Risk factors of uncontrolled hypertension in urban slums of Central India: A Community health worker based two-year follow up

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Abstract

**Background:** Hypertension is a leading cause of cardiovascular diseases its control is poor. There exists heterogeneity in levels of blood-pressure control among various population subgroups. Present study conducted in framework of National Program for prevention and control of cancer, diabetes, cardiovascular diseases and stroke (NPCDCS) in India, aims to estimate proportion of optimal blood pressure control and identify potential risk factors pertaining uncontrolled hypertension consequent to initial screening.

**Methods:** We conceived a cohort of individuals with hypertension confirmed in a baseline screening in sixteen urban slum clusters of Bhopal (2017-2018). Sixteen Accredited Social Health Activists (ASHAs) were trained from within these urban slum communities. Individuals with hypertension were linked to primary care providers and followed-up for next two years. Obtaining optimal blood-pressure control (defined as SBP< 140 and DBP<90 mm of Hg) was a key outcome. Role of baseline anthropometric, and CVD risk factors was evaluated as predictors of blood-pressure control on univariate and multivariate analysis.

**Results:** Of a total of 6174 individuals, 1571 (25.4%) had hypertension, of which 813 were previously known and 758 were newly detected during baseline survey. Two year follow up was completed for 1177 (74.9%). Blood-pressure was optimally controlled in 301 (26%) at baseline, and in 442 (38%) individuals at two years (absolute increase of 12%; 95% CI 10.2-13.9). Older age, physical-inactivity, higher BMI and newly diagnosed hypertension were significantly associated with uncontrolled blood-pressure.

**Conclusions:** In the current study we found about six of every ten individuals with hypertension were on-treatment, and about four were optimally controlled. These findings provide a benchmark for NPCDCS, in terms of achievable goals within short periods of follow-up.

**Key words:** hypertension, optimal blood pressure control, community health worker, physical inactivity
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Introduction
Hypertension is a leading cause of cardiovascular diseases and in India its control is poor. Among those with hypertension, in urban India less than half are aware of their elevated blood pressure, and only one in five individuals are controlled. The estimates in rural areas are worse, with only one-fourths being aware, and one in ten individuals controlled. Previous studies by our group have estimated prevalence of hypertension and other cardiovascular risk factors in state wide representative survey of Madhya Pradesh. We found that 22.3% of all individuals had hypertension, but only 11.8% were on some medication. The proportion of those controlled is likely to be only about half of those on medication. In order to improve control, availability and access to quality health-care is imperative, in order to reduce cardiovascular mortality and morbidity. Pathway for effective blood pressure control requires individuals to be “screened”; all screened individuals who have elevated blood pressure must be “aware” of their status; all those who are aware need to get “treated”; and all those treated should be “controlled”. There occurs a loss of numbers at each of these screening-awareness-treatment-control pathway the corresponding numbers in a recent systematic review of studies from India were 76%, 44%, 13% and 8% respectively. Belonging to male gender, living in a rural area, being poor, and single are considered as factors associated with such a loss in numbers at each step in this study.

Once diagnosis of hypertension is made, untreated and uncontrolled hypertension becomes a significant and challenging concern. There are numerous implementation challenges, especially with lowered target blood pressure goals. A successful blood pressure control model would require a team based approach at primary care level, with a focus on improved adherence supported achieved by improved self-management at patient level, supported by the health system. Health system is expected to provide improved access to medications, and health awareness in the communities. Various engagement strategies have been used in the last decade, including but not limited to mobile-health applications, telemedicine services, using fixed dose combinations, and community health worker (CHW) based engagement strategies. Previous cluster-randomized trials of CHW based adherence promotion and blood pressure control strategies have demonstrated feasibility of such interventions. While some population based studies have had a limited impact on blood-pressure levels, other facility based studies have shown larger benefits. Clusters where more members have uncontrolled hypertension at baseline, with a higher baseline blood-pressure, have reported greater and more significant reductions. Even amongst a homogenous health-system, heterogeneity in blood pressure control exists, attributable to better patient engagement. These findings suggest that some population subgroups, have low health system or CHW engagement levels, and are likely to
be at a higher risk of uncontrolled blood-pressure. It is important to identify such high-risk population subgroups, so that more focussed strategies can be designed for them.

National Program for prevention and control of cancer, diabetes, cardiovascular diseases and stroke (NPCDCS) in India recommends annual hypertension screening for all adults, and proportion of optimally controlled individuals as a facility level indicator. Once screened, the program recommends CHWs to engage with communities, so as to improve linkages of individuals with hypertension to the primary-care facilities. Once the screening and awareness gap is bridged, the proportion of individuals with hypertension that access primary care facilities and those who are controlled is likely to multiply. Aim of the current study is to identify risk-factors for uncontrolled hypertension, subsequent to initial screening, as envisaged in NPCDCS. The findings would be useful in understanding of long-term challenges in blood-pressure control, and designing of their mitigation strategies.

Methods

**Design and Ethics Statement:** We designed a cohort study to answer our research question. The study design was approved by the Institutional human ethics committee (IHEC-LOP/2017/EF00045). All the participants provided a written informed consent for the study related procedures.

**Setting:** The study was conducted in 16 urban slum clusters of Bhopal, a city with population of about 18 Lakhs, located in central India. A baseline door-to-door survey was conducted in the urban slum clusters between November 2017 and March 2018, details of which are provided elsewhere. Briefly, all consenting non-pregnant adults above the age of 30 years formed a cross-section, in whom cardiovascular disease (CVD) risk assessment was performed by Accredited social health activists (ASHAs), who are CHWs in these communities. Study supervisors provided oversight, and also confirmed key variables, before stratifying individuals as high risk. Individuals identified at a high CVD risk, especially those with hypertension and diabetes were sought to be linked to urban primary health centres (UPHCs) which are primary-care public-health facilities in these communities. All participants were however free to seek care from alternate private-providers of their choice. Limited generic anti-hypertensive drugs (Amlodipine, Losartan, and Hydrochlorothiazide) are available at no-cost from UPHCs with a prescription refill duration varying from 2-4 weeks. Participants who visit primary-care providers usually incur out-of-pocket expenditure for their drug therapy, with a refill duration dependent on their capacity to pay.

**Participants:** Cohort of individuals with hypertension(either a previously known or a newly detected hypertension), was identified from within the base-line cross-section. During the baseline survey, individuals who reported themselves as diagnosed to have hypertension in the past, were defined as having *previously known-hypertension*. We also screened for hypertension as part of baseline assessment. ASHAs obtained a first-set of blood-pressure values using a digital sphygmomanometer.
(Omron digital apparatus, Model 7200, Kyoto, Japan) at home of the participants. All the blood pressure readings were then confirmed in a second set of readings obtained by the study supervisor, using the same device. Each set of blood-pressure readings consisted of an average of three values, obtained one-minute apart, using a standardized technique. A person was defined as a newly detected hypertensive, if the blood pressure values were above Systolic blood pressure (SBP) of 140 mm Hg or a Diastolic blood pressure (DBP) of 90mm Hg on both the occasions. All individuals with hypertension (previously known or newly detected) were provided with referrals for physicians available at UPHC, who initiated them with or optimized their anti-hypertensive medication. All cohort members, who completed the two-year follow-up assessment in November-December 2019 are included in the current study.

Procedures: We followed the cohort of individuals with hypertension (previously known or newly detected) for two years. Follow-up was performed using the existing human resources in the public health-delivery system, facilitated by cloud-based data-management tools, and study supervisors. We prepared a list of members of the cohort using Commcare database, and stratified them by cluster. We provided cohort-list of each cluster to respective ASHA, who was responsible for visiting each cohort member at-least once in every three-months, to promote adherence to drug therapies, measurement of blood pressure, and to provide focussed CVD-prevention health education. Monetary incentives were given to ASHAs for every completed follow-up (rupees 50 INR about 1 USD). In each visit, ASHAs recorded linkage to UPHC or a private care provider, and continuation of drug therapy. We defined treatment interruption as failure to obtain a prescription-refill for two-weeks or more after exhaustion of previously obtained drug supplies.

We designed a cloud-based digital tool using CommCare based application to facilitate follow-up. This tool was available on mobile phones of all ASHAs, and in addition to facilitate follow-up, it provided access to baseline values of the participants, and also was to be used for data-entry of each subsequent visit. Study supervisors monitored cohort follow-up using this CommCare based application, and performed additional site-visits for troubleshooting. We also conducted a quarterly-meeting of all ASHAs and study supervisors to monitor follow-ups. A community clinic based one-year adherence assessment was performed by a team of pharmacologists who were trained to assess pill-burden and adherence to previously prescribed therapies. This assessment was limited to those who were on any anti-hypertensive drug therapy in the previous month.

Outcome assessment: Blood pressure control at two-year assessment visit was the key outcome. It was defined as optimally controlled if average SBP was less than 140mm Hg and DBP was less than 90mm Hg, and severely uncontrolled if SBP was more than 160mm Hg, and DBP more than 100mm Hg. This two-year assessment was performed by independent field investigators, who visited households of all participants and measured their blood pressures. Multiple mop-up visits were
conducted, and facilitation by ASHAs and study supervisors was solicited to improve proportion of follow-ups.

**Statistical Analysis:** ASHAs and study supervisors entered all study-variables obtained in baseline survey, confirmatory-visits, UPHC-visits, or on follow-up using mobile-phone based data collection system. All the variables were stored on cloud-based CommCare data-management system. The demographic and cardiovascular-risk variables (age, gender, education level, wealth quintiles, tobacco use, alcohol consumption, physical activity levels, body-mass index, waist circumference) were obtained from entries in the baseline questionnaire. History of hypertension obtained at baseline and subsequently obtained SBP and DBP values were used for classification of hypertension status. Primary-care physician consultation decisions culminating in drug escalation, de-escalation or no action, were taken from UPHC visit logs. The distribution of these explanatory variables was compared with respect to outcome, using appropriate tests of significance. The difference was considered as significant if p-value for null hypothesis was less than 0.05.

We performed a multivariable logistic regression, to evaluate independent risk factors of uncontrolled hypertension. All explanatory variables that were marginally significant on univariate analysis (p<0.25) were included in the full model. Assumptions for using logistic regression were tested and Hosmer-Lemeshow Goodness-of-fit was also used. All data analysis and visualizations were done using Statistical software R \(^{18}\) and **arsenal** \(^{19}\), **finalfit** \(^{20}\), **ggplot2** \(^{21}\), **ggpubr** \(^{22}\), **ggstatplot** \(^{23}\), **gtsummary** \(^{24}\), **performance** \(^{25}\) and **tidyverse** \(^{26}\) packages.

**Results**

In November 2017 we initiated a baseline survey in 16 urban slum clusters of Bhopal. Of 6174 individuals surveyed at baseline, we identified a total of 1571 individuals (25.4%) with hypertension; and all of these were sought to be visited by CHWs once in every two months. A total of 1177 (74.9%) individuals completed two-year follow up visit done in November-December 2019. Individuals who were lost to follow up were more likely to be men, who were older, and were newly detected with hypertension. (Table S1) Of 1177 individuals who completed follow up, 623 (53%) knew about their hypertension status at baseline, and 554 (47%) were newly detected during screening. At baseline, 301 (26%) individuals were optimally controlled, and at the end of two years their proportion increased to 442 (38%), an absolute increase of 12% (95%CI 10.2-13.9). There was a significant decline of 1.7 (95%CI -2.9 to -0.5) and 1.7mm Hg (95%CI (-2.4 to -1.1) in mean SBP and DBP respectively from baseline to follow up. This decline was largely due to reduction in SBP among those with uncontrolled hypertension. (Table 1, Figure 1)

The proportion of individuals with uncontrolled blood pressure was progressively higher in each age band (55%, 63%, 67% and 73% in those with baseline age of 30-44, 45-59, 60-74, and above 75 years respectively). We observed a significant decline in SBP and DBP, across all age-bands.
of individuals with uncontrolled hypertension at baseline. About 65% of individuals who were sedentary at baseline, developed uncontrolled hypertension, as compared to only 54% of those who were non-sedentary. This difference was statistically significant. Individuals who were newly detected to have hypertension, and those who had elevated blood-pressure at baseline, were more likely to be uncontrolled on follow-up. (Table 2, Figure 2)

A total of 699 (59.4%) individuals were initiated on anti-hypertensive drug therapy, 533 of these were linked to UPHC, and 166 to private-care providers. All of these individuals received follow up visits by ASHAs, and during these visits self-reported adherence to prescribed therapies was similar in both optimally controlled and uncontrolled individuals. (84.4% vs 85.8%; p=0.842) An independent adherence assessment was also done at the end of one-year in 263 of the UPHC attendees, and perceived adherence was lower in those subsequently found to be uncontrolled (69.5% vs 79.1%; p=0.006). The proportion of individuals who were uncontrolled after two years was significantly higher amongst those who were linked to UPHC as compared to those linked to private-providers (67% vs 61%; p=0.009). Of those linked to UPHC, median number of visits to the facility was similar in optimally controlled and uncontrolled subgroups (p=0.436) and 116 (21.7%) individuals had one or more visit culminating in a drug-escalation advise. While 24 (20.6%) of individuals who were advised drug-escalation were optimally controlled, remaining 92 (79%) were not. Of the 478 of 1177 individuals (40.6%), defaulted for initiation of drug-therapy, and 276 (58%) had their blood pressures above 140/90 mm Hg at two-year follow up.

We performed multivariable logistic regression to identify risk-factors for uncontrolled hypertension. Hosmer-Lemeshow goodness-of-fit test was non-significant, there was no multi-collinearity, assumptions of homogeneity of variance, residual distribution and absence of influential observations were met, however model’s explanatory power was weak (Tjur’s R2=0.06, RMSE=0.46). After adjusting for age, and gender newly detected hypertension (OR 2.42 (1.78-3.31)), and BMI (OR 1.04 (1.01-1.07)) were significant independent risk-factors for uncontrolled hypertension. (Table 3)
Discussion

In the current study we found that after initial screening and two-year follow-up, about six of every ten individuals with hypertension were on-treatment, and about four were optimally controlled. While overall proportion of individuals with optimally controlled blood-pressure rose over the two-year period, this modest increase was due to blood-pressure control in less than a-third of newly detected hypertensives. More than two-thirds of the remaining newly detected and about half of previously known hypertensives remained uncontrolled. Those who were uncontrolled, were more likely to be older, had a higher BMI, and were newly detected to have hypertension. These findings demonstrate that obtaining blood-pressure control in vulnerable communities, though feasible is challenging. These findings provide a benchmark for NPCDCS, in terms of achievable goals within short periods of follow-up.

A recent systematic review reported that in India only 13% of all individuals with hypertension are treated, and a meagre 8% are controlled. Our baseline screening bridged the awareness gap, and CHW based adherence reinforcement improved proportion of on-treatment and controlled individuals to 60% and 38% respectively. While these numbers are encouraging, and approach and even exceed proportions for control achieved in previous studies in high-income settings, they bring-forth challenges of initiating anti-hypertensive drugs in all who need them, improving adherence in those initiated, and appropriate dosing requirements. In the current study education, wealth, or gender did not increase risk of uncontrolled hypertension. These socioeconomic characteristics are perceived as proxy-indicators for awareness, access or empowerment. It is likely that more complex behavioural phenomenon such as fear, reluctance and adverse impact of being labelled with an illness, affected both initiation and adherence to prescribed drug therapies. Of less than half of all participants who attended UPHC, drug-escalation attempts were no-different in those who were uncontrolled. Therapeutic inertia remains an important physician level barrier to optimal blood pressure control. We found that risk of being uncontrolled was consistently higher with increasing age, a factor that contributes to therapeutic inertia. Further, presence of fixed-dose combinations in the drug formulary in UPHCs could have helped reduce inertia, as use of combination treatment in newly detected hypertensives is likely to achieve a faster blood-pressure control.

Physical activity is important to achieve blood-pressure control, and is an important component of various population based programs. Self-reported physical activity levels correlate well with reduced blood pressure levels. In the current study, hypertensive individuals who reported themselves to be sedentary at baseline were more-likely to be uncontrolled two years later. While this effect observed on univariate analysis, was not significant when adjusted for age and gender, it is an important life-style measure that has a strong legacy effect. Improved physical activity achieves blood pressure reduction through diverse mechanisms such as reduction in vascular resistance,
sympathetic activity, inflammation and stress. It also leads to lower BMI, which was an independent predictor of blood-pressure control in our study. While some studies, such as SPRINT trial have found no relationship between BMI and blood-pressure control, another large study from China found a significant lowering effect. While mean BMI of participants in SPRINT trial was 29 kg/m², it was 24.4 kg/m² in the Chinese study. Mean BMI of our participants was 25.8 kg/m², closer to that of the Chinese study. It is likely that blood-pressure control in population sub-groups with a lower BMI is more feasible, as compared to those with obesity.

Improving blood pressure control is challenging, and regular follow up with intensive pharmacotherapy is most useful to achieve this goal. In a Cochrane review of 56 randomized control trials, other measures such as self-monitoring, appointment reminders, and health-education had little independent effects and were less useful. Feasibility of achieving even lower targets than envisaged in NPCDCS, was demonstrated in intensive blood-pressure control arm in SPRINT trial. Similar intensive management is also possible through CHWs in low-income settings. Two recent trials have demonstrated this effect. First, HOPE4 study demonstrated that CHW based intensive blood pressure control can improve proportion of optimally controlled individuals to 69% as compared to 30% in standard care arm. Second, in another randomized control trial from Argentina, CHW led multi-dimensional care that involved intensive health-coaching, home BP monitoring, audits and feedbacks optimally controlled 72% individuals. When CHWs are provided with intensive supportive supervision, empowered to obtain quick feedbacks on treatment decisions, it can help improve therapeutic inertia and achieve better control levels.

We have established a cohort of individuals with hypertension, with an aim to improve CHW based care delivery in vulnerable populations, and generate evidence that may help implementation of NPCDCS. We used efficient data-management systems, within the programmatic settings to establish a system of community based follow-up. Our study however has had some limitations. We could follow up only three-fourths of our intended cohort, mostly due to migration, and limited availability at home due to long working hours of many participants. Proportion of individuals on-treatment was modest, reflecting the real-world apprehensions many individuals with hypertension have, regarding initiation of drug therapy. Further, the process of obtaining prescription refills from a health-facility often requires missing work on that day, which may not be feasible for the working populations. Last, our follow up duration was only two years. While this is short, but we believe it is sufficient to demonstrate improvements within program settings.

To conclude, newly detected individuals with hypertension, and those who are obese, are two such subgroups that need more intensive monitoring and follow-up to improve optimal control levels in the community. CHWs based follow-ups are feasible, but more intensive treatments and follow-up systems are needed for better blood-pressure control outcomes.
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Conflict of interest – Authors declare no conflict of interest.

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Ethics approval- The study design was approved by the Institutional Human Ethics Committee of All India Institute of Medical Sciences, Bhopal(Ref: IHEC-LOP/2017/EF00045).

Informed consent- Participant Information Sheet in Hindi language was provided to each participant. All participants provided written informed consent prior to initiation of any study procedures.

Data Statement- Raw data of this study is not deposited in any public repository. However, anonymized raw data of this study would be available to academicians or researchers on reasonable request to corresponding author.

Author contributions: RJ conceived the study; AJ, APP, SA and SK developed the protocol; AL, SKN and NS acquired data, AJ, SA and SK supervised data acquisition, APP, AJ and RJ analysed data and wrote first draft. All authors critically reviewed the first draft and provided inputs for its revisions.
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Table 1: Change in cardiovascular risk factors over two-year follow-up in the cohort (n=1177)

| Variables                        | Baseline (2017) | Follow Up (2019) | Absolute Difference (CI) | p-value  |
|----------------------------------|-----------------|------------------|---------------------------|----------|
| All participants (N=1177)        |                 |                  |                           |          |
| SBP (mean, SD)                   | 146.6 (20.6)    | 145.0 (21.2)     | -1.7 (-2.9 to -0.5)       | 0.007    |
| DBP (mean, SD)                   | 88.2 (12.6)     | 86.5 (12.6)      | -1.7 (-2.4 to -1.1)       | <0.001   |
| Optimal BP control               | 301 (26%)       | 442 (38%)        | +141 (12%)                | <0.001   |
| BMI (mean, SD)                   | 25.7 (4.9)      | 25.8 (5.2)       | +0.1 (-0.05 to 0.18)      | 0.257    |
| Obese or overweight              | 536 (54%)       | 533 (54%)        | -3 (1%)                   | 1.000    |
| Waist Circum. (mean, SD)         | 89.4 (14.4)     | 92.2 (12.2)      | 2.9 (2.3 to 3.5)          | <0.001   |
| Abdominal Obesity                | 817 (79%)       | 868 (82%)        | 51 (3%)                   | 0.0008   |
| Previously known hypertension at baseline (N=623) |                 |                  |                           |          |
| SBP (mean, SD)                   | 141.8 (22.9)    | 141.6 (21.0)     | -0.2 (-1.9 to 1.5)        | 0.825    |
| DBP (mean, SD)                   | 84.3 (13.4)     | 83.8 (12.3)      | -0.5 (-1.4 to 0.5)        | 0.316    |
| Optimal BP Control               | 301 (48%)       | 284 (46%)        | -17 (2%)                  | 0.277    |
| BMI (mean, SD)                   | 26.2 (4.9)      | 26.3 (5.0)       | 0.1 (-0.05 to 0.26)       | 0.178    |
| Obese or overweight              | 320 (59%)       | 313 (57%)        | -7 (2%)                   | 0.371    |
| Waist Circum. (mean, SD)         | 89.9 (14.8)     | 93.1 (12.3)      | 3.2 (2.3 to 4.0)          | <0.001   |
| Abdominal Obesity                | 464 (85%)       | 488 (87%)        | +22 (2%)                  | 0.021    |
| Newly detected hypertension at baseline (N=554) |                 |                  |                           |          |
| SBP (mean, SD)                   | 152.0 (16.1)    | 148.7 (20.7)     | -3.3 (-5.0 to -1.6)       | <0.001   |
| DBP (mean, SD)                   | 92.7 (10.1)     | 89.5 (12.3)      | -3.2 (-4.14 to -2.2)      | <0.001   |
| Optimal BP control               | 0 (0%)          | 158 (29%)        | +158 (29%)                | <0.001   |
| BMI (mean, SD)                   | 25.2 (4.9)      | 25.2 (5.4)       | 0.0 (-0.15 to 0.18)       | 0.865    |
| Obese or overweight              | 216 (48%)       | 220 (49%)        | +4 (1%)                   | 0.429    |
| Waist Circum. (mean, SD)         | 88.7 (14.0)     | 91.3 (12.0)      | 2.6 (1.7 to 3.5)          | <0.001   |
| Abdominal Obesity                | 353 (72%)       | 380 (76%)        | +27 (4%)                  | 0.161    |
Table-2: Distribution of status of BP control among various socio-demographic, behavioral and biological variables

| Baseline Characteristics | All (N = 1,177) | Blood-pressure outcome after follow-up | p-value |
|--------------------------|----------------|----------------------------------------|---------|
|                          | Optimal control (N = 442 (38%) | Not controlled (N = 735 (62%)) |         |
| Mean age                 | 51.7 (12.7)    | 49.9 (12.3)                             | 52.9 (12.8) | <0.001 <0.001 |
| Age Group                |                |                                        |         |
| 31-40                    | 284            | 134 (47%)                              | 150 (53%)  |
| 41-50                    | 347            | 124 (36%)                              | 223 (64%)  |
| 51-60                    | 272            | 101 (37%)                              | 171 (63%)  |
| 60+                      | 274            | 83 (30%)                               | 191 (70%)  |
| Gender                   |                |                                        | 0.669    |
| Men                      | 482            | 185 (38%)                              | 297 (62%)  |
| Women                    | 695            | 257 (37%)                              | 438 (63%)  |
| Education                |                |                                        | 0.047    |
| Literate                 | 685            | 274 (40%)                              | 411 (60%)  |
| Illiterate               | 492            | 168 (34%)                              | 324 (66%)  |
| Wealth Quintiles         |                |                                        | 0.641    |
| Q1                       | 148            | 49 (33%)                               | 99 (67%)   |
| Q2                       | 179            | 70 (39%)                               | 109 (61%)  |
| Q3                       | 218            | 81 (37%)                               | 137 (63%)  |
| Q4                       | 230            | 93 (40%)                               | 137 (60%)  |
| Q5                       | 332            | 120 (36%)                              | 212 (64%)  |
| Tobacco                  |                |                                        | 0.688    |
| Non-user                 | 725            | 276 (38%)                              | 449 (62%)  |
| User                     | 452            | 166 (37%)                              | 286 (63%)  |
| Alcohol                  |                |                                        | 0.688    |
| Non-user                 | 951            | 354 (37%)                              | 597 (63%)  |
| User                     | 226            | 88 (39%)                               | 138 (61%)  |
| Physical Activity        |                |                                        | <0.001   |
| Non-sedentary            | 285            | 131 (46%)                              | 154 (54%)  |
| Sedentary                | 892            | 311 (35%)                              | 581 (65%)  |
| Fruits and Vegetables [Median servings] | 1.0 (0.5, 2.0) | 1.0 (1.0, 2.0) | 1.0 (0.5, 2.0) | 0.081 |
| Mean Salt Intake [gm/person/day] | 8.3 (6.7, 11.1) | 8.3 (6.7, 11.1) | 8.3 (6.7, 11.1) | 0.803 |
| Mean Edible-oil Intake [ml/person/day] | 30.0 (25.0, 42.0) | 30.0 (25.7, 42.0) | 30.0 (25.0, 42.0) | 0.808 |
| Abdominal Obesity        |                |                                        | 0.418    |
| Non-obese                | 360            | 142 (39%)                              | 218 (61%)  |
| Obese                    | 816            | 300 (37%)                              | 516 (63%)  |
| HTN History              |                |                                        | <0.001   |
| Newly Detected           | 554            | 158 (29%)                              | 396 (71%)  |
| Past HTN                 | 623            | 284 (46%)                              | 339 (54%)  |
| BP Status                |                |                                        | <0.001   |
| Not controlled           | 876            | 245 (28%)                              | 631 (72%)  |
| Controlled               | 301            | 197 (65%)                              | 104 (35%)  |
| Dysglycemia              |                |                                        | 0.417    |
| Absent                   | 822            | 302 (37%)                              | 520 (63%)  |
| Present                  | 355            | 140 (39%)                              | 215 (61%)  |
| Weight                   |                |                                        | 0.169    |
| 62.5 (13.6)              | 61.7 (13.6)    | 62.9 (13.6)                            |
| BM1                      | 25.8 (5.2)     | 25.5 (5.3)                             | 26.0 (5.2)  |
| Waist Circumference      |                |                                        | 0.172    |
| Weight                   |                |                                        | 0.376    |
| 88.9 (17.9)              | 88.6 (16.5)    | 89.1 (18.8)                            |
| Random Blood Sugar       |                |                                        | 0.696    |
| 138.2 (61.0)             | 138.1 (60.9)   | 138.3 (61.2)                           |
### Table-3: Logistic regression analysis for determinants of uncontrolled hypertension

| Baseline variables                          | OR (univariable)          | OR (multivariable)          |
|---------------------------------------------|----------------------------|----------------------------|
| Age                                         | 1.02 (1.01-1.03, p<0.001)  | 1.02 (1.01-1.04, p<0.001)   |
| Women vs Men                                | 1.06 (0.84-1.35, p=0.625)  | 0.95 (0.69-1.30, p=0.744)   |
| Illiterate vs Literate                      | 1.29 (1.01-1.64, p=0.041)  | 1.21 (0.88-1.65, p=0.241)   |
| Tobacco User vs Non-user                    | 1.06 (0.83-1.35, p=0.643)  | -                          |
| Alcohol User vs Non-user                    | 0.93 (0.69-1.26, p=0.632)  | -                          |
| Physical Inactivity vs Non-sedentary         | 1.59 (1.21-2.08, p=0.001)  | 1.44 (1.05-1.98, p=0.024)   |
| BMI                                         | 1.02 (0.99-1.04, p=0.211)  | 1.04 (1.01-1.07, p=0.007)   |
| Waist Circumference                         | 1.00 (0.99-1.01, p=0.650)  | -                          |
| Newly Detected HTN at baseline vs Previously known HTN | 2.10 (1.65-2.68, p<0.001) | 2.38 (1.80-3.17, p<0.001)   |
| Dysglycemia at baseline vs No Dysglycemia    | 0.89 (0.69-1.15, p=0.381)  | -                          |

Number in data frame = 1177, Number in model = 997, Missing = 180, AIC = 1247.8, C-statistic = 0.65, H&L = Chi-sq(8) 5.81 [p=0.669]

OR-Odds Ratio, BMI-Body Mass Index, HTN-Hypertension
Figure 1: Change in SBP from baseline to follow up by history of hypertension (n=1177)

Multi-panel paired box and violin plots showing distribution of Systolic Blood Pressure (SBP) at different time periods. Panels are labelled history of hypertension and status of blood pressure control at 2017. Change in individual’s reading is denoted by dotted connecting line. Mean change is indicated by solid red connecting line.
Figure-2: Change in SBP and DBP in the study population by baseline-BP control status in each age-band.

Multi-panel plot showing mean of systolic and diastolic blood pressure recorded in 2017 and 2019. Each panel represents specific age group labelled on top panels and type of blood pressure on extreme right panels. Colour of the joining line indicates status of blood pressure control in 2017.
# Table S1: Comparison of distribution of socio-demographic variables among those who were followed up and those lost to follow up

| Characteristic         | Overall, N = 1,571 | Followed, N = 1,177 (75%) | Lost to F/U, N = 394 (25%) | p-value |
|------------------------|--------------------|---------------------------|----------------------------|---------|
| **Age**                | 52.1 (13.3)        | 51.7 (12.7)               | 53.3 (15.0)                | 0.154   |
| **Gender**             |                    |                           |                            | <0.001  |
| Men                    | 687 (44%)          | 482 (41%)                 | 205 (52%)                  |         |
| Women                  | 884 (56%)          | 695 (59%)                 | 189 (48%)                  |         |
| **Education**          |                    |                           |                            | 0.955   |
| Literate               | 913 (58%)          | 685 (58%)                 | 228 (58%)                  |         |
| Illiterate             | 658 (42%)          | 492 (42%)                 | 166 (42%)                  |         |
| **Wealth Quintiles**   |                    |                           |                            | 0.689   |
| Q1                     | 199 (14%)          | 148 (13%)                 | 51 (15%)                   |         |
| Q2                     | 236 (16%)          | 179 (16%)                 | 57 (16%)                   |         |
| Q3                     | 276 (19%)          | 218 (20%)                 | 58 (17%)                   |         |
| Q4                     | 310 (21%)          | 230 (21%)                 | 80 (23%)                   |         |
| Q5                     | 434 (30%)          | 332 (30%)                 | 102 (29%)                  |         |
| **BMI**                | 25.7 (5.2)         | 25.8 (5.2)                | 25.2 (5.3)                 | 0.111   |
| **Waist Circumference**| 88.8 (17.3)        | 88.9 (17.9)               | 88.4 (15.1)                | 0.443   |
| **Physical Activity**  |                    |                           |                            | 0.271   |
| Non-sedentary          | 392 (25%)          | 285 (24%)                 | 107 (27%)                  |         |
| Sedentary              | 1,179 (75%)        | 892 (76%)                 | 287 (73%)                  |         |
| **Abdominal Obesity**  |                    |                           |                            | 0.036   |
| Non-obese              | 503 (32%)          | 360 (31%)                 | 143 (36%)                  |         |
| Obese                  | 1,065 (68%)        | 816 (69%)                 | 249 (64%)                  |         |
| **Alcohol**            |                    |                           |                            | 0.203   |
| Non-user               | 1,257 (80%)        | 951 (81%)                 | 306 (78%)                  |         |
| User                   | 314 (20%)          | 226 (19%)                 | 88 (22%)                   |         |
| **Tobacco**            |                    |                           |                            | 0.004   |
| Non-user               | 935 (60%)          | 725 (62%)                 | 210 (53%)                  |         |
| User                   | 636 (40%)          | 452 (38%)                 | 184 (47%)                  |         |
| **Dysglycemia 2017**   |                    |                           |                            | 0.020   |
| Absent                 | 1,122 (71%)        | 822 (70%)                 | 300 (76%)                  |         |
| Present                | 449 (29%)          | 355 (30%)                 | 94 (24%)                   |         |
| **HTN History**        |                    |                           |                            | <0.001  |
| Newly Detected         | 813 (52%)          | 554 (47%)                 | 259 (66%)                  |         |
| Past HTN               | 758 (48%)          | 623 (53%)                 | 135 (34%)                  |         |
Table-S2: Distribution of Health-care seeking pattern and adherence to drug therapy by blood pressure control outcome as determined on follow-up (n=1177)

| Characteristic                                      | Overall, N = 1,177 | Optimal, N = 442 (38%) | Not controlled, N = 735 (62%) | p-value |
|-----------------------------------------------------|--------------------|------------------------|------------------------|---------|
| **Facility linkage for Drug therapy**               |                    |                        |                        |         |
| Govt Facility (UPHC)                                | 533                | 176 (33%)              | 357 (67%)              | 0.009   |
| Private Facility                                    | 166                | 64 (39%)               | 102 (61%)              |         |
| Neither                                             | 478                | 202 (42%)              | 276 (58%)              |         |
| **Visit log at UPHC**                               |                    |                        |                        |         |
| Number of visits (Median, IQR)                      | 2.0 (1.0, 9.2)     | 3.0 (1.0, 10.0)        | 2.0 (1.0, 9.0)         | 0.436   |
| Visits resulting in drug escalation                 | 0.0 (0.0, 1.0)     | 0.0 (0.0, 0.0)         | 0.0 (0.0, 1.0)         | 0.042   |
| Participants with drug escalation                   | 116                | 24 (21%)               | 92 (79%)               | 0.097   |
| **Follow up by ASHAs**                              |                    |                        |                        |         |
| Directly followed-up by ASHA                        | 928                | 348 (38%)              | 580 (62%)              | 0.999   |
| Perceived Adherence (100)                           | 85.3 (29.5)        | 84.4 (30.9)            | 85.8 (28.6)            | 0.842   |
| **Independent adherence assessment in a sample of those on regular therapy** |                    |                        |                        |         |
| Number                                              | 263                | 78                     | 185                    |         |
| Pill Burden (Daily)                                 | 2.6 (2.2)          | 2.6 (2.4)              | 2.6 (2.1)              | 0.660   |
| Perceived Adherence (100)                           | 72.3 (36.5)        | 79.1 (34.5)            | 69.5 (37.1)            | 0.006   |