Original Article

Additive association of knowledge and awareness on control of hypertension: a cross-sectional survey in rural India

Rathina Srinivasa Ragavan[a], Rohina Joshi[b,c], Roger G. Evans[d], Michaela A. Riddell[a], Kavumpurathu R. Thankappan[e,f], Clara K. Chow[b,g,h], Brian Oldenburg[i], Ajay S. Mahal[j,k], Kartik Kalyanram[l], Kamakshi Kartik[l], Oduru Suresh[a,l], Nihal Thomas[m], Gomathyamma K. Mini[e,n], Velandai K. Srikanth[a,o], Pallab K. Maulik[b,c,p], Mohammed Alim[c,q], Rama K. Guggilla[r], Doreen Busingye[a], and Amanda G. Thrift[a]

See editorial comment on page 44

Objective: To determine whether there is an interaction between knowledge about hypertension and awareness of hypertension on the treatment and control of hypertension in three regions of South India at different stages of epidemiological transition (see Video, Supplemental Digital Content 1, http://links.lww.com/HJH/B426).

Methods: Using a cross-sectional design, we randomly selected villages within each of rural Trivandrum, West Godavari, and Chittoor. Sampling was stratified by age group and sex. We measured blood pressure and administered a questionnaire to determine knowledge and awareness of hypertension. Logistic regression was used to assess associations of awareness and knowledge about hypertension with its treatment and control in participants with hypertension, while examining for statistical interaction.

Results: Among a total of 11 657 participants (50% male; median age 45 years), 3455 had hypertension. In analyses adjusted for age and sex, both knowledge score [adjusted odds ratio (aOR) 1.14 [95% confidence interval (CI) 1.12–1.17)] and awareness [aOR 104 (95% CI 82–134)] were associated with treatment for hypertension. Similarly, both knowledge score [aOR 1.10; 95% CI (1.08–1.12)] and awareness [aOR 13.4; 95% CI (10.7–16.7)], were positively associated with control of blood pressure in those with hypertension, independent of age and sex. There was an interaction between knowledge and awareness on both treatment and control of hypertension (*P* of attributable proportion <0.001 for each).

Conclusion: Health education to improve knowledge about hypertension and screening programs to improve awareness of hypertension may act in an additive fashion to improve management of hypertension in rural Indian populations.

Keywords: awareness, control of hypertension, diagnosis of hypertension, education, health literacy, knowledge, treatment

Abbreviations: AP, attributable proportion; BP, blood pressure; IRR, incidence-rate ratios; LMICs, low-to-middle income countries; PSU, primary sampling unit; RERI, relative excess risk because of interaction; SEP, socioeconomic position; SI, synergy index; WHO-STEPS, World Health Organization STEP-wise approach to disease surveillance; WHR, waist–hip ratio

INTRODUCTION

As rural Indian regions advance along the epidemiological transition, there is an increase in the prevalence of noncommunicable diseases, such as hypertension [1–3]. Rural regions encompass approximately 70% of the Indian population, and with India expected to be the most populous country by 2050 [4], the absolute burden

Journal of Hypertension 2021, 39:107–116

[a]School of Clinical Sciences at Monash Health, Monash University, Melbourne, [b]The George Institute for Global Health, University of New South Wales, Sydney, Australia, [c]George Institute for Global Health, Delhi, India, [d]Cardiovascular Disease Program, Biomedicine Discovery Institute and Department of Physiology, Monash University, Melbourne, Australia, [e]Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, [f]Department of Public Health & Community Medicine, Central University of Kerala, Kasaragod, Kerala, India, [g]Westmead Applied Research Centre, The University of Sydney, Sydney, New South Wales, [h]Department of Cardiology, Westmead Hospital, Sydney, [i]Melbourne School of Population and Global Health, University of Melbourne, [j]School of Public Health and Preventive Medicine, Monash University, [k]Nossal Institute for Global Health, Melbourne School of Population and Global Health, University of Melbourne, Melbourne, Australia, [l]Rishi Valley Rural Health Centre, Chittoor District, Andhra Pradesh, [m]Department of Endocrinology, Diabetes & Metabolism, Christian Medical College, Vellore, Tamil Nadu, [n]Global Institute of Public Health, Ananthapuri Hospitals and Research Institute, Trivandrum, Kerala, India, [o]Peninsula Clinical School, Central Clinical School, Monash University, Frankston, Australia, [p]George Institute for Global Health – Oxford University, Oxford, UK, [q]Clinical Neurosciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada and [r]Department of Population Medicine and Civilization Diseases Prevention, Faculty of Medicine with the Division of Dentistry and Division of Medical Education in English, Medical University of Bialystok, Bialystok, Poland

Correspondence to Amanda G. Thrift, Principal Investigator, School of Clinical Sciences at Monash Health, Epidemiology and Prevention Unit, Level 5, Block E Monash Medical Centre, Monash University, Melbourne, Australia. Tel: +61 3 8572 2656; fax: +61 3 9902 4240; e-mail: Amanda.thrift@monash.edu

Received 7 June 2020 **Revised** 26 June 2020 **Accepted** 26 June 2020

J Hypertens 39:107–116

DOI:10.1097/HJH.0000000000002594

of hypertension in these regions will rise substantially [5]. As hypertension is the most important modifiable risk factor for cardiovascular disease [6], accounting for more than 54% of strokes and 47% of ischemic heart disease events [7], reducing high blood pressure (BP) is imperative for reducing cardiovascular events.

Making patients aware of their hypertension (awareness) is the primary step in the management of hypertension [8]. In both observational and intervention studies, awareness of hypertension and knowledge about its causes and consequences have been associated with better treatment and control of high BP in many high-income and low-to-middle income populations [9–15]. However, it is unclear whether awareness and knowledge contribute in an additive fashion to treatment and control of hypertension, or whether these associations extend to regions with different social, cultural, and economic environments. We tested the hypothesis that knowledge about hypertension and awareness of hypertension are independently associated with both the treatment and control of hypertension in rural India, and that being both aware of one's hypertension and having knowledge about hypertension contribute to treatment and control of hypertension, more than either by itself.

METHODS

This investigation was conducted across three rural regions in South India [16], each of which is at a different stage of epidemiological transition [17]. These regions were: a rural region in the north of the District of Trivandrum in Kerala (herein referred to as Trivandrum), West Godavari (herein referred to as Godavari) in Northern Andhra Pradesh, and Chittoor (Rishi Valley region) in Southern Andhra Pradesh. The three regions are socioeconomically very diverse in terms of access to healthcare, income, education, and literacy (Table S1, http://links.lww.com/HJH/B425) [17]. Of the three sites, Rishi Valley is the least socioeconomically advanced, whilst Trivandrum is the most socioeconomically advanced (Table S1, http://links.lww.com/HJH/B425) [17].

Study design

For each of the three regions, wards (Trivandrum), villages (Godavari) or hamlets (Rishi Valley) were identified as the primary sampling unit (PSU). The PSUs were then randomly selected, using computer randomization, for inclusion in this cross-sectional study.

Power was based on outcomes for a cluster randomized controlled trial (Clinical Trials Registry – India, CTRI/2016/02/006678) [18], nested within this cross-sectional study. This meant that, for the present hypotheses, the sample size was larger than required for our primary hypothesis.

Recruitment

Participants were recruited between January 2014 and December 2015. Potential participants were randomly selected from population censuses, which were either available through polling booth registers (in Trivandrum) or were collected for the purpose of this study (Godavari and the Rishi Valley). Sampling was stratified by age and sex, before recruitment for Trivandrum and Godavari, and after screening in the Rishi Valley, into approximately equal numbers of people in 12 age and sex groups (18–24, 25–34, 35–44, 45–54, 55–64, 65+). To reduce bias, when eligible individuals were unavailable at the first visit they were revisited on a second or third occasion. A total of 11 657 participants were randomly recruited (Figure S1, http://links.lww.com/HJH/B425).

Ethics

The study was approved by relevant ethics committees and informed consent was obtained from all participants prior to their inclusion in the study (details in Supplementary Methods, http://links.lww.com/HJH/B425).

Training

Data collectors were trained in measurement of anthropometry and BP, in accordance with the WHO STEP-wise approach to disease surveillance (WHO-STEPS) protocol [19], for at least 5 days. Follow-up training was also conducted approximately a month after initial training to ensure that data collection complied with the WHO-STEPS protocol and was consistent between regions [19].

Clinical measurements

BP and heart rate were measured from the right arm using a digital automatic BP monitor (OMRON HEM-907, OMRON Healthcare Company, Kyoto, Japan), after participants had been seated quietly for at least 15 min [19]. BP was measured at least three times at 3 min intervals and measurements continued until readings differed by less than 10 mmHg for SBP and less than 6 mmHg for DBP, with a maximum of five measurements. The mean of the last two consecutive readings was used to define mean SBP and DBP. Height, weight, and waist and hip circumferences were also measured systematically (details in Supplementary Methods, http://links.lww.com/HJH/B425).

Self-reported data

Questionnaires were used to obtain information about demographics, lifestyle, socioeconomic position (SEP), knowledge about hypertension, and awareness of hypertensive status. The questionnaires were developed in English and translated into Telugu, for use in Andhra Pradesh, and Malayalam, for use in Kerala, and then back-translated to ensure that the meaning of the questions were maintained. Research staff were trained to interview participants individually and to complete the questionnaires after reading the questions aloud to participants. Hard copies of questionnaires were scanned at each region, sent to the coordinating centre, captured and verified using Teleform Elite Version 9 software (Cardiff, San Jose, California, USA), and then uploaded into a Microsoft Access database.

Knowledge about hypertension was assessed using questions about the effects of high BP, benefits of treating high BP, and measures to prevent hypertension (Table S2, http://links.lww.com/HJH/B425). When participants selected both correct and incorrect answers to a multiple choice question they were deemed to have answered that question incorrectly. The number of correct responses to the questions assessing knowledge about hypertension was

summed to generate a knowledge score ranging from 0 to a maximum of 10. In addition, knowledge score was dichotomized into groups of approximately equal size (cut point <5 and ≥5).

Participants' were categorized as being aware of hypertension if they responded, 'yes' to the question 'Have you previously been told by a doctor or health worker that you have elevated (high) blood pressure or hypertension?'.

Calculation of parameters

For the analyses, age was categorized as 60 years or less or above 60 years or used as a continuous variable. Hypertension was defined as having either a SBP at least 140 mmHg, and/or a DBP at least 90 mmHg, and/or on medication(s) to lower BP. Annual income, level of education, BMI, physical activity and waist–hip ratio (WHR) were also categorized for analyses (see Supplementary Methods, http://links.lww.com/HJH/B425).

Main outcomes

Participants were regarded as being treated for hypertension if they reported that they had previously been prescribed BP-lowering medication and/or reported that they were currently taking medication that lowers BP.

Controlled BP was defined as having SBP less than 140 mmHg and DBP less than 90 mmHg in those categorized as hypertensive patients.

Statistical analyses

Data cleaning (see Supplementary Methods, http://links.lww.com/HJH/B425) and statistical analyses were all performed in Stata 15.0 (StataCorp, College Station, Texas, USA).

For all continuous variables, we report medians (Quartile 1, Quartile 3), whereas proportions for categorical variables are reported as percentages (95% confidence intervals). Mann–Whitney *U*-tests (continuous variables) and χ^2 tests (categorical variables) were used to determine whether there were differences between women and men (P_{gender}).

We used univariable logistic regression to quantify the associations between the dichotomous outcomes of treatment or controlled BP and exposure variables including knowledge about, and awareness of, hypertension. We used multivariable logistic regression to determine factors associated with treatment of hypertension and the control of BP, independent of age, sex, BMI, and other factors. To determine the interaction between the dichotomized variables of knowledge and awareness of hypertension, we further assessed the relative excess risk due to interaction (RERI), the attributable proportion (AP), and the Synergy Index (SI), using the technique described by VanderWeele & Knol [20]. We also conducted sensitivity analyses of these associations stratified by age as the risk of hypertension increases with age. Multivariable logistic regression was used to determine the factors associated with awareness of hypertension. A Poisson regression was used to determine the factors associated with knowledge about hypertension using a count of the number of questions correctly answered, with outcomes presented as incidence-rate ratios (IRRs). Whenever variables were missing for a participant, that participant was excluded from any analyses involving that variable.

RESULTS

Sample characteristics

The median age of women and men in our sample was 45 years (Table 1). All other factors differed between women and men, including mean BP levels, measures of SEP, and risk factors. Notably, few women consumed alcohol (<1%) and only 56.4% were literate. In those with hypertension, a greater proportion of women were treated for hypertension (45.4%) than men (36.7%), whilst more men had hypertension of greater severity (6.9%) than women (5.1%).

In the sample screened, hypertension was most common in Trivandrum [35%; 95% CI (33–36)] and least common in the Rishi Valley [23%; 95% CI (21–24)]. Among those with hypertension ($n = 3455$), self-reported use of antihypertensive medications was least in the Rishi Valley (48%) and approximately 70% in Godavari and Trivandrum (Fig. 1a), similar to the proportion of those aware of their hypertension (Fig. 1b). Among those who were treated for hypertension, 6.5% (144 participants) were unaware of their hypertension. Control of BP was also poorest in the Rishi Valley (23%), compared with approximately 46% in Godavari and Trivandrum ($P < 0.05$) (Fig. 1a).

The median number of questions answered correctly for knowledge about hypertension was greatest in Trivandrum [9 (7, 10)], followed by Godavari [6 (2, 9)] and was least in the Rishi Valley [2 (0, 5)]. Although approximately 75% of participants correctly reported that high BP adversely affects health, fewer participants correctly identified which diseases are prevented when BP is controlled, being least in the Rishi Valley (7.5%), intermediate in Godavari (41%) and greatest in Trivandrum (54%; $P_{\text{region}} < 0.001$; Figure S2, http://links.lww.com/HJH/B425).

Knowledge, awareness, and treatment of hypertension

Both knowledge score [OR 1.14 (95% CI 1.12–1.17) per unit increase in score] and awareness [OR 104 (95% CI 82–134) were associated with treatment for hypertension (Fig. 2; Table S3, http://links.lww.com/HJH/B425). In interaction analyses, there was an additive effect of awareness and having a knowledge score of at least 5 on being treated for hypertension [SI; 1.64 (1.15–2.33) $P = 0.01$], an association that appeared to be limited to those aged above 60 years (Table 2).

Knowledge, awareness, and control of hypertension

Knowledge score was positively associated with the control of BP in both those with hypertension [adjusted odds ratio (aOR) 1.10; 95% CI (1.08–1.12)] and those treated for hypertension [aOR 1.03; 95% CI (1.01–1.06)], independent of age and sex (Fig. 2a, Table S4, http://links.lww.com/HJH/B425). Similarly, awareness of hypertension, independent of age and sex, was positively associated with the

TABLE 1. Demographics, blood pressure, and socioeconomic characteristics of participants by sex

Characteristics	Women ($n = 5852$)[a]	Men ($n = 5784$)[a]	P_{gender}
Age [years, median (Q1, Q3)]	45.0 (30.0, 60.0)	45.0 (30.0, 60.0)	0.81
Blood pressure			
SBP [mmHg, median (Q1, Q3)][b]	116.0 (106.5, 130.0)	122.5 (114.0, 134.0)	<0.001
DBP [mmHg, median (Q1, Q3)][b]	71.5 (64.5, 79.5)	74.5 (67.0, 82.0)	<0.001
Hypertension[b]	1807 (30.9)	1648 (28.5)	0.005
Grade 3 hypertension[b]	92 (5.1)	113 (6.9)	0.003
Treated for hypertension	820 (45.4)	604 (36.7)	<0.001
Marital status[c]			
Never married	361 (6.2)	1108 (19.2)	<0.001
Married	4084 (70.1)	4426 (76.8)	<0.001
Separated/divorced	109 (1.9)	35 (0.6)	<0.001
Widow/widower	1273 (21.9)	191 (3.3)	<0.001
Literate: can read and write[c]	3287 (56.4)	4139 (72.0)	<0.001
Education level[d]			
No formal schooling	1915 (32.9)	952 (16.6)	<0.001
Primary education	1421 (24.5)	1595 (27.7)	
Secondary education	1627 (28.0)	1998 (34.7)	
Tertiary education	850 (14.6)	1209 (21.0)	
Monthly income (Rs)[e]			
≤1000	1729 (35.2)	1413 (27.5)	<0.001
>1000–1900	898 (18.3)	1228 (23.9)	
>1900–3000	1186 (24.2)	1375 (26.7)	
>3000	1097 (22.3)	1129 (21.9)	
Ration card[c]			
No ration card	252 (4.3)	191 (3.3)	<0.001
Above poverty line card	1285 (22.1)	1202 (20.9)	
Below poverty line card	4103 (70.5)	4267 (74.2)	
Poorest of the poor card	184 (3.2)	94 (1.6)	
BMI (kg/m^2, median (Q1, Q3))[c]	23.3 (19.8, 27.0)	22.3 (19.5, 25.2)	<0.001
WHR (ratio, median (Q1, Q3))[d]	0.85 (0.78, 0.91)	0.93 (0.87, 0.98)	<0.001
Physical activity[b]			
Q1 (least active)	1419 (24.4)	1475 (25.6)	<0.001
Q2	1570 (27.0)	1353 (23.5)	
Q3	1615 (27.7)	1258 (21.9)	
Q4 (most active)	1218 (20.9)	1671 (29.0)	
Alcohol consumption[d]			
Never or infrequently	5800 (99.7)	4154 (72.2)	<0.001
Within the past 30 days	16 (0.3)	1600 (27.8)	

[a]Number (%) unless otherwise indicated (the denominator constitutes the full sample of women and men separately, except for Grade 3 hypertension and treatment of hypertension in which the denominator constitutes women and men with hypertension). Rs, Indian rupees; WHR, waist–hip ratio. *P*-values for comparing women to men were generated using Wilcoxon rank-sum tests for continuous variables and using χ^2 tests for categorical variables. Hypertension was defined as having either SBP at least 140 mmHg, or DBP at least 90 mmHg, and/or taking blood pressure (BP)-lowering medications. Grade 3 hypertension was defined as BP at least 180 mmHg systolic and/or at least 110 mmHg diastolic. Physical activity was grouped into four quartiles of metabolic equivalent of tasks.
[b]Six missing observations.
[c]Forty-eight to 58 missing observations.
[d]Sixty-six to 69 missing observations.
[e]One thousand five-hundred and eighty-one missing observations. In total, 21 further individuals are missing data on sex, and so are not included in any of the data in this table.

control of BP in those with hypertension [aOR 13.4; 95% CI (10.7–16.7)], but was inversely associated with the control of BP among those who were treated [aOR 0.48; 95% CI (0.32–0.71)] (Fig. 2b). In interaction analyses, there appeared to be an additive effect of awareness and having a knowledge score of at least 5 on control of BP [AP; 0.23 (0.10–0.37); *P* less than 0.001 Table 3]. However, an interaction was not evident when the analysis was restricted to those who received treatment for their hypertension (Table S5, http://links.lww.com/HJH/B425).

Importantly, among those treated for hypertension, awareness of hypertension was greater with each increasing level of severity of hypertension (Table S6, http://links.lww.com/HJH/B425), but this association did not appear to differ with knowledge (Table S7, http://links.lww.com/HJH/B425).

Factors associated with knowledge and awareness

Factors positively associated with knowledge score included age 60 years or less, and lifestyle factors, such as unhealthy BMI and unhealthy WHR (Fig. 3; Table S8, http://links.lww.com/HJH/B425). Socioeconomic factors, such as literacy, greater levels of educational attainment, and greater income were also positively associated with knowledge score. With each greater level of education, the incidence-rate ratios (IRR) for knowledge score increased. In contrast to these variables relating to SEP, consumption of alcohol more than once a month was inversely associated with knowledge score when adjusted for age and sex (Fig. 3; Table S8, http://links.lww.com/HJH/B425).

Factors positively associated with awareness of hypertension included greater SEP and unhealthy levels of

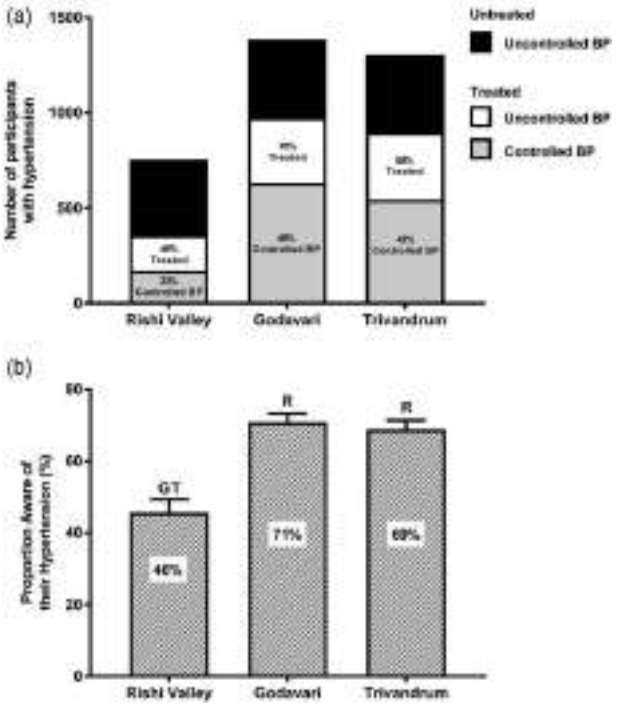

FIGURE 1 (a) Prevalence, treatment, control of hypertension and (b) awareness of hypertension in samples in the Rishi Valley, Godavari, and Trivandrum. (a) Proportion of those treated and those with controlled blood pressure (BP) are shown as percentage of those with hypertension. Hypertension was defined as those with SBP at least 140 mmHg and/or DBP at least 90 mmHg and/or those taking antihypertensive medication(s). Treated was defined as those who received treatment for hypertension. Controlled BP was defined as SBP less than 140 mmHg and DBP less than 90 mmHg. (b) *P* value was generated using χ^2, comparing the proportions of those with awareness in the three regions. Dunn's multiple comparisons were used to assess pair-wise relationships between the three regions. G denotes *P* less than 0.01 for comparison with Godavari. T denotes *P* less than 0.01 for comparison with Trivandrum. R denotes *P* less than 0.01 for comparison with the Rishi Valley. *N* = 3455 (771 Rishi Valley, 1380 Godavari, 1304 Trivandrum); 18 missing observations from the Rishi Valley. Error bars show 95% confidence intervals.

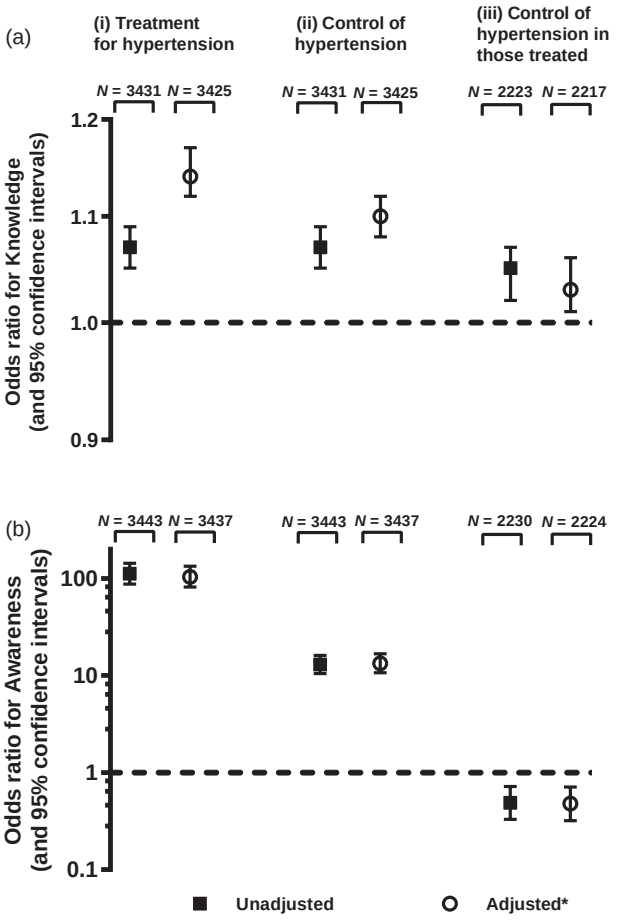

FIGURE 2 Unadjusted and adjusted odds ratios for associations of (a) knowledge score and (b) awareness with (i) treatment for hypertension, (ii) control of hypertension, and (iii) control of hypertension in those treated. All *P* less than 0.05 for the odds ratio differing from unity. *Denotes odds ratios adjusted for age and sex. Missing observations: (a) treatment (30 unadjusted, 36 adjusted); controlled (30 unadjusted, 36 adjusted); controlled in those treated (6 unadjusted, 14 adjusted); (b) treatment (18 unadjusted, 24 adjusted); controlled (18 unadjusted, 24 adjusted); controlled in those treated (1 unadjusted, 7 adjusted).

adiposity (Fig. 4; Table S9, http://links.lww.com/HJH/B425). When adjusted for age and sex, secondary and tertiary education were associated with greater odds for awareness of hypertension than primary education or no schooling. Being aged 60 years or less, male, and consuming alcohol at least once in the past month were inversely associated with being aware of one's hypertension.

DISCUSSION

In three diverse populations in rural India, we found that greater awareness of hypertension and better knowledge about hypertension were independently and additively associated with control of BP. Furthermore, this greater awareness and knowledge appeared to be associated with better treatment for hypertension in an additive manner. We also identified that awareness and knowledge are strongly associated with SEP as measured by income, literacy, or educational attainment. Additionally, awareness, treatment, and control of hypertension differed according to region, with poorer awareness, treatment and control being the most common in the poorest region. Even just a few years of schooling seemed to have a substantial effect on awareness and knowledge, demonstrating the imperative for universal access to education. Our findings also provide an impetus for educational programs specifically targeted towards increasing knowledge of chronic diseases, such as hypertension.

The strong association of being treated for hypertension with both awareness and knowledge likely arises from two mechanisms. Firstly, awareness likely results from a confirmed clinical diagnosis that is conveyed to the patient [8], together with advice about lifestyle patterns and the need for adhering to medications, if prescribed. Secondly, knowledge about hypertension is associated with better access to healthcare and engaging in routine health checks [21–23], thus providing opportunities for treatment. The fact that knowledge and awareness both appear to contribute independently to treatment of hypertension, in an additive fashion, highlights that treatment might be greatly enhanced by targeting these factors together. Not only do the opportunities for treatment arise with better knowledge, but there is considerable importance in screening patients, correctly diagnosing their status of hypertension, and clearly informing them of their condition.

TABLE 2. Association of awareness of hypertension and knowledge about hypertension with treatment for hypertension among women and men, for all age groups and stratified by age, three rural regions in India, 2014–2015

	Knowledge about hypertension						Knowledge within strata of awareness		Measure of interaction on Additive scale		
	Knowledge score <5			Knowledge score ≥5							
	N +/− treated	OR (95% CI)	*P*	*N* +/− treated	OR (95% CI)	*P*	OR (95%CI)	*P*	Index	OR (95% CI)	*P*
All ages											
Unaware of hypertension	62/514	1.00		82/556	1.45 (1.02–2.09)	0.04	1.46 (1.01–2.10)	0.04			
Aware of hypertension	770/63	99.6 (68.8–144)	<0.001	1309/75	163 (114–234)	<0.001	1.64 (1.15–2.34)	0.01			
Awareness within strata of knowledge		100 (69.0–145)	<0.001		117 (83.3–164)	<0.001					
									RERI	63.2 (13.3–113.1)	0.01
									AP	0.39 (0.17–0.60)	<0.001
									SI	1.64 (1.15–2.33)	0.01
Age group 60 years or less											
Unaware of hypertension	33/278	1.00		42/403	0.98 (0.60–1.60)	0.94	1.01 (0.61–1.65)	0.98			
Aware of hypertension	318/29	90.7 (53.7–153)	<0.001	752/59	111 (70.7–174)	<0.001	1.21 (0.76–1.93)	0.43			
Awareness within strata of knowledge		92.1 (54.4–156)	<0.001		112 (73.9–170)	<0.001					
									RERI	20.3 (−25.9 to 66.5)	0.40
									AP	0.18 (−0.20 to 0.56)	0.35
									SI	1.23 (0.77–1.96)	0.40
Age group > 60 years											
Unaware of hypertension	29/236	1.00		40/153	2.18 (1.30–3.68)	<0.01	2.18 (1.29–3.86)	<0.01			
Aware of hypertension	452/34	108 (64.4–182)	<0.001	557/16	295 (156–556)	<0.001	2.73 (1.48–5.04)	<0.01			
Awareness within strata of knowledge		108 (64.2–182)	<0.001		140 (75.3–259)	<0.001					
									RERI	185 (16.8–354)	0.03
									AP	0.63 (0.40–0.85)	<0.001
									SI	2.71 (1.47–4.99)	<0.01

Data are presented as odds ratios (95% confidence interval), and all analyses are adjusted for age. Interaction exists if CI of RERI does not include 0 and/or CI of AP does not include 0 and/or CI of SI does not include 1. AP, attributable proportion; CI, confidence interval; OR, odds ratio; RERI, relative excess risk due to interaction; SI, Synergy Index. $n = 3431$ for all ages (30 missing observations for knowledge or awareness). $n = 1914$ for those aged ≤60 years (11 missing observations for knowledge or awareness). $n = 1517$ for those aged >60 years (19 missing observations for knowledge or treatment).

TABLE 3. Association of awareness of hypertension and knowledge about hypertension with control of hypertension among women and men, for all age groups and stratified by age, three rural regions in India, 2014–2015

	Knowledge about hypertension						Knowledge within strata of awareness		Measure of interaction on additive scale		
	Knowledge score <5			Knowledge score ≥5							
	N +/− controlled	OR (95% CI)	*P*	*N* +/− controlled	OR (95% CI)	*P*	OR (95% CI)	*P*	Index	OR (95% CI)	*P*
All ages											
Unaware of hypertension	44/532	1.00		64/574	1.24 (0.83–1.86)	0.30	1.50 (0.99–2.27)	0.06			
Aware of hypertension	421/412	13.0 (9.24–18.2)	<0.001	815/569	17.2 (12.4–23.8)	<0.001	1.28 (1.08–1.53)	0.01			
Awareness within strata of knowledge		13.2 (9.36–18.5)	<0.001		13.7 (10.3–18.2)	<0.001					
									RERI	3.98 (1.23–6.73)	0.01
									AP	0.23 (0.10–0.37)	<0.001
									SI	1.33 (1.10–1.61)	0.01
Age group 60 years or less											
Unaware of hypertension	25/286	1.00		37/408	0.96 (0.56–1.64)	0.88	1.16 (0.67–2.00)	0.60			
Aware of hypertension	195/152	15.1 (9.54–24.0)	<0.001	507/304	19.1 (12.4–29.5)	<0.001	1.24 (0.96–1.60)	0.11			
Awareness within strata of knowledge		15.1 (9.50–24.1)	<0.001		19.9 (13.6–29.1)	<0.001					
									RERI	4.02 (−0.38 to 8.44)	0.07
									AP	0.21 (0.01–0.42)	0.04
									SI	1.29 (0.97–1.70)	0.08
Age group above 60 years											
Unaware of hypertension	19/246	1.00		27/166	2.12 (1.14–3.93)	0.02	2.11 (1.13–3.92)	0.02			
Aware of hypertension	226/260	11.2 (6.81–18.5)	<0.001	308/265	15.1 (9.22–24.8)	<0.001	1.35 (1.06–1.72)	0.02			
Awareness within strata of knowledge		11.3 (6.82–18.5)	<0.001		7.16 (4.62–11.1)	<0.001					
									RERI	2.79 (−0.65 to 6.23)	0.11
									AP	0.18 (−0.02 to 0.38)	0.07
									SI	1.25 (0.95–1.62)	0.11

Data are presented as odds ratios (95% confidence interval), and all analyses are adjusted for age. Interaction exists if CI of RERI does not include 0 and/or CI of AP does not include 0 and/or CI of SI does not include 1. AP, attributable proportion; CI, confidence interval; OR, odds ratio; RERI, relative excess risk due to interaction; SI, Synergy Index. $n = 3431$ for all ages (30 missing observations for knowledge or awareness). $n = 1914$ for those aged 60 years or less (11 missing observations for knowledge or awareness). $n = 1517$ for those aged more than 60 years (19 missing observations for knowledge or treatment).

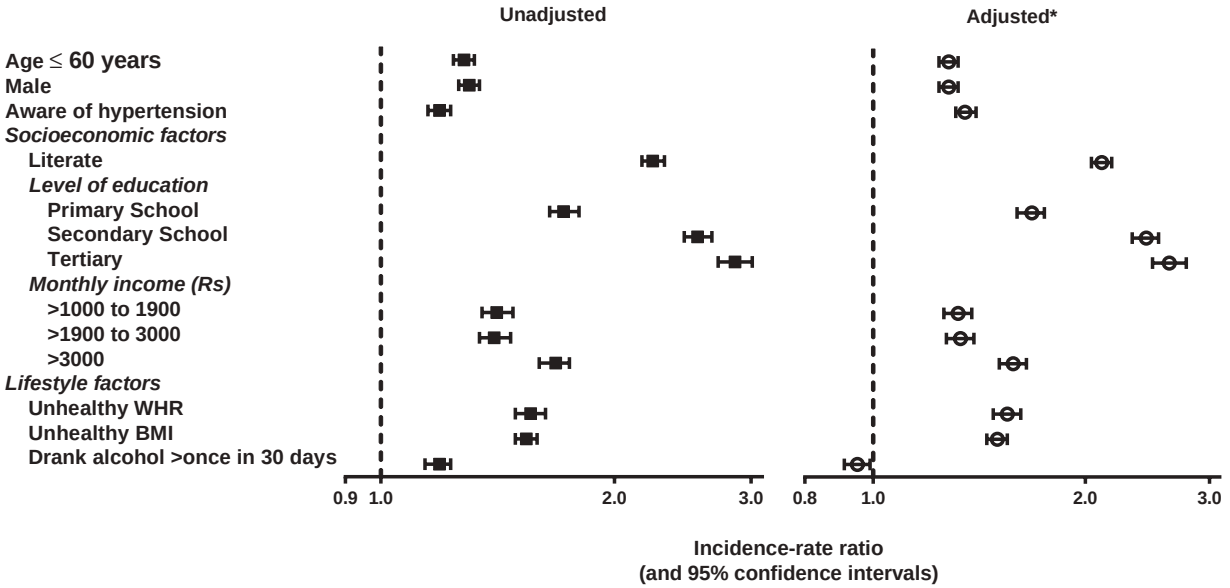

FIGURE 3 Unadjusted and adjusted incidence-rate ratios for factors associated with knowledge score. Data were obtained using Poisson regression. Error bars that do not cross the line of null effect indicate *P* less than 0.05. *Age 60 years or less was adjusted for sex; male was adjusted for age; and all other variables were adjusted for both age and sex. Unhealthy waist–hip ratio (WHR) denotes WHR at least 0.80 for women and at least 0.90 for men. Unhealthy BMI denotes BMI at least 23 kg/m^2. *N* = 2986 to 3431 for all variables except income (591–596 missing observations for income).

Similar to the findings for treatment, both awareness and knowledge appeared to be additively associated with control of BP, demonstrating the critical role of both awareness and knowledge in controlling BP. Presumably, this effect is largely driven by the dual influences of awareness of, and knowledge about, hypertension on adherence to treatment regimens [12,24–26]. This highlights likely pathways for facilitating control of BP and emphasizes the importance of educating patients about their condition.

Our observation of a stronger association between awareness and treatment of hypertension than awareness and control of BP indicates that other factors, such as adoption of healthy changes in lifestyle and better adherence to prescribed treatment, are very likely to be areas to target in order to improve control of BP. Further support that knowledge facilitates healthy lifestyles is provided by our observation that knowledge was associated with control of BP even in those unaware of their hypertension. This

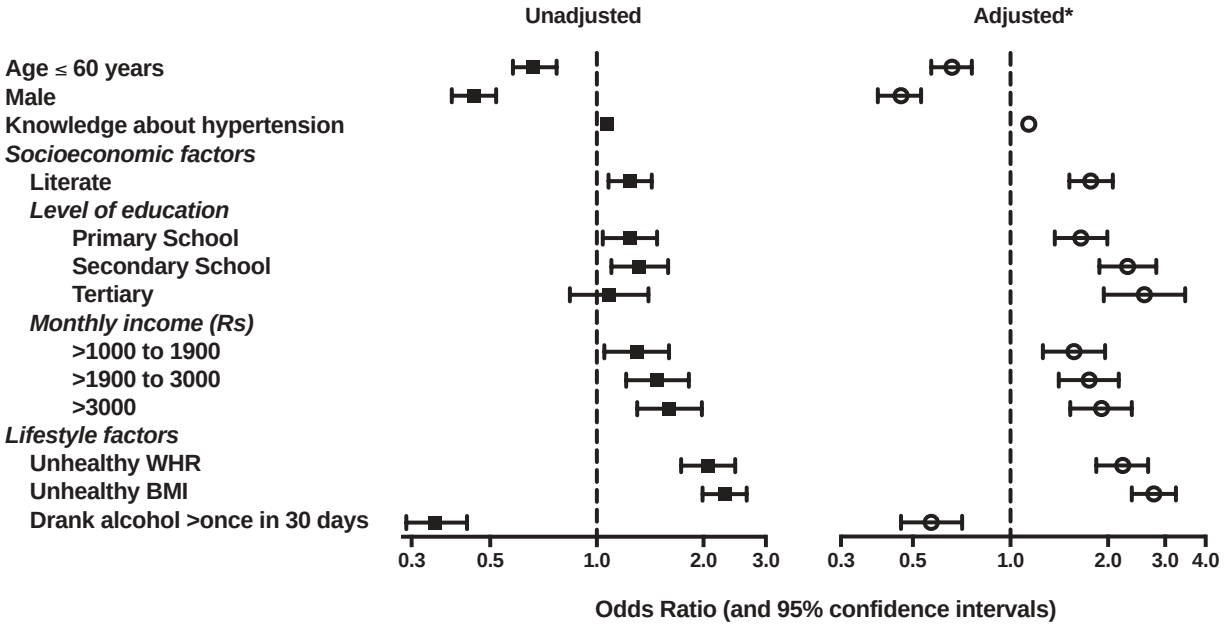

FIGURE 4 Unadjusted and adjusted odds ratios for factors associated with awareness of hypertension. Data were obtained using logistic regression. Error bars that do not cross the line of null effect indicate *P* less than 0.05. *Age 60 years or less was adjusted for sex; male was adjusted for age; and all other variables were adjusted for both age and sex. Unhealthy waist–hip ratio (WHR) denotes WHR at least 0.80 for women and at least 0.90 for men. Unhealthy BMI denotes BMI at least 23 kg/m^2. *N* = 3392 to 3443 for all variables except income (581–586 missing observations for income).

potential mechanism is further supported by our finding that people with controlled BP were more likely to abstain from alcohol than those with uncontrolled BP (data not shown).

Interestingly, in an analysis restricted to the sample of patients treated for hypertension, BP was less likely to be controlled in those aware of their hypertension than in those who remained unaware of their hypertension. This finding appears counterintuitive. However, we speculate that this observation may be as patients who are aware of their condition are more likely to have hypertension that is long-standing, severe, or is poorly responsive to treatment [27]. In support of this, we found that among those treated for hypertension, for each increasing level of severity of hypertension, there appeared to be greater awareness of hypertension. It is likely that people with more severe hypertension are more likely aware of their hypertension as they may have repeatedly attempted to control their BP and been advised that their BP is not being controlled [28]. So this may simply reflect the effort involved in trying to control severe BP. Thus, the severity of hypertension potentially influences the relationship between awareness and control of hypertension.

There appears to be considerable heterogeneity in knowledge about hypertension and awareness of hypertension, even within rural regions in India, potentially somewhat driven by education. More than 50% of those in Trivandrum correctly identified the effects of hypertension as well as measures to prevent high BP, compared with less than 10% in the Rishi Valley, a figure similar to that found in other studies conducted in India and other LMICs [26,29]. Poor educational attainment appears to be a critical barrier, not only to individuals' knowledge about hypertension but also to awareness of hypertension, a finding also reported by others [11]. In other research, higher levels of education have been shown to be associated with greater access to healthcare and better health literacy [26,30], and therefore, greater ability to interpret and understand health advice [31]. Overall, increasing education appears to promote both greater awareness of one's own hypertension and better knowledge about hypertension.

Education likely provides a means to overcome barriers to treating and controlling hypertension. Factors, such as healthcare providers' knowledge about hypertension, healthcare guidelines, patients' access to healthcare, and affordability of healthcare [24,32–34], influence the management of hypertension. Improving public health awareness campaigns and extending screening of hypertension in the population, particularly to those with minimal education, is likely to alleviate these barriers. For example, extending screening programs to cover a larger proportion of the population and educating individuals about their diagnosis is likely to facilitate better treatment of hypertension [35]. May Measurement Month is a global campaign, initiated by the International Society of Hypertension, that is specifically aimed at addressing these issues (https://maymeasure.com/). Similarly, improving public education about hypertension can empower patients with strategies to manage high BP [35]. For example, in Nepal, using community health volunteers to educate participants about hypertension, Neupane *et al.* [14], found a significant improvement in their control of hypertension. Similar interventions may be employed in rural India to better manage hypertension in these populations.

There were several limitations in the present study. The questionnaires were modified specifically for each region, which resulted in slight variations in the number of questions administered to participants. As a result, some questions were asked of only a few participants and had to be excluded from the analyses. The questions on knowledge also included some multiple choice responses, which may have prompted participants to provide correct answers, thereby resulting in an overestimate of knowledge. Despite this, knowledge was still poor overall. The fact that participants could choose incorrect as well as correct responses somewhat reduced the likelihood that all responses would be correct. Furthermore, while efforts were made to interview eligible family members separately, there may have been some situations where participants may have overheard responses, also providing a prompt to answer certain questions on knowledge in a particular way. Finally, as our study was cross-sectional, we are unable to establish causation or determine temporality between the exposure and outcome variables. Therefore, whilst we could identify that knowledge and awareness of hypertension are independently and additively associated with the treatment and control of BP, we were not able to establish that knowledge or awareness causes or leads to treatment and control.

Our study also has a number of strengths, particularly the large sample size of 11 657 participants. The use of such a large sample, across three very diverse regions, allows some generalizability to other parts of rural India. The fact that our sampling strategy generated equal numbers of participants across age and sex groups enabled a robust assessment of the contribution of age to awareness, treatment, and control of hypertension. To ensure standardization across regions, data collectors were trained in collection of BP measurements according to the WHO-STEPS protocol [19]. The questions on knowledge about hypertension were extensive and enabled a robust assessment of relevant knowledge about hypertension. These measures strengthened the internal validity of the dataset and enabled some generalization to the population of interest.

Other investigators have examined the association between knowledge and awareness separately on the management of hypertension and produced similar results to our findings [3–5,13]. However, this study provides the first evidence that better awareness of one's own hypertension and better knowledge about hypertension are independently and additively associated with better treatment and control of hypertension in disadvantaged rural India.

In conclusion, knowledge about, and awareness of, hypertension are important targets for improving treatment and control of hypertension in rural India. These can be addressed by introducing programs and campaigns to screen for hypertension and improving health literacy through community, workplace, or school programs.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of the health workers who collected the data presented in this article.

Sources of funding: This work was supported by the National Health and Medical Research Council (NHMRC, Australia) under the Global Alliance for Chronic Diseases Hypertension Program (GNT1040030). The following acknowledge fellowship support: A.G.T. (NHMRC GNT1042600]; C.K.C. (NHMRC GNT1105447 co-funded by the National Heart Foundation of Australia (NHFA); R.J. (NHFA 100484); P.K.M. (Wellcome Trust/Department of Biotechnology India Alliance Intermediate Career Fellowship IA/I/13/1/500879); R.K.G. (Marie Sklodowska-Curie Actions Fellowship (H2020-EU.1.3.4). Grant agreement ID: 754432).

Conflicts of interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare no support from any organization for the submitted work (apart from a government funding body as outlined below); C.K.C. reports grants from the National Health and Medical Research Council (NHMRC) and National Heart Foundation of Australia, outside the submitted work; R.G.E. reports grants from the NHMRC, during the conduct of the study. K.Kal., K.Kar., and A.G.T. report grants from NHMRC for this study and for other projects outside the submitted work; R.K.G. reports research grants from the European Commission and the Polish Ministry of Science and Higher Education, outside the submitted work. R.K.G. reports being a shareholder in three Indian multinational pharmaceutical companies (Ajanta Pharma Limited, Divi's Laboratories Limited, and NATCO Pharma Limited); there are no other relationships or activities that could appear to have influenced the submitted work.

REFERENCES

1. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *Lancet* 2005; 365:217–223.
2. Reddy KS. Hypertension control in developing countries: generic issues. *J Hum Hypertens* 1996; 10 Suppl 1:S33–S38.
3. Reddy KS, Naik N, Prabhakaran D. Hypertension in the developing world: a consequence of progress. *Curr Cardiol Rep* 2006; 8:399–404.
4. Anchala R, Kannuri NK, Pant H, Khan H, Franco OH, Di Angelantonio E, Prabhakaran D. Hypertension in India: a systematic review and meta-analysis of prevalence, awareness, and control of hypertension. *J Hypertens* 2014; 32:1170–1177.
5. Gupta R, Gaur K, Ram CVS. Emerging trends in hypertension epidemiology in India. *J Hum Hypertens* 2019; 33:575–587.
6. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, *et al.*, National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, National High Blood Pressure Education Program Coordinating Committee. The Seventh Report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA* 2003; 289:2560–2572.
7. GBD Mortality Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; 385:117–171.
8. Mills KT, Bundy JD, Kelly TN, Reed JE, Kearney PM, Reynolds K, *et al.* Global disparities of hypertension prevalence and control: a systematic analysis of population-based studies from 90 countries. *Circulation* 2016; 134:441–450.
9. Akoko BM, Fon PN, Ngu RC, Ngu KB. Knowledge of hypertension and compliance with therapy among hypertensive patients in the Bamenda health district of Cameroon: a cross-sectional study. *Cardiol Ther* 2017; 6:53–67.
10. Glynn LG, Murphy AW, Smith SM, Schroeder K, Fahey T. Self-monitoring and other nonpharmacological interventions to improve the management of hypertension in primary care: a systematic review. *Br J Gen Pract* 2010; 60:e476–e488.
11. Alam DS, Chowdhury MA, Siddiquee AT, Ahmed S, Niessen LW. Awareness and control of hypertension in Bangladesh: follow-up of a hypertensive cohort. *BMJ Open* 2014; 4:e004983.
12. Jones C, Simpson SH, Mitchell D, Haggarty S, Campbell N, Then K, *et al.* Enhancing hypertension awareness and management in the elderly: lessons learned from the Airdrie Community Hypertension Awareness and Management Program (A-CHAMP). *Can J Cardiol* 2008; 24: 561–567.
13. Gupta R, Gupta VP, Prakash H, Agrawal A, Sharma KK, Deedwania PC. 25-year trends in hypertension prevalence, awareness, treatment, and control in an Indian urban population: Jaipur Heart Watch. *Indian Heart J* 2018; 70:802–807.
14. Neupane D, McLachlan CS, Mishra SR, Olsen MH, Perry HB, Karki A, Kallestrup P. Effectiveness of a lifestyle intervention led by female community health volunteers versus usual care in blood pressure reduction (COBIN): an open-label, cluster-randomised trial. *Lancet Glob Health* 2018; 6:e66–e73.
15. Ozoemena EL, Iweama CN, Agbaje OS, Umoke PCI, Ene OC, Ofili PC, *et al.* Effects of a health education intervention on hypertension-related knowledge, prevention and self-care practices in Nigerian retirees: a quasi-experimental study. *Arch Public Health* 2019; 77:23.
16. Riddell MA, Joshi R, Oldenburg B, Chow C, Thankappan KR, Mahal A, *et al.* Cluster randomised feasibility trial to improve the Control of Hypertension In Rural India (CHIRI): a study protocol. *BMJ Open* 2016; 6:e012404.
17. Thrift AG, Ragavan RS, Riddell MA, Joshi R, Thankappan KR, Chow C, *et al.* Hypertension in rural India: the contribution of socioeconomic position. *J Am Heart Assoc* 2020; 9:e014486.
18. Gamage DG, Riddell MA, Joshi R, Thankappan KR, Chow CK, Oldenburg B, *et al.* Effectiveness of a scalable group-based education and monitoring program, delivered by health workers, to improve control of hypertension in rural India: a cluster randomised controlled trial. *PLoS Med* 2020; 17:e1002997.
19. World Health Organization. WHO STEPS: surveillance manual - update: June 2008. Available at: http://www.who.int/ncds/surveillance/steps/STEPS_Manual.pdf . (Accessed 10 October 2018)
20. VanderWeele TJ, Knol MJ. A tutorial on interaction. *Epidemiol Methods* 2014; 3:33–72.
21. Kusuma YS, Gupta SK, Pandav CS. Knowledge and perceptions about hypertension among neo- and settled-migrants in Delhi, India. *CVD Prevent Control* 2009; 4:119–129.
22. Parmar P, Rathod G, Rathod S, Goyal R, Aggarwal S, Parikh A. Study of knowledge, attitude and practice of general population of Gandhinagar towards hypertension. *Intl J of Curr Microbiol App Sci* 2014; 3: 680–685.
23. Sanne S, Muntner P, Kawasaki L, Hyre A, DeSalvo KB. Hypertension knowledge among patients from an urban clinic. *Ethn Dis* 2008; 18: 42–47.
24. Zinat Motlagh SF, Chaman R, Ghafari SR, Parisay Z, Golabi MR, Eslami AA, Babouei A. Knowledge, treatment, control, and risk factors for hypertension among adults in Southern Iran. *Int J Hypertens* 2015; 2015:897070.
25. Sepanlou SG, Kamangar F, Poustchi H, Malekzadeh R. Reducing the burden of chronic diseases: a neglected agenda in Iranian healthcare system, requiring a plan for action. *Arch Iran Med* 2010; 13:340–350.
26. Businge D, Arabshahi S, Evans R, Riddell MA, Srikanth VK, Kartik K, *et al.* Knowledge of risk factors for hypertension in a rural Indian population. *Heart Asia* 2019; 11:e011136.
27. Yaxley JP, Thambar SV. Resistant hypertension: an approach to management in primary care. *J Family Med Prim Care* 2015; 4: 193–199.
28. Oparil S, Calhoun DA. Managing the patient with hard-to-control hypertension. *Am Fam Physician* 1998; 57:1007–1014; 1019–1020.

29. Almas A, Godil SS, Lalani S, Samani ZA, Khan AH. Good knowledge about hypertension is linked to better control of hypertension; a multicentre cross sectional study in Karachi, Pakistan. *BMC Res Notes* 2012; 5:579.
30. Bokhour BG, Cohn ES, Cortes DE, Solomon JL, Fix GM, Elwy AR, *et al*. The role of patients' explanatory models and daily-lived experience in hypertension self-management. *J Gen Intern Med* 2012; 27:1626–1634.
31. Viera AJ, Cohen LW, Mitchell CM, Sloane PD. High blood pressure knowledge among primary care patients with known hypertension: a North Carolina Family Medicine Research Network (NC-FM-RN) study. *J Am Board Fam Med* 2008; 21:300–308.
32. Busingye D, Arabshahi S, Evans RG, Srikanth VK, Kartik K, Kalyanram K, *et al*. Factors associated with awareness, treatment and control of hypertension in a disadvantaged rural Indian population. *J Hum Hypertens* 2017; 31:347–353.
33. Ahn S, Smith ML, Cho J, Bailey JE, Ory MG. Hypertension awareness and associated factors among older Chinese adults. *Front Public Health* 2013; 1:67.
34. Minor D, Wofford M, Wyatt SB. Does socioeconomic status affect blood pressure goal achievement? *Curr Hypertens Rep* 2008; 10:390–397.
35. Gupta R, Yusuf S. Towards better hypertension management in India. *Indian J Med Res* 2014; 139:657–660.