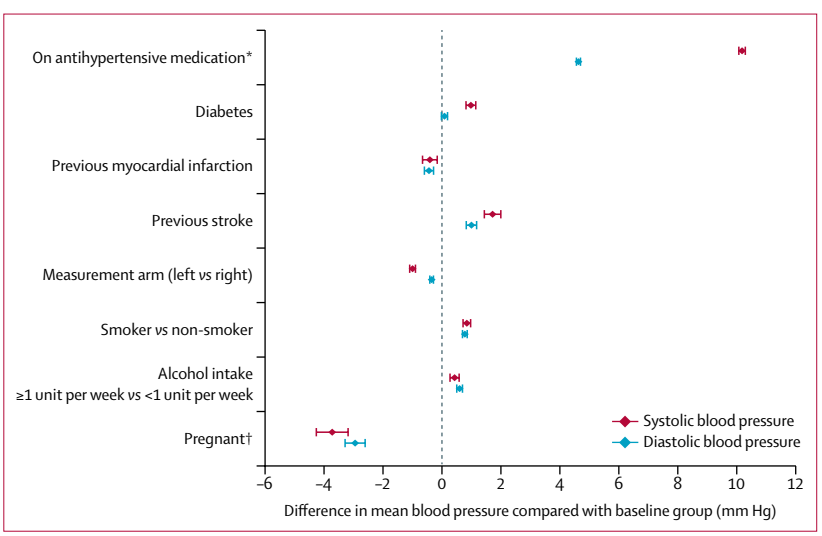

Figure 2: **Difference in mean blood pressure according to individual characterstics from linear mixed model adjusted for age, sex and, antihypertensive medication (except where annotated)**
*Adjusted for age and sex. †Adjusted for age and antihypertensive medication.

Discussion

MMM 2017 is the largest synchronised, standardised multinational screening campaign of any cardiovascular risk factor ever to be done. After the survey, we contacted attendees at our investigator meeting (January, 2018) by email and asked the question, "Was MMM17 the largest blood pressure screening event that has ever taken place in your country?". 34 (74%) of the 46 responders said it was the largest screen in their country. That 1·2 million adults could be screened in 80 countries during a 1-month period, with only 7 months' preparation, shows that mass screening is possible and can greatly enhance blood pressure awareness in large numbers of people.

That more than 250 000 adults (about 20% of those screened) were detected with either untreated or inadequately treated hypertension is commensurate with extensive, previously collated data showing low levels of awareness and inadequate control of hypertension.[5–7]

Because MMM relied heavily on volunteer staff, donations of devices to measure blood pressure, and locally raised support and funds, the cost of the campaign was modest, with ISH spending only about US$0·22 per patient screened. The identification of more than 250 000 adults with increased blood pressure (153 905 untreated adults plus 105 456 treated adults, but with uncontrolled blood pressure) for this modest level of central funding makes the exercise appear cost-effective, at approximately $1 per identified case. Pending

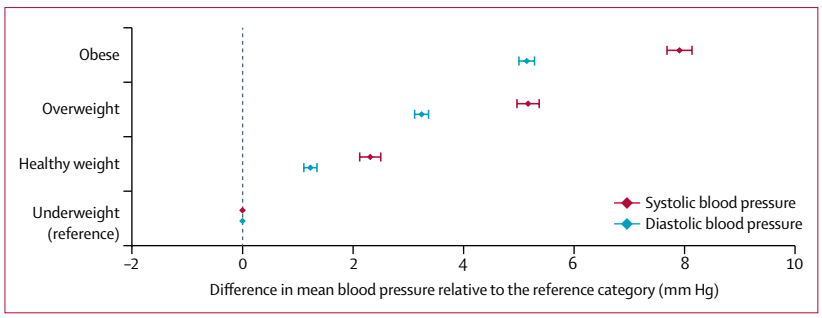

Figure 3: **Difference in mean blood pressure according to body-mass index from linear mixed model, adjusted for age, sex, and antihypertensive medication, with underweight as the reference category**

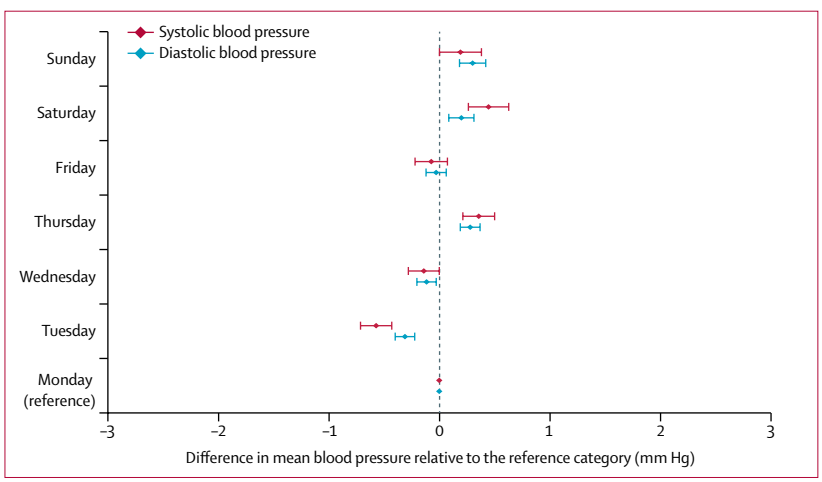

Figure 4: **Difference in mean blood pressure according to day of the week from linear mixed model adjusted for age, sex, and antihypertensive medication, with Monday as the reference day**

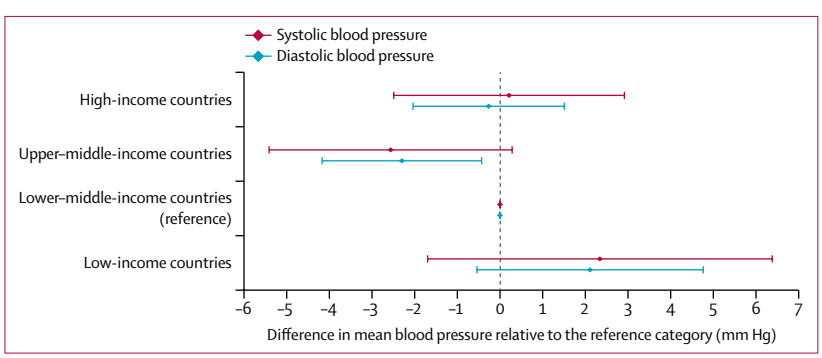

Figure 5: **Differences in mean blood pressure according to country income from a linear mixed model adjusted for multiple confounders, with lower-middle-income countries as the reference category**
The model was adjusted for age, sex, antihypertensive medication, body-mass index, ethnicity, diabetes, previous myocardial infarction or stroke, alcohol intake, smoking habit, measurement arm, and day of the week.

the establishment of blood pressure surveillance systems around the world, this inexpensive annual screening campaign could help offset the enormous health burden attributed to increased blood pressure.

In trials, clinic-based blood pressure measurements are often done by recording three readings and calculating the mean of the second and third readings. This practice is supported by our findings in that worldwide, blood pressures decreased significantly with each subsequent reading, with a marked difference in the proportion of people with hypertension depending on which reading was used, and the prevalence of hypertension was lowest when derived from the mean of the second and third readings. Thus, if values from only one set of readings are to be used to diagnose hypertension, which is unfortunately very common, the mean of the second and third readings are perhaps most suitable, unless further readings can be taken.

In view of the convenience sampling, which involved the use of divergent screening sites and a wide range of types of participants, it is inappropriate to compare the variable prevalences of hypertension observed around the world. However, associations with blood pressure in such large cross-sectional datasets are of interest, being internally valid.[19] Their external validity is much less affected in a sample of this size and diversity by not necessarily representing the global population. We confirmed lower blood pressures in pregnant women, the usual patterns of systolic and diastolic blood pressures with age, and alcohol consumption was also found to be associated with increased blood pressures. Our findings highlight that people with treated hypertension and established diabetes or cerebrovascular disease have less well controlled blood pressure, which emphasises the need for more assertive treatment in such high-risk patients.

That blood pressures were higher with readings from the right arm than from the left arm could be associated with right handedness being more common than left handedness and that, on average, right upper arms are larger than left upper arms. However, other hypothesised explanations for higher blood pressure on the right arm include the anatomy of the aortic arch and its branches.[20] The increased blood pressures in smokers is at odds with findings from several previous studies[21] and might reflect reporting bias by participants or the inability to distinguish duration and degree of exposure.

The variation in systolic blood pressure by day of the week, with the highest systolic blood pressures on Saturday and lowest blood pressures on Tuesdays, presumably relates to increased and decreased exposure, respectively, to one or more environmental factors that exert a pressor effect. For example, in some cultures, intakes of alcohol are higher during the weekend than during the week, although adjustment for the crude strata of alcohol intakes we recorded did not affect this finding. However, alcohol consumption is also likely to be under-reported, and the accuracy of reported intake might differ by region and culture. Further interrogation of these data in regions where alcohol is rarely consumed might shed light on these findings.

The proportion of participants with hypertension (including those on treatment) worldwide was high (34·9%), but had we applied the definition espoused in the most recent American guidelines, in which stage-1 hypertension was redefined as systolic blood pressure

above 130 mm Hg or diastolic blood pressure above 80 mm Hg, or both,[22] the proportion of people with hypertension almost doubles to 57·4%.

Limitations of these data include that, by design, they were not intended to be based on representative samples of the countries where screening took place and hence true prevalences cannot be reported. Furthermore, although almost 40% of readings were taken using OMRON devices and common training materials, standardisation of blood pressure measurement methods around the world was undoubtedly suboptimal; this was exemplified by three readings not being taken from about a third of participants. However, by virtue of having more than 800 000 participants with all three recordings, we could adjust submitted data based on one reading to the mean of the second and third readings using multiple imputation. The need to make this adjustment is evident in the decrease in mean blood pressure and hypertension between the three readings (table 2), with the proportion of people with hypertension being lower after imputation than when derived from any single reading.

As in any blood pressure screening taking place on a single occasion, a proportion of false-positive diagnoses is likely to have arisen. However, healthy diet and lifestyle advice was provided, and appropriate follow-up advice was given. Even if only 50% of new hypertension cases were correctly identified, about 75 000 adults with true hypertension were identified in MMM 2017, and at worst, harmless advice was provided to those who had blood pressure in the high end of the normal range rather than truly hypertensive pressures. Unfortunately, we could not assess the effect of these interventions on participants with increased blood pressure.

The mobile application produced for the campaign was suboptimally designed and caused several logistical problems. Most of the data were therefore entered onto spreadsheets, often having been collected manually and transferred. This resulted in under-reporting of several questions and also slowed down data collection. Furthermore, data cleaning was a much more protracted procedure, which delayed the generation of this report.

The analyses of mean blood pressures and prevalence of hypertension, and the choice of which readings are used to define these outcomes (table 2), highlight the importance of standardising such data when making comparisons between populations and when making the diagnosis at an individual level. As expected, a high mean blood pressure correlated with a high prevalence of hypertension across regions after adjusting for age and sex. Hence small differences in mean blood pressure, albeit highly significant, also reflect differences in the prevalence of hypertension. We found significant differences across regions in the proportions of individuals with hypertension who were not receiving treatment and in the proportion of patients receiving antihypertensive treatment who had controlled blood pressure. The differences (albeit mainly non-significant) in blood pressure by income level could explain some of the observed regional differences in blood pressure. Future region-specific and country-specific analyses will help elucidate these questions.

With valuable lessons learnt, the MMM campaign is being repeated in 2018 with a much improved data collection system, and it is anticipated that at least a similar sized population will be screened in May, 2018, with more complete data. Increased focus on the effect of other variables such as room temperature and altitude (at the site of blood pressure measurement) will be investigated more thoroughly in 2018.

Meanwhile, pending the establishment of systematic blood pressure surveillance systems around the world, we believe that MMM as a large blood pressure screening campaign based on convenience sampling is a useful and reasonably inexpensive tool to help raise awareness in the general population, and potentially among health policy makers, and to thereby help address the burden of disease caused by hypertension. We therefore propose that MMM should continue on an annual basis as long as large numbers of people with increased blood pressure can be identified and until suitable surveillance systems are in place.

Contributors

TB contributed towards literature search, data analysis and interpretation, figures and tables, and writing of the manuscript. AES contributed towards the original design of the MMM Campaign, development of the protocol, and critical evaluation and interpretation of the results and manuscript. MT contributed towards the drafting of the protocol, review of the study design, data collection and interpretation and provided a critical review of the manuscript. LMB contributed to the design of the campaign, assisted with the activities in Australia, and reviewed the manuscript. FJC contributed towards the study design, protocol writing, and data interpretation. CA contributed towards data management and analysis plan and provided oversight and interpretation of the analyses. RRC contributed towards supervision of screening sites in the Philippines and was the country leader, which included data collection, encoding or transcribing and transmission of data. RRC also assisted with the review of the final manuscript. AD organised the data collection in Africa and Mozambique and contributed to reviewing the manuscript. RK was South Africa country co-leader and contributed towards the study design in South Africa, ethics application for sites in South Africa, data collection, and quality control of data entry and final approval. DTL contributed towards data interpretation, reviewed the study design, and reviewed the manuscript. PMN contributed towards the data collection and provided input on evaluation of results as the chair of the ISH-Regional Activity Group for Europe. DP contributed to the design of the campaign, coordinated most of the activities in India, and reviewed the manuscript. AJR contributed towards MMM 2017 in Latin America as a coordinator, read and reviewed and gave considerations and agreement to the final manuscript. MPS contributed towards the study design, data collection, and data interpretation and writing. JW contributed towards data collection. MAW contributed towards the study design and the interpretation of the data and made substantial editing contributions. NRP contributed towards conceiving and designing the campaign, drafted the initial protocol, was academic project manager of the campaign, planned and wrote the first draft of the manuscript, and coordinated the input of the coauthors into the submitted manuscript.

Declaration of interests

AES declares having sponsored participation in Masterclass to medical specialists from Novartis. CA declares having received an Honorarium from the International Society of Hypertension for statistical analysis. PMN declares having received lecture honorarium from Astrazeneca and Novo Nordisk. DP declares having received an unrestricted

educational grant for the study in India from Torrent Pharmaceuticals, outside the submitted work. MAW is a steering committee member for Medtronic and Boston Scientific, consultant and advisor for ReCor, OMRON, and Astellas, a member of the scientific advisory board for Ablative Solutions, and a speaker for Menarini. NRP reports grants from Servier and Pfizer, personal fees from Servier, and fees for arranging and speaking at educational meetings from AstraZeneca, Lri Therapharma, Napi, Servier, and Pfizer; he holds no stocks or shares in any such companies. All other authors declare no competing interests.

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