A Systematic Review and Meta-Analysis of the prevalence of hypertension among adults (15-49) in India from the year 2010 to 2020

A Capstone project submitted to Johns Hopkins Bloomberg School of Public Health & IIHMR University in partial fulfilment of the requirements for the award of the degree of Master of Public Health

By

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Abstract

Different estimates are reported on studies that are conducted on prevalence of hypertension in various parts of India. Up-to date assessments on the magnitude of hypertension in India is unfortunately unavailable. For the identification of relevant records for eligibility screening and quality assessment, grey literature and scientific search engines are used. Pooled prevalence, meta-regression, subgroup analysis publication bias and heterogeneity evaluation are performed by statistical analysis that explains the assessment, and extraction of data from selected articles is performed through standardized spreadsheets. We include 24 studies (reference 19-42) in the meta-analysis (31,144 individuals). As depicted in Figure 1, the pooled prevalence of hypertension is 20% (95%CI, 16.0 to 24.0), while the prevalence in individual studies range between 7.0% and 42%. These results are based on a random-effects model, which is applied due to the substantial heterogeneity between studies ($t2 = 0.37$, heterogeneity $I2 = 98.6\%$, degree of freedom = 23, $P < 0.0001$).

Acknowledgements

The present work was done under the guidance of Dr Daya Krishan Mangal, Dean Researcher and Professor IIHMR University and Dr Neeraj Sharma, Research Officer, PhD Scholar (Epidemiology), IIHMR University.

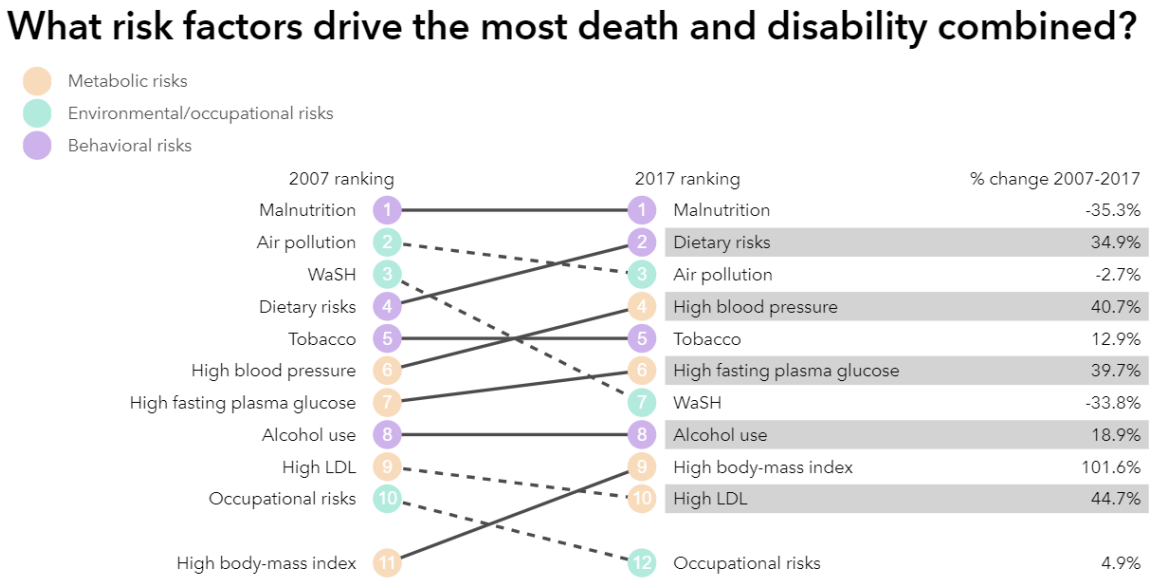
Contents

Research Question

What is the prevalence of hypertension among adults of age 15 to 49 years in India from the year 2010 to 2020

Background (Rationale)

India is in an advanced phase of epidemiological transition where infectious are being replaced by diseases non-communicable diseases (NCDs), especially cardiovascular disease (CVD) and their risk factors such as hypertension. In most individuals, high blood pressure does not develop any symptoms, and in most, the only way to diagnose hypertension is by measuring blood pressure. Sedentary lifestyle, eating junk food, and rapid urbanization are some of the reasons for the increased prevalence of hypertension in India among certain individuals. As hypertension does not develop any apparent symptoms, it's also considered a "Silent Killer". In a publication in Lancet, the authors referred to hypertension as " the largest epidemic ever known to mankind". (1) Fifty-seven per cent of all deaths due to stroke and 24% of all deaths due to coronary heart disease (CHD) in India is directly associated with hypertension. (2) Hypertension is one of the four risk factors in health in India, which has an immense contribution to the disease burden, disability and mortality rate. (3) The global burden of cardiovascular disease is majorly affected by hypertension which is known as the most common cardiovascular disease and is the leading risk factor for mortality. (4) Indians develop coronary heart disease at a younger age (< 40 years of age) regardless of geographical or residential status.(5) Ironically, those who can't even cover their medical bills are the ones who are most affected by hypertension in India.



Top 10 risks contributing to DALYs in 2017 and percent change, 2007-2017, all ages, number (6)

One of the significant public health concerns is hypertension, therefore, making it an important area of study due to the high prevalence and significant risk factor for cardiovascular diseases and additional complication such as stroke. Non-communicable diseases (NCDs) have grown to become a significant public health problem in India, which accounts for 62% of the total burden of foregone DALYs (Disability-Adjusted Life Years) and 53% of total deaths. (7) At the time of writing, there is no up-to-date assessment that has an evidence on the scale of hypertension in India. The last systematic review of prevalence of hypertension in adults was completed in 2014. The current study aims to fill the gap in evidence by estimating the prevalence of hypertension in India. The study will also examine the pattern of this disease among adults. The previous studies on hypertension assessed that 33% of urban and 25% of the rural population in India are suffering from hypertension. Out of the total rural hypertensive patients, only 25% are aware of their hypertension status whereas out of the urban hypertensives, 42% are aware of their hypertension status. (8) As per a research report $1/10^{th}$ of rural and $1/5^{th}$ of the urban population in India take some kind of treatment for hypertension to keep their blood pressure in check. (8) Early diagnosis of high blood pressure is an essential intervention

for prevention and management. The initial management of high blood pressure could prevent microvascular or macrovascular damage. (9) The World Health Organization has projected that by the year 2030, in India, a stroke will be one of the leading causes of death, i.e. 36% with hypertension (HTN) being the leading risk factor contributing to stroke. (10) HTN is responsible for 30–50% of the stroke cases in India. (10) The prevalence of hypertension is very rapidly increasing globally, with forecasts that estimate a 30% increase in the prevalence of hypertension by the year 2025. (11) Study suggests that three-quarters of the world's hypertensive population will be living in low and middle-income countries as per projections. (11)

Aims and Objectives

This systematic review aims to approximate the prevalence of hypertension among adults within the ages of 15-49 years in India. The primary objective of this study is to understand the most recent prevalence of hypertension in India.

The previous study conducted and published in the year 2014 was a systematic review and meta-analysis of the prevalence of hypertension in India which included adult age group of ≥18 years, and the prevalence of hypertension was concluded as 29.8%. This systematic review will update the systematic review that was published in 2014.

Ethical considerations

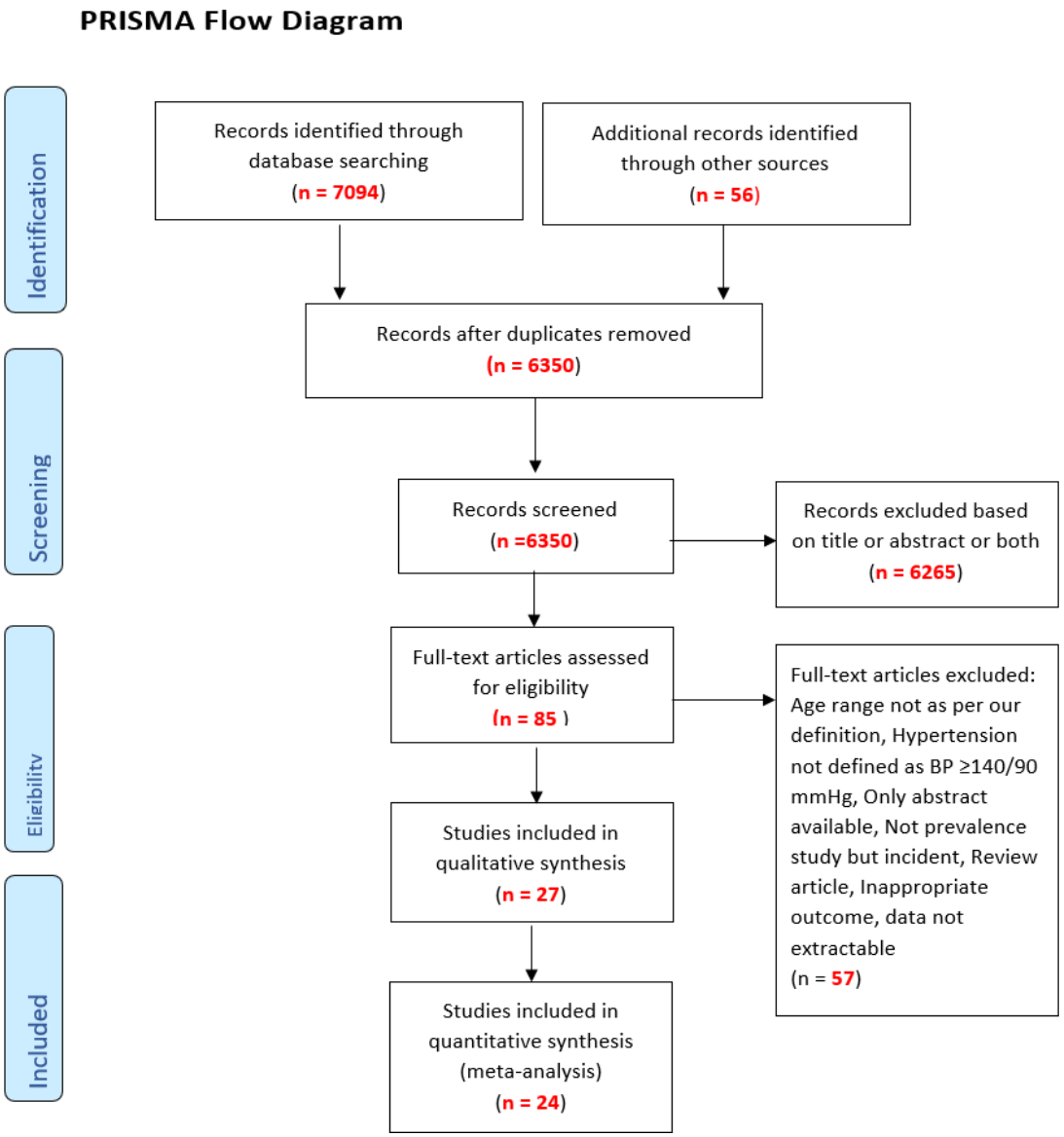
The study is based on a systematic review of published literature; hence no ethical approval was required for conducting it. In a systematic review, the data is collected through a systematic review of published and unpublished literature, "The Institutional Review Boards" for the ethical conduct of research that does not have any guidelines for a systematic review. Despite such, care was taken to perform all studies that are included in our review providing evidence of ethical approval and informed consent from all patients or respondents where required.

Methods

Preferred Reporting Items for Systematic Reviews Meta-Analyses (PRISMA) is followed in the reporting of this review statement. The use of PRISMA helps in providing a higher quality of a systematic review. A reported protocol was developed and is available; the protocol enables the readers to recognize deviations from planned methods in completed studies and helps in identification of any bias the interpretation of review results and conclusions.

Justification of the study period

The study period for the systematic review is from the year 2010 to 2020. In the data that is available for the global burden of disease, it can be appreciated that high blood pressure in the year 2007 was ranked at number six and a decade later the ranking has increased to number four as the burden of the disease increased.



Study Protocol

Review question

- What is the prevalence of hypertension among adults age 15 to 49 years in India between the year 2010 to 2020?

Searches

- We searched PubMed, EMBASE, Scopus and Google Scholar
- We included English language articles only in the review
- The search included studies conducted for India

Types of research to be included in the systematic review

All kinds of studies, i.e. cross-sectional, Cohort study, or population based survey were included in the search to make the search comprehensive. We identified all studies that were reporting the prevalence of hypertension among adults and coincided with our inclusion criteria. In the systematic review, we are including studies that were undertaken during 2010 to 2020. Although we checked the references of all the studies screened for any research that was undertaken during 2010-2020.

Participants/population

We will have a limitation in age for the population for adults age between 15 to 49 years of age. As per the National Family Health Survey (NFHS), the age classification of an adult is age 15-49 years of age.

Inclusion criteria

We included articles adhering to the following criteria:

- The study was cross-sectional, Cohort study or Randomized controlled trials
- Conducted among Adults (15-49 years) on the prevalence of hypertension and sufficient data was available in the article to extract the prevalence of hypertension between 15-49 years
- Articles must be in English language only
- The studies publication years between the year 2010 to 2020
- Adult hypertension defined as Systolic Blood Pressure ≥ 140mmHg and Diastolic Blood Pressure ≥ 90 mmHg taken at lease in two separate intervals as per government of India (European Society of Cardiology/European Society of Hypertension, Joint National Committee 7 and 8, and International Society of hypertension.

Table 1. **Guidelines for definition of raised blood pressure used in comparison study, India**

No. of readings by guideline	Reading considered	Hypertension diagnosis	Blood pressure category[a]	Blood pressure (mm Hg)	
				Systolic	Diastolic
European Society of Cardiology/European Society of Hypertension[7]					
At least three (if different by ≥ 10 mm Hg, at least four)	Average of last two readings	Other than Grade 3, two visits required	Optimal[b]	< 120	< 80
			Normal	120 to 129	80 to 84
			High normal	130 to 139	85 to 89
			Grade 1 hypertension	**140 to 159**	**90 to 99**
			Grade 2 hypertension	160 to 179	100 to 109
			Grade 3 hypertension	≥ 180	≥ 110
			Isolated systolic hypertension	≥ 140	< 90
Government of India[8]					
At least two (if different by ≥ 5 mm Hg, at least three)	Lowest	Other than Grade 3, two visits required	Optimal[b]	< 120	< 80
			Normal	120 to 129	80 to 84
			High normal	130 to 139	85 to 89
			Grade 1 hypertension	**140 to 159**	**90 to 99**
			Grade 2 hypertension	160 to 179	100 to 109
			Grade 3 hypertension	≥ 180	≥ 110
			Isolated systolic hypertension[b]	≥ 140	< 90
			Hypertensive urgency	> 180	> 110
			Hypertensive emergency	> 180	> 110 to 120
American College of Cardiology/American Heart Association[9]					
At least two	Average	Two visits or more	Normal[b]	< 120	< 80
			Elevated[b]	120 to 129	< 80
			Stage 1 hypertension[c]	**130 to 139**	**80 to 89**
			Stage 2 hypertension	≥ 140	≥ 90
National Institute for Health and Clinical Excellence/British and Irish Hypertension Society[10]					
At least two (if readings different, at least three)	Average of last two readings	Two visits or more	Normal[b]	< 135	< 85
			Stage 1 hypertension	**≥ 135**	**≥ 85**
			Stage 2 hypertension	≥ 150	≥ 95
			Severe hypertension	≥ 180	≥ 110
Eighth Joint National Committee[11]					
At least two	Average	Two visits or more	Normal[b]	< 120	< 80
			Prehypertension	120 to 139	80 to 89
			Stage 1 hypertension	**140 to 159**	**90 to 99**
			Stage 2 hypertension	≥ 160	≥ 100
International Society of Hypertension[12]					
At least two	Average	Two visits or more	Normal[b]	< 120	< 80
			Prehypertension	120 to 139	80 to 89
			Stage 1 hypertension	**140 to 159**	**90 to 99**
			Stage 2 hypertension	≥ 160	≥ 100

Hg: mercury.
[a] Bold formatting indicates the blood pressure category at which medical treatment is initiated.
[b] Categories for which both systolic and diastolic blood pressure measurements of less than threshold are required; patients are assigned to other categories if either of their systolic or diastolic blood pressure measurement is within the given limit.
[c] Medical treatment initiated only if the patient has a Framingham risk score (risk of developing cardiovascular disease over the next 10 years) of ≥ 10%.

Bull World Health Organ 2019;97:799–809 | doi: http://dx.doi.org/10.2471/BLT.19.234500

Exclusion criteria

- The studies for children less than 15 years or adults more than 49 years and Geriatric population
- If the study was of "Pulmonary Hypertension" and not atrial hypertension
- Adult hypertension is defined as Blood Pressure ≥ 160/95 mmHg
- If the study is hospital-based studies and Expert reviews
- Reviews, abstracts, conference proceedings, letters and studies not performed on humans

Main outcome

Prevalence of hypertension among adults age 15-49 years in India from the year 2010 to 2020

Literature Search Strategy

A systematic search was done in May 2020, and a comprehensive search was done in three electronic databases such as PubMed (2010 to present), Embase (2010 to till date) and Scopus (2011 to till date). Few studies/articles were also taken from Internet search engines like Google Scholar as well as Welch library (2010 to present). A combination of medical subject headings (MESH) terms, Boolean operators that were used were 'AND' and 'OR' with filters set for the last ten years and full free articles. The search terms incorporated a combination of keywords and index terms related to hypertension (e.g. Hypertension, High Blood Pressure, Elevated Blood Pressure) and the outcome (e.g. prevalence, burden, epidemiology). The detailed search strategy used to extract the studies is provided below:

Search strategy for Adults

PubMed (960 articles)

Search: **prevalence OR burden disease OR epidemiology AND hypertension OR blood pressure AND adult AND India** Filters: **Free full text, in the last 10 years, English, Female, Male, Adult: 19+ years, Young Adult: 19-24 years, Adult: 19-44 years**

((("epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "prevalence"[All Fields] OR "prevalence"[MeSH Terms] OR "prevalance"[All Fields] OR "prevalences"[All Fields] OR "prevalence s"[All Fields] OR "prevalent"[All Fields] OR "prevalently"[All Fields] OR "prevalents"[All Fields] OR (("burden"[All Fields] OR "burdened"[All Fields] OR "burdening"[All Fields] OR "burdens"[All Fields]) AND ("disease"[MeSH Terms] OR "disease"[All Fields] OR "diseases"[All Fields] OR "disease s"[All Fields] OR "diseased"[All Fields])) OR ("epidemiologically"[All Fields] OR "epidemiology"[MeSH Terms] OR "epidemiology"[All Fields] OR "epidemiologic"[All Fields] OR "epidemiological"[All Fields])) AND ("hypertense"[All Fields] OR "hypertension"[MeSH Terms] OR "hypertension"[All Fields] OR "hypertension s"[All Fields] OR "hypertensions"[All Fields] OR "hypertensive"[All Fields] OR "hypertensive s"[All Fields] OR "hypertensives"[All Fields])) OR

("hypertension"[MeSH Terms] OR "hypertension"[All Fields] OR ("elevated"[All Fields] AND "blood"[All Fields] AND "pressure"[All Fields]) OR "elevated blood pressure"[All Fields])) AND ("adult"[MeSH Terms] OR "adult"[All Fields] OR "adults"[All Fields] OR "adult s"[All Fields]) AND ("india"[MeSH Terms] OR "india"[All Fields] OR "india s"[All Fields] OR "indias"[All Fields])

Translations

prevalence: "epidemiology"[Subheading] OR "epidemiology"[All Fields] OR "prevalence"[All Fields] OR "prevalence"[MeSH Terms] OR "prevalance"[All Fields] OR "prevalences"[All Fields] OR "prevalence's"[All Fields] OR "prevalent"[All Fields] OR "prevalently"[All Fields] OR "prevalents"[All Fields]

burden: "burden"[All Fields] OR "burdened"[All Fields] OR "burdening"[All Fields] OR "burdens"[All Fields]

disease: "disease"[MeSH Terms] OR "disease"[All Fields] OR "diseases"[All Fields] OR "disease's"[All Fields] OR "diseased"[All Fields]

epidemiological: "epidemiologically"[All Fields] OR "epidemiology"[MeSH Terms] OR "epidemiology"[All Fields] OR "epidemiologic"[All Fields] OR "epidemiological"[All Fields]

hypertension: "hypertense"[All Fields] OR "hypertension"[MeSH Terms] OR "hypertension"[All Fields] OR "hypertension's"[All Fields] OR "hypertensions"[All Fields] OR "hypertensive"[All Fields] OR "hypertensive's"[All Fields] OR "hypertensives"[All Fields]

elevated blood pressure: "hypertension"[MeSH Terms] OR "hypertension"[All Fields] OR ("elevated"[All Fields] AND "blood"[All Fields] AND "pressure"[All Fields]) OR "elevated blood pressure"[All Fields]

adult: "adult"[MeSH Terms] OR "adult"[All Fields] OR "adults"[All Fields] OR "adult's"[All Fields]

India: "india"[MeSH Terms] OR "india"[All Fields] OR "india's"[All Fields] OR "indias"[All Fields

Embase Session Results (No. Query Results 5,977)

#2

#1 AND (**2010**:py OR **2011**:py OR **2012**:py OR **2013**:py OR **2014**:py OR **2015**:py OR **2016**:py OR **2017**:py OR **2018**:py OR **2019**:py OR **2020**:py)

AND '**hypertension**'/dm AND ('**case control study**'/de OR '**cohort analysis**'/de

OR **'cross sectional study'**/de OR **'human'**/de OR **'randomized controlled trial'**/de) AND **'article'**/it AND ([adult]/lim OR [young adult]/lim)

15,327

#1

(('**prevalence**'/exp OR **prevalence** OR **'burden of disease'**/exp OR **'burden of disease'** OR (('**burden**'/exp OR **burden**) AND **of** AND ('**disease**'/exp OR **disease**)) OR **epidemiological**) AND ('**hypertension**'/exp OR **hypertension**) OR **'elevated blood pressure'**/exp OR **'elevated blood pressure'** OR (**elevated** AND ('**blood**'/exp OR **blood**) AND ('**pressure**'/exp OR **pressure**))) AND ('**adult**'/exp OR **adult**) AND ('**india**'/exp OR **india**)

Scopus: 157 document results

TITLE-ABS-**KEY (prevalence OR burden AND of AND disease OR epidemiological AND hypertension OR elevated AND blood AND pressure AND adult AND india)** AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (AFFILCOUNTRY , "India")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))

Screening of the articles for the Systematic Review (Adults)

The first step in the study selection is to screen the titles and abstracts for it to fit with the research question and the inclusion and exclusion criteria. The initial search has retrieved 7094 potentially useful review articles/studies from the three databases (PubMed, Embase, Scopus) and 56 articles/studies from other internet searches. All these studies, i.e. a total of 7150, are downloaded in the “Covidence” software online. The software automatically identifies the duplicated studies that are downloaded from different databases and the ones that are removed are about 800 studies/articles. We have excluded all duplicate studies; the remaining 6350 studies/articles, a manual “Title and abstract

screening" are conducted. After the title and abstract screening, 6256 studies/research articles are removed as these studies are not prevalence studies, and are not as per the inclusion criteria. For the remaining eighty-five articles/study, full-text review (critical appraisal of the full text) of the articles are conducted to assess the eligibility. Fifty-seven studies are removed due to one of the following reasons - age range not as per our definition, hypertension not defined as BP ≥140/90mmHg, only abstract being available, the studies are not prevalence studies but are of the incidents of hypertension, review article, inappropriate outcome or data not extractable. From these, only twenty-seven articles are included for quality assurance. On quality assurance, four studies are removed as they are graded poorly in quality assurance. Twenty-four studies are included in the quantitative synthesis or meta-analysis.

Data Extraction

A data collection form is developed prior to the implementation of the search strategy. This data collection tool is used to extract pertinent information from the selected full-text articles. The following information is extracted for included study: Authors name, publication year, setting in which research was conducted, place of study, age of participants in the study, sample size, the overall prevalence of hypertension, the prevalence in male and female, study design, and diagnostic criteria for hypertension.

Full-Text Review								
Study Name	Year	Region	Age	Sample Size	No of Cases	Prevalence	Type of Study	Hypertension definition
P Das	2012	North India	18-24	600	74	13%	Cross-Sectional	SBP ≥ 140 mmHg & DBP≥ 90 mmHg
Tushar Acharyya	2010	North India	25-64	1052	360	34.20%	Cross-Sectional	≥140 mmHg & ≥90 mmHg
Samuel A. Abariga	2019		15-49	212007	NA	13.00%	NFHS	JNC7
Jai Parkash	2019	North India	20+	450	164	36.40%	Cross-Sectional	140 mmHg / 90 mmHg
Sushil K. Bansal,	2012	North India	15+	698	203	32.30%	Cross-Sectional	BP ≥ 140/90 mmHg
T.N. Anand	2018	South India	>=24	2558		51.1	Cross-Sectional	NA
Anubha Agarwal	2019	North India	20+	38,457	8156	21.20%	Cross-Sectional	140/90 mmHg
PRABHA ADHIKARI	2019	South India	20+	551	227	41.19%	Cross-Sectional	JNC 7
Balkrishna B. Adsul	2011	West India	>=15	1337		3.40%	Cross-sectional	JNC 7
Dibyendu Banerjee	2014	South India	18+	909	161	17.70%	Cross-Sectional	BP 140/90 mmHg
Suvro Banerjee	2016	South India	>=20	10,175	4304	42%	Cross-Sectional	≥140 mmHg / ≥90mmHg
Aroor Bhagyalaxmi	2013	North India	15-64	3489	947	27.14245	NA	BP ≥ 140/90 mmHg
Mahadev D. Bhise	2018	South India	18+	110880	NA	25.10%	Secondary Analysis	140mmHg and/or 90 mmHg
A Bhansali	2014	India	20+	14059	NA	26.30%	Cross-Sectional	(SBP/DBP) <140/90mmHg respectively
R. C. Chauhan	2014	South India	18+	560	144	25.30%	Population Based Survey	(SBP) of ≥140 mmHg or DBP ≥90 mmHg
S Ganesh Kumar	2014	South India	21-60	192	85	44.30%	Cross-Sectional	(SBP/DBP) +140/<90mmHg and <140/90mmHg respectively
Souraja Datta	2017	South India	30+	252	66	26.20%	Cross-Sectional	≥140 mmHg and /or a diastolic reading ≥90 mmHg1,2.
MG Deo	2016	South India	40+	410		16.80%	Cross-sectional	≥140/≥90 mmHg
SUPRIYA DWIVEDI	2017	North India	18-45	323	64	19.8	Cross-Sectional	JNC6 JNC7
Soumitra Ghosh	2019	India	15-49	811917	NA	11.3	Cross-Sectional	140mmHg or DBP of 90 mmHg
Jugal Kishore	2016	North India	18+	1005	142	14.1	Cross-Sectional	BP>140mmHg or DBP ⩾90mmHg)

Manmohan Gupta	2011	South India	18-85	263	114	43.3	Cross-Sectional	BP>140mmHg or DBP ⩾90mmHg)
Ashok Kumar Patel	2010	North India	18+	1100	212	19.3	NA	JNC VIII
Imaad Mohammed Ismail	2016	South India	16-35	634	10	1.577287	Cross-Sectional	JNC VIII
Sitanshu Sekhar Kar	2015	South India	NA	907		21.1	NA	NA
Tejas Y. Limaye	2016	South India	30-40	1350	184	13.5	Cross-Sectional	SBP≥ 140 and/or DBP≥90 mmHg
Shishir Kumar	2018	North India	21-80	820	151	18.41	Cross-Sectional	JNC VIII guidelines
Rajeev Gupta	2012	India	20=+	6106	NA	30.4	Cross-Sectional	BP ≥ 140/90
Gautam K. Kshatriya	2018	South India	20-60	1431	NA	12.6	Cross-Sectional	≥140 mmHg and /or a DBP of ≥90 mmHg
Gautam K. Kshatriya	2016	India	20-60	2156	NA	11.7	Cross-Sectional	blood pressure _140/90 mmHg
Saswata Ghosh	2016	North India	>=18	27589	NA	12.5	Cross-Sectional	SBP ≥ 140 mmHg & DBP≥ 90 mmHg
D S Prasad	2012	South India	20-80	1178	431	36	Cross-Sectional	SBP ≥ 140 mmHg & DBP≥ 90 mmHg
Mohmmedirfan H. Momin	2012	North India	20=+	1493	455	30.5	Cross-Sectional	(SBP) of ≥140 mmHg or DBP ≥90 mmHg
II Meshram	2012	South India	>=20	4193	1641	40	Cross-Sectional	(≥140/≥90 mmHg
Kath A. Moser	2014	India	18+	10671	3420	24.6	Cross-Sectional	BP>140mmHg or DBP ⩾90mmHg)
S. A. Rizwan	2014	India	18+	64674		16.1	Systematic Review	BP>140mmHg or DBP ⩾90mmHg)
Anu Mary Oommen	2016	South India	30-64	6196	NA		Cross-Sectional	BP>140mmHg or DBP ⩾90mmHg)
Dorairaj Prabhakarana	2017	India	20-65	3528	NA	NA	CARRS Stud	BP _ 140 and/or _90 mm Hg
Sathya Prakash Manimunda	2011	South India	18+	975		50.5	Cross-Sectional	SBP of ≥ 140 mm Hg and a DBP of ≥ 90 mm Hg
Mandeep Singh	2017	South India	>=15	16636	4494	27	Door-Door Survey	JNC 7
Jaya Prasad Tripathy	2017	North India	18-69	5127	2030	40.1	Cross-Sectional	JNC VIII
Pascal Geldsetzer	2017	India	18+	1320555	350273	26.5	Cross-Sectional	SBP of ≥ 140 mm Hg and a

								DBP of ≥ 90 mm Hg
AONUNGDOK TUSHI	2018	North India	25-64	472	204	43%	Cross-Sectional	SBP of ≥ 140 mm Hg and a DBP of ≥ 90 mm Hg
Priyanka Sajeeva	2018	South India	25-64	298	144	48.3	Cross-Sectional	SBP of ≥ 140 mm Hg and a DBP of ≥ 90 mm Hg
Daniel J. Corsi	2019	India	>=20	757958	101175	14.4	Cross-Sectional	Cutoff points of systolic blood pressure 140 mmHg or greater or diastolic blood pressure 90 mm Hg or greater
Jonas Prenissl	2019	India	15-49	731864	131391	17.9	Cross-Sectional	≥140mmHg or a measured diastolic blood pressure of ≥90mmHg
Tsering Norboo	2014	North India	20-94	2800	1037	37	Cross-Sectional	BP ≥ 140/90
Syed M Shah	2014	India	18+	NA	NA	34.5	Cross-sectional	≥140mmHg or a measured diastolic blood pressure of ≥90mmHg
Prakash Chand Negi	2016	North India	>=20	3968	706	19.7	Cross-Sectional	BP ⩾ 140mmHg and/or diastolic BP ⩾90mmHg)
Vishal Vennu	2019	NA	18+	699481		5.2	Cross-sectional	ANALYSIS OF NFHS 2015-2016
JS Thakur	2019	North India	18-69	5078		26.2	Cross-Sectional	SBP>140 and/or DBP> 90
Sivasubramanian Ramakrishnan	2019	India	18+	180335		30.7	cross-sectional	BP>140mmHg or DBP ⩾90mmHg)
Manisha Dubey	2019	India	18+	797161		7.5	Secondary Analysis	NA
Maharaj Biswas	2011	North India	20-69	1115	200	17.93	Door-Door Survey	BP>140mmHg or DBP ⩾90mmHg)
Prashant R Kokiwar	2012	North India	30+	924	NA	19.04	Cross-Sectional	Greater than 140/90 mmHg
Ayan Ghosh, Deblina Sarkar	2013	North India	20+	977	114	11.43	Cross-Sectional	JNC 7
Syed Esam Mahmood	2013	North India	18+	1509	671	44.46	Observational Study	BP ≥ 140/90
Jayalakshmy Ramakrishnan	2013	South India	20-59	256	NA	30.5	Cross-Sectional	BP ≥ 140/90

Debdutta Ganguli	2011	East India	40-85	415		53.6	Population Based Survey	JNC 7
Ahsana Shah	2013	North India	20-80	1768	321	18.16	NA	BP ≥ 140/90 mmHg
Navya N	2015	South India	18+	156		9.6	Cross-sectional	NA (not mentioned)
Shikha Singh	2017	North India	25-64	559	130	32.9	Cross-Sectional	JNC 7
STEFFI VEIENTLENA	2018	South India	>=20	299	50	16.72	Cross-Sectional	BP ≥140 mmHg systolic and ≥90 mmHg diastolic
Simran Sidhu	2017	North India	18-22	204	19	9.3	Cross-Sectional	BP≥140 mmHg or diastolic blood pressure (DBP) ≥100 mmHg
VINITA THAPLIYAL	2018	North India	18-45	300	NA	24	Cross-Sectional	JNC 8 criteria
M. Vinceti	2019	North India	>=18	680	100	33.5	Cross-Sectional	Systolic BP _ 140 mm Hg, diastolic BP _ 90 mm Hg or history of hypertension
P S Sarma	2019	South India	18-69	12000	NA	30.4	Cross-Sectional	SBP>140 and/or DBP> 90
Meenakshi Kalyan	2020	West India	20-80	29324		20.5	Cross-sectional	JNC 8
Yuvaraj BY	2010	South India	>=18	1900	349	18.3	Cross-Sectional	SBP>140 and/or DBP> 90
Anindita Dutta	2012	North India	>=18	1186	293	24.7	Cross-Sectional	Greater than 140/90 mmHg
Sanjeet Panesar1	2013	North India	20-59	310	43	17.4	Cross-Sectional	BP ≥ 140/90 mmHg
A Joshi1	2013	India	18+	429		18	Cross-sectional	BP ≥ 140/90 mmHg
R Gupta	2015	India	>=20	NA		29	Systematic Review	BP ≥ 140/90 mmHG or DBP ≥90mmHg
Sunil Kumar Raina	2016	North India	>=20+	401	43	12.9	Cross-Sectional	BP ≥ 140/90 mmHG or DBP ≥90mmHg
Shivani S. Manjrekar	2014	South India	30-45	400		5.7	Cross-sectional	140mmHg or DBP of 90 mmHg
Arjun Lakshman	2014	South India	21-60	179	75	41.3	Cross-Sectional	BP ≥ 117/90 mmHG or DBP ≥90mmHg
Ajeet S. Bhadoria	2014	North India	>=20	911	155	17	Cross-Sectional	≥ 140mmHg or DBP ≥90mmHg
Abhijit Mandal	2014	North India	>18	300	53	17.7	Cross-Sectional	BP ≥140 mmHg systolic and ≥90 mmHg diastolic
Tanu Anand1	2018	North India	>=20	403	55	7	Mixed Methods Study	≥140mmHg or DBP of 90 mmHg

Shalini Srivastav	2017	North India	18-65	207	38	17.8	STEPS	≥140mmHg or DBP of 90 mmHg
Nabarun Karmakar	2017	East India	20+	615		26.1	Observational Study	≥140mmHg or DBP of 90 mmHg
Prabhdeep Kaur	2011	South India	25-64	10463	2247	21.4	Cross-Sectional	(SBP) C140 mmHg or diastolic blood pressure (DBP) C90 mmHg
T. K. Raja	2017	South India	18+	225		26.2	Cross-sectional	NA
RAJSINH MOHITE	2019	West India	18-60	460		23.04	Cross-sectional	NA
Palanivel Chinnakali	2012	Puducherry, south India.	age 60 years and above	211	85	40.50%	cross-sectional study	SBP ≥140mmHg or DBP ≥90mmHg

Quality Assessment

The practicality of results from the systematic reviews depend on the quality of the individual studies included in the review, so a quality assurance of all the selected studies is done by the grading method. Study Quality Assessment Tools are taken from the National heart, lung, and blood institute. (12) (Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Available online at https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools/cohort). Study Quality Assessment tool is used to assess the quality of the studies. Nine questions are relevant from the total of fourteen items provided in the tool. The criteria for recording the results are divided into three parts, good (Grade 7 to 9), fair (Grade 4 to 6), and low (Grade 1 to 3).

Quality Assurance

A	D	U	L	T		S	T	U	D	Y	QU	AL	ITY	ASS	URAN	CE
Study No	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	SCORE	RATE G/F/P
01	1	1	0	1	0	0	0	N/A	1	1	1	N/A	N/A	0	6	Fair
02	1	1	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	8	Good
04	1	0	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	7	Good
05	1	1	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	8	Good
11	1	1	1	1	0	0	0	N/A	1	1	1	N/A	N/A	0	7	Good
16	1	1	1	1	1	0	0	N/A	1	1	1	N/A	N/A	1	9	Good
23	1	1	1	1	1	0	0	N/A	1	1	1	N/A	N/A	0	8	Good
26	0	0	0	1	0	0	0	N/A	1	0	1	N/A	N/A	0	3	Poor
33	1	1	0	1	1	0	0	N/A	1	1	1	N/A	N/A	0	6	Fair
35	1	0	1	0	0	0	0	N/A	1	1	1	N/A	N/A	1	6	Fair
41	1	0	1	1	1	0	0	NA	1	1	1	NA	NA	1	8	Good
43	0	0	1	0	1	0	0	N/A	1	1	1	N/A	N/A	0	5	Fair
52	1	0	1	0	0	0	0	N/A	0	1	0	N/A	N/A	0	3	Poor
54	1	0	1	1	0	0	0	N/A	1	1	1	N/A	N/A	0	6	Fair
55	1	0	1	0	1	0	0	N/A	0	0	0	N/A	N/A	0	4	Fair
56	1	0	1	1	0	0	0	N/A	1	1	0	N/A	N/A	0	5	Fair
57	1	1	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	8	Good
62	1	0	1	1	1	0	0	N/A	1	1	1	N/A	N/A	1	8	Good
63	1	0	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	7	Good
69	1	0	1	1	0	0	0	N/A	1	1	1	N/A	N/A	0	6	Fair
71	1	0	1	1	1	0	0	N/A	0	0	1	N/A	N/A	1	6	Fair
72	1	0	1	0	0	0	0	N/A	0	0	1	N/A	N/A	0	3	Poor
74	1	0	1	1	1	0	0	N/A	1	1	1	N/A	N/A	0	7	Good
76	1	1	1	1	0	0	0	N/A	1	1	1	N/A	N/A	1	8	Good
79	1	0	1	0	1	0	0	N/A	0	1	1	N/A	N/A	1	6	Fair
80	1	1	1	1	1	0	0	N/A	1	1	1	N/A	N/A	0	8	Good
82	1	0	1	1	1	0	0	N/A	1	1	1	N/A	N/A	1	8	Good

1	YES
0	NO
7-9	Good
4-6	Fair
1-3	Poor

Statistical Analysis

The number of cases with hypertension and sample size (effect size and its respective standard error) is analyzed using the OpenMeta[analyst] software and metaprop command of the meta package in R software to obtain the pooled estimate of prevalence and the Clopper-Pearson 95% confidence (95% CI) interval. Proportions are transformed in a generalized linear mixed model with the logit transformation. (13) Between-study heterogeneity is investigated with the use of Cochran's Q, and Higgin's I^2.(14) Heterogeneity is judged as low, moderate, or high at I^2 values of 25-50%, 50-75%, or

>75%, respectively. In the instance of significant heterogeneity, subgroup analysis would be carried out by the region of study. For publication bias, a funnel plot is created, and an Egger's test is conducted based on the weighted linear regression of the effect size (proportion) on its standard error. (15) Below is the table of all that are included studies for Meta-Analysis.

Selected studies for Meta-Analysis

Study Name	Year	Region N/S	Region 2	Sample Size	HTN	Age-Sub groups	Prevalence	Age	N	Case	Prevalence
P Das (20)	2012	North India	East India	102	6	<= 20	5.8823529	**20-24**	**600**	**78**	**13**
				378	24	21-22	6.3492063				
				120	48	23-24	40				
Tushar Acharyya (21)	2010	North India	East India	1052	360	25-64	34.220532	**25-44**	**527**	**136**	**25.80645**
		M 267+ F 260		527	136	25-44	25.806452				
				525	224	45-64	42.666667				
Jai Parkash (22)	2019	North India	North India	26	3	20-29	11.538462	**20-49**	**302**	**101**	**33.44371**
				100	24	30-39	24				
				176	74	40-49	42.045455				
				148	63	50+	42.567568				
Sushil K. Bansal (23)	2012	North India	North India	698	203	15+					
				220	38	15-24	17.272727	**15-44**	**559**	**134**	**23.97138**
				143	36	25-34	25.174825				
				121	36	35-44	29.752066				
				75	24	45-54	32				
				66	30	55-64	45.454545				
				51	29	65-74	56.862745				
				17	7	75-84	41.176471				
				5	0	>=85	0				
Suvro Banerjee (24)	2016	South India	East India	1,163	97	20-30	8.3404987	**20-50**	**6,023**	**1934**	**32.11024**
				2262	660	31-40	29.177719				
				2598	1177	41-50	45.30408				
				2100	1130	51-60	53.809524				
				1438	890	61-70	61.891516				
				476	293	71-80	61.554622				

				85	47	>80	55.294118				
S Ganesh Kumar (25)	2014	South India	south India	39	11	21-30	28.205128	**21-40**	**148**	**62**	**41.89189**
				58	28	31-40	48.275862				
				51	23	41-50	45.098039				
				44	23	51-60	52.272727				
Ashok Kumar Patel (26)	2010	North India	North India	388	32	18-25	8.2474227	**18-45**	**861**	**110**	**12.77584**
				253	23	26-35	9.0909091				
				220	55	36-45	25				
				137	57	46-60	41.605839				
				102	45	>60	44.117647				
Mohmmedirfan H. Momin (27)	2012	North India		226	12	20-29	5.3097345	**20-49**	**1169**	**298**	**25.49187**
			West India	368	67	30-39	18.206522				
				575	219	40-49	38.086957				
				324	157	>=50	48.45679				
				1493	455		30.475553				
Kath A. Moser (28)	2014	India	India	1527	199	18-29	13.032089	**18-49**	**4465**	**964**	**21.59015**
				1593	350	30-39	21.971124				
				1345	415	40-49	30.855019				
				2823	1043	50-59	36.946511				
				2108	832	60-69	39.468691				
				1275	581	70+	45.568627				
				10671	3420		32.04948				
Jaya Prasad Tripathy (29)	2017	North India	North India	804	152	18-24	18.905473	**18-44**	**3295**	**979**	**29.71168**
				2491	827	25-44	33.199518				
				1760	1051	45-69	59.715909				
AONUNGDOK TUSHI (30)	2018	North India	East India	236	66	25-44	27.966102	**25-44**	**236**	**66**	**27.9661**
				236	138	45-64	58.474576				
Maharaj Biswas (31)	2011	North India	East India	330	30	20-29	9.0909091	**20-49**	**770**	**105**	**13.63636**
				230	30	30-39	13.043478				
				210	45	40-49	21.428571				
				130	55	50-59	42.307692				
				215	60	60-69	27.906977				

Prashant R Kokiwar (32)	2012	North India	North India	336	27	30-39	8.0357143	**30-49**	**589**	**72**	**12.22411**
				253	45	40-49	17.786561				
				154	35	50-59	22.727273				
				181	69	>=60	38.121547				
				924	176	Total	19.047619				
Ayan Ghosh (33)	2013	North India	East India	196	9	20-29	7.89	**20-49**	**591**	**39**	**6.598985**
				183	7	30-39	6.14				
				212	23	40-49	20.17				
				167	29	50-59	25.44				
				132	36	60-69	31.58				
				107	10	70+	8.77				
				997	114		11.43				
Syed Esam Mahmood (34)	2013	North India	North India	254	70	18-30	27.559055	**18-40**	**1043**	**409**	**39.21381**
				470	181	31-40	38.510638				
				319	158	41-50	49.529781				
				320	183	51-60	57.1875				
				146	79	>60	54.109589				
				1509	671	total	44.466534				
Shikha Singh (35)	2017	North India	Nortyh India	202	26	25-34	12.871287	**25-44**	**368**	**66**	**17.93478**
				166	40	35-44	24.096386				
				101	35	45-54	34.653465				
				90	29	55-64	32.222222				
				559	130	25-64	23.255814				
STEFFI VEIENTLENA (36)	2018	South India	South India	127	23	20-39	18.110236	**20-39**	**127**	**23**	**18.11024**
				141	23	40-59	16.312057				
				31	4	60+	12.903226				
Yuvaraj BY (37)	2010	South India	south India	448	22	18-29	4.9				
				475	57	30-39	12	**18-49**	**1287**	**173**	**13.44211**
				364	94	40-49	25.8				
				301	71	50-59	26.6				
				213	65	60-69	30.5				
				99	31	70+	31.3				
				1900	349	>=18	18.37				
Sanjeet Panesar (38)	2013	North India	North India	138	8	20-29	5.7971014	20-49	268	33	12.31343
				83	14	30-39	16.86747				

				47	11	40-49	23.404255				
				41	10	50-59	24.390244				
				310	43	20-59	13.870968				
Sunil Kumar Raina (39)	2016	North India	North India	73	1	20-29	1.369863	**20-49**	**318**	**32**	**10.06289**
				142	16	30-39	11.267606				
				103	15	40-49	14.563107				
				46	4	50-59	8.6956522				
				37	7	>=60	18.918919				
				401	43		10.723192				
Arjun Lakshman (40)	2014	South India	South India	39	7	20-29	17.948718	**20-49**	**166**	**66**	**39.75904**
				75	34	30-39	45.333333				
				52	25	40-49	48.076923				
				13	8	50-59	61.538462				
				179	75	20-59	41.899441				
Tanu Anand (41)	2018	North India	North India	257	51	20-24	19.844358	**20-49**	**341**	**65**	**19.06158**
				84	14	35-49	16.666667				
				62	11	>=50	17.741935				
Shalini Srivastav (42)	2017	North India	North India	25	1	18-25	4	**18-45**	**165**	**22**	**13.33333**
				83	11	26-35	13.253012				
				57	10	36-45	17.54386				
				27	8	46-55	29.62963				
				15	8	56-65	53.333333				
				207	38		18.357488				
Prabhdeep Kaur (43)	2011	South India	South India	3746	308	25-34	8.2221036	**25-44**	**6926**	**767**	**11.07421**
				3180	459	35-44	14.433962				
					488	45-54					
					427	55-64					
					1682	25-64					

Results

Prevalence of hypertension in Adults (15-49)

In all, 24 studies are included in the meta-analysis (31,144 individuals). As depicted in Figure 1, the pooled prevalence of hypertension is 20% (95%CI, 16.0 to 24.0), while the

prevalence in individual studies range between 7.0% and 42%. These results are based on a random-effects model, which is applied because of the substantial heterogeneity between studies (t2 = 0.37, heterogeneity I2 = 98.6%, degree of freedom = 23, P < 0.0001).

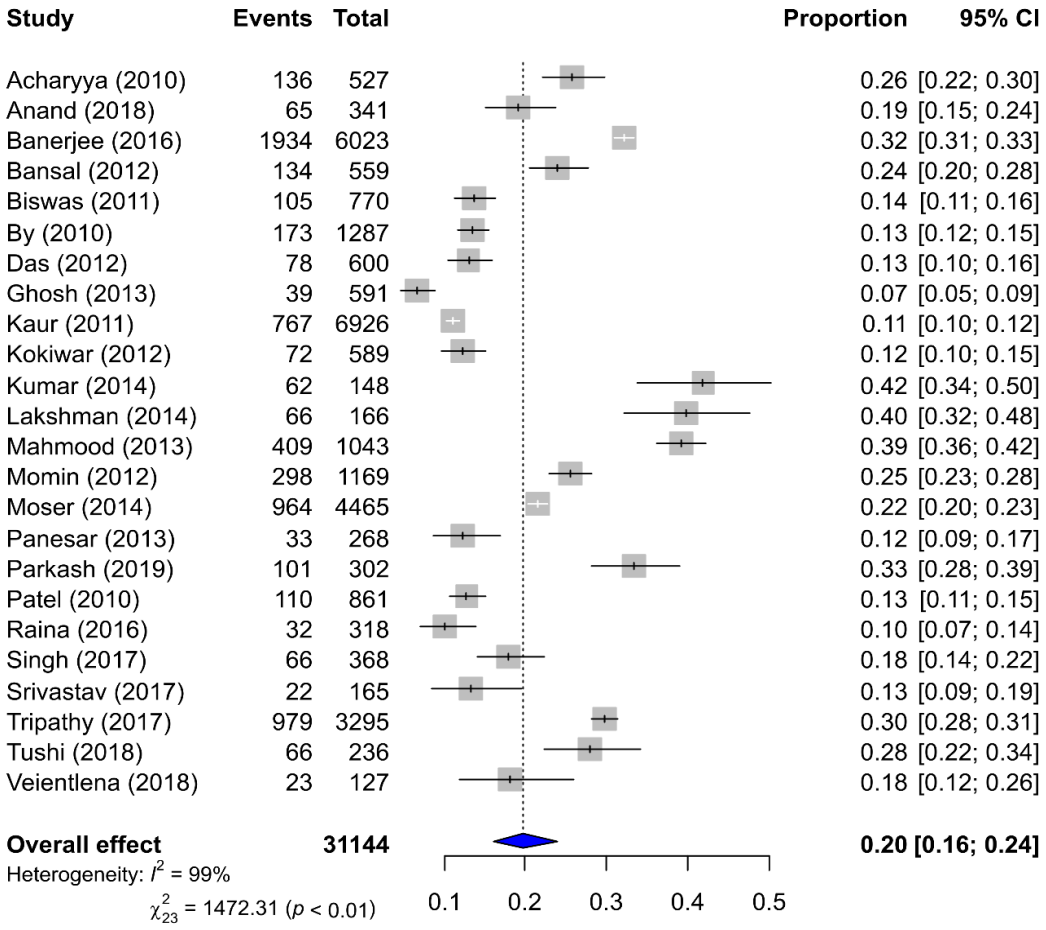


Figure 1: forest plot of the prevalence of hypertension in the included studies.

Subgroup analysis of different regions in India (North/South/East/West)

Based on the region where studies have been carried out, subgroup analysis of studies in East India include 8,747 individuals (6 studies), 8109 individuals in North India (11 studies), South India include 8,654 individuals (5 studies) and West India include 1,169 individuals (1 study, Figure 2). The prevalence of hypertension is relatively higher in the Western region (25%, 95%CI, 23% to 35%) and South India (22%, 95%, 13% to 35%) as compared to Eastern India (18%, 95%CI, 11% to 27%) and North India (19%, 95%CI,

14% to 25%); however, regional difference is not significant (Q for subgroup difference = 10.47, degree of freedom = 4, P = 0.0332). The heterogeneity remains significant in both subgroups (P < 0.0001 for all the three subgroups (Western India only has one study present so heterogeneity is not applicable, Figure 2).

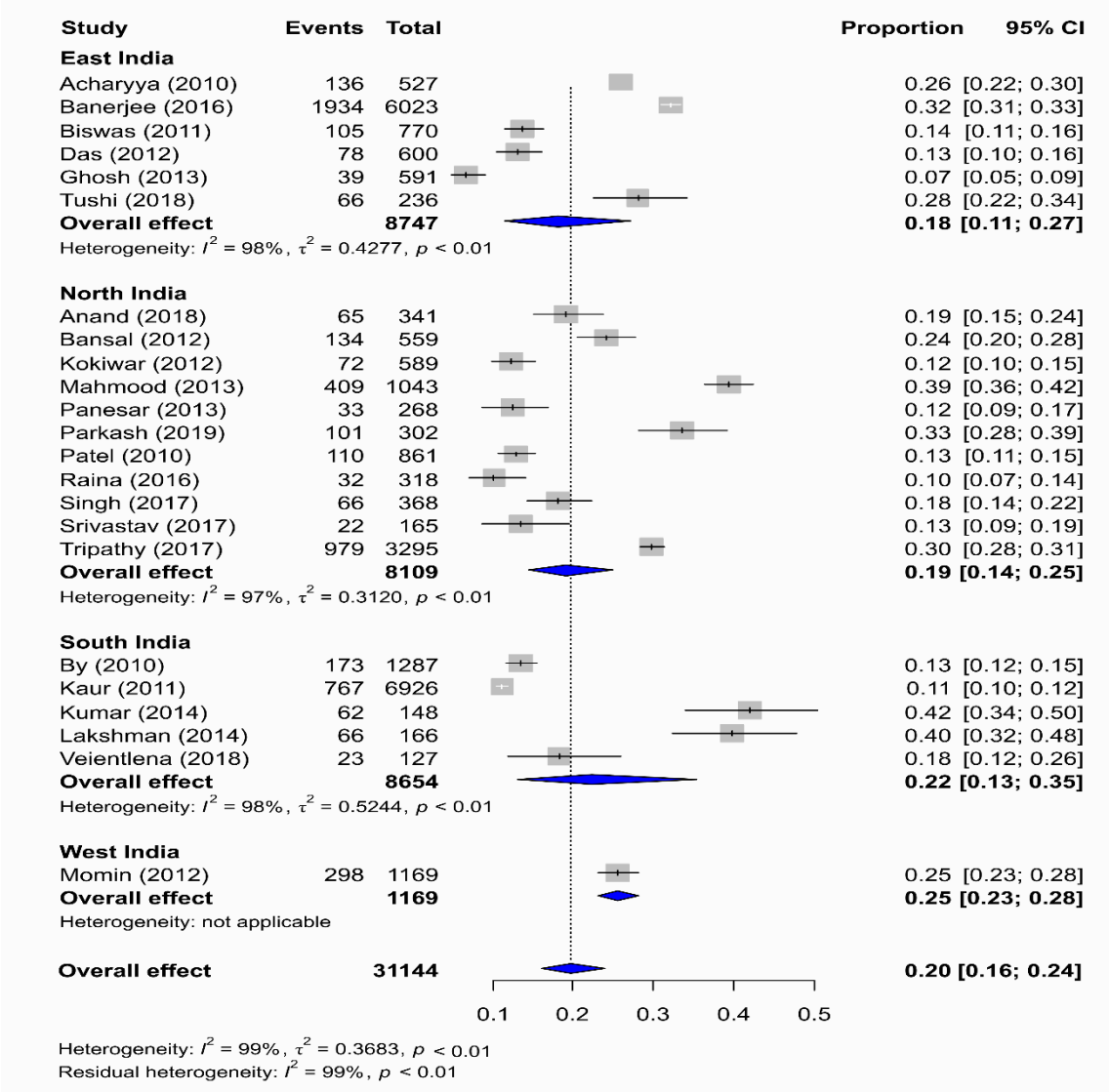


Figure 2: forest plot of subgroup analysis of the prevalence of hypertension by region of included studies.

Subgroup analysis as north and south India, Adults (15-49)

Based on the region where studies have been carried out, subgroup analysis of studies in North India include 12,002 individuals (17 studies) and 14,677 individuals in South India (6 studies, Figure 3). The prevalence of hypertension is relatively higher in the Southern

region (23.7%, 95%CI, 15.1% to 35.2%) as compared to North India (18.3%, 95%, 14.5% to 22.9%); however, regional difference is not significant (Q for subgroup difference = 2.12, degree of freedom = 2, P = 0.346). The heterogeneity remains significant in both subgroups (P < 0.0001 for all, Figure 3).

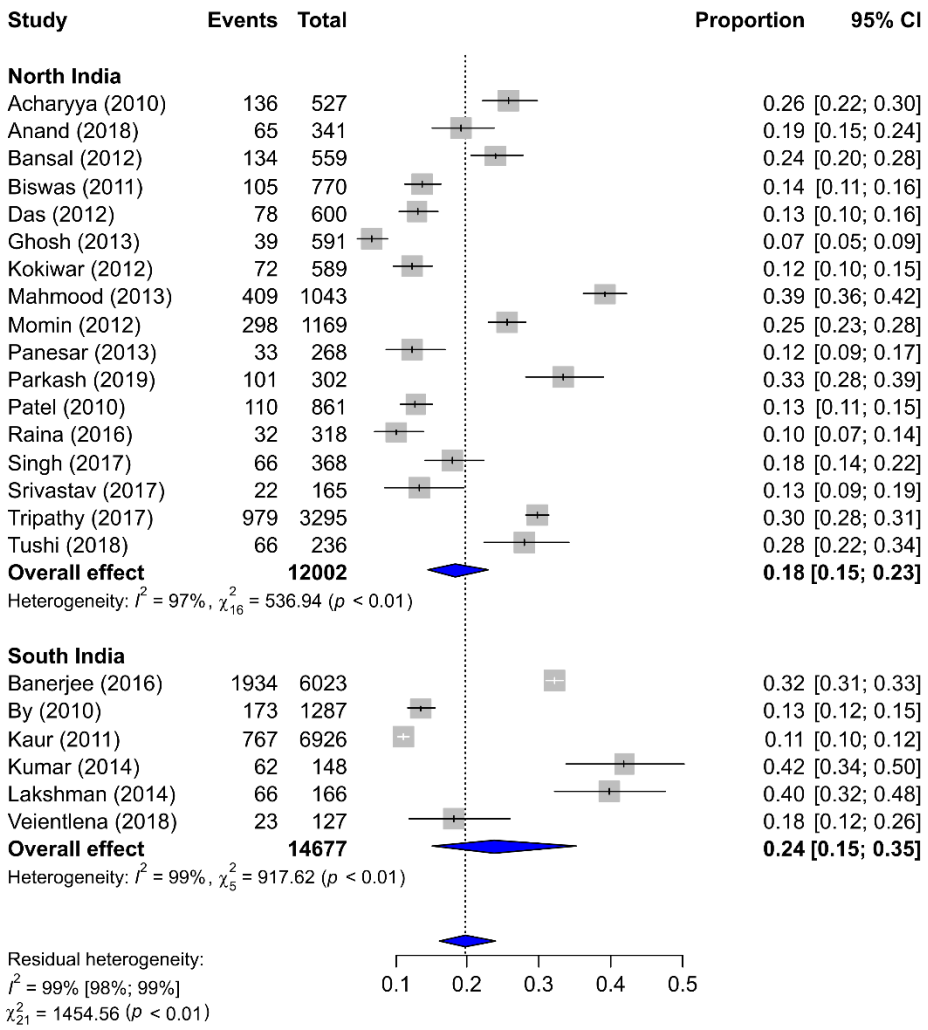


Figure 3: Forest plot of the subgroup analysis of the prevalence of hypertension by the region of each study.

Publication bias

Publication bias is visually assessed by producing a funnel plot (Figure 3), showing asymmetrically distributed pattern of effect sizes around the mean effect estimate, indicating no publication bias. This is corroborated in the results of Egger's test for small-study effects (intercept = -3.65 [CI, -9.14 to -1.84], t = -1.32, P = 0.200).

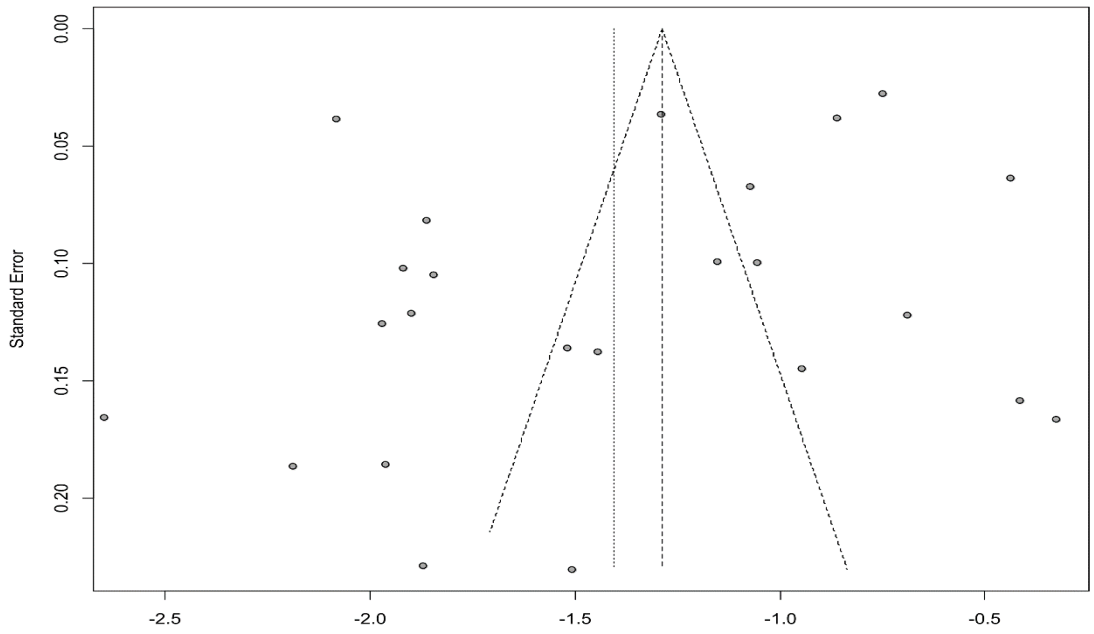


Figure 3: Funnel plot for the assessment of publication bias.

Strengths and Limitation

Studies that are included in the meta-analysis are studies of only high-quality, and there is no evidence of publication bias as can be seen in the funnel plot for the assessment of publication bias. Time to conduct the systematic review is very short; hence the reason for limiting the search to one decade in the systematic review. Only articles that are published in “English” are selected for the study, and papers in any other languages are not reviewed. The data extraction done in systematic review and meta-analysis of the studies/articles is only as reliable as the approaches used to approximate the prevalence in each study. The meta-analysis cannot overcome the complications that are inherited in the design and implementation of the primary research. A systematic review also does not correct biases that may occur as an outcome of selective publication. The studies that report significant effects are more likely to be identified summarized, and are subsequently pooled in meta-analysis, than those studies that report smaller effect sizes. This is known as publication bias. It is reported that a large difference in the sample size between studies, and inclusion of a lesser number of studies/articles tend to yield a pooled

estimate that has low power and precision, thereby resulting in a higher heterogeneity and a higher I^2. (16) Even after considerate attempts to examine potential sources, large and unexplained heterogeneity persist. Selection bias.

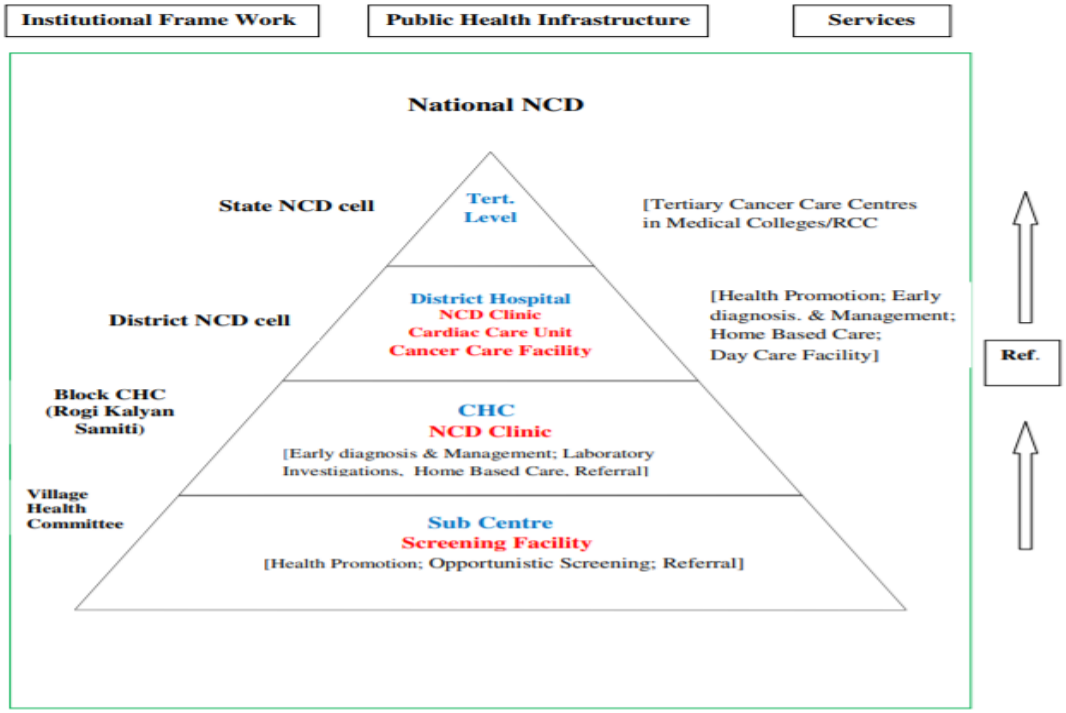
Discussion

A comprehensive review of studies/articles is done to conduct this systematic review. The pooled estimate for the prevalence of measured hypertension in the adult population age group 15-45 in India, based on 24 studies published between 2010 and 2020, is 20%. However, the pooled estimate for subgroups for North and South India is 18% in north India and 24% in south India. The differences between the prevalence of hypertension between north and south India that can be noted in the study may be due to the differences in socio-economic conditions, quality of healthcare services and risk factors provided. Majority of studies completed are cross-sectional studies. More than 50% of the studies are rated good in quality assurance. Risk factors such as consumption of tobacco, alcohol, eating unhealthy foods (Increase salt intake, increased consumption of red meat, processed foods rich in trans and saturated fats) and sedentary lifestyle like reduced physical activity contribute to a high prevalence of hypertension. These days many jobs require long hours of sitting in front of computers; people spending long hours on mobile devices in sitting or lying down positions, rapid urbanization (increased used of cars and buses even for small distances), economic progress in urban areas, obesity and increased mental stress especially in males (17). A significant public health challenge worldwide is the increasing prevalence of hypertension and its prevention, detection, medical management and control should be given very high priority. (11) Prevalence of hypertension as per National Family Health Survey (NFHS) 2015-2016, eleven percent of women and fifteen percent of men age 15-49 have hypertension. (18)

Conclusion

As the pooled estimate for the prevalence of measured hypertension in the adult population age group 15-45 in India, based on 24 studies published between 2010 and 2020, is 20%, one advice to the policymakers is that the study can serve as an input for designing early life preventive and control strategies that can help in reducing the prevalence of hypertension in adults and also the diseases that are associated with hypertension. According to the National Programme for prevention and control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) early diagnosis of chronic non-communicable diseases there is an opportunistic screening of people of age 30 and above at the point of primary contact with any health care facility, be it the village, CHC, District hospital, tertiary care hospital etc. Opportunistic screening involves basic clinical examination consisting of asking relevant questions and easily conducted physical measurements such as a history of tobacco consumption and measurement of blood pressure etc, to identify individuals who are at a high risk of diabetes and CVD. (19). The study findings suggest that guidelines may be developed for opportunistic screening of blood pressure as early as 15 years of age as it may benefit in early diagnosis and management of hypertension which can prevent significant complications of associated diseases with hypertension. Early detection of hypertension, will have an impact in reducing health-related costs in the long term and also bring an improvement in the health outcomes of individuals.

Figure 3: Services available under NPCDCS at different levels



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