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Global Evidence on Undiagnosed and Uncontrolled Hypertension: A Systematic Review and Meta-analysis of Population-Based Studies

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Abstract **Background:** Hypertension care involves distinct stages of diagnosis, treatment, and blood pressure control. We synthesized population-based evidence on undiagnosed and uncontrolled hypertension and related care indicators across the settings represented by eligible studies. **Methods:** This systematic review included 25 observational articles reporting measured blood pressure and extractable denominators for at least one hypertension care outcome. Separate random-effects meta-analyses of logit-transformed proportions were undertaken for undiagnosed hypertension, uncontrolled hypertension among treated participants, uncontrolled hypertension among all participants with hypertension, awareness/diagnosis, treatment, and blood pressure control. Search end date: (VERIFY LAST SEARCH DATE0. Risk of bias was assessed using AXIS or the Newcastle–Ottawa Scale, as applicable. **Results:** The pooled proportion undiagnosed among participants meeting study-specific hypertension definitions was 46.4% (95% CI 42.8–50.1%; I^2=99.7%). Uncontrolled blood pressure was estimated separately among treated hypertensive participants (49.6%; 95% CI 37.2–62.1%; I^2=99.5%) and among all hypertensive participants (78.7%; 95% CI 71.2–84.6%; I^2=99.9%). In different evidence subsets, pooled awareness/diagnosis, treatment, and control were 52.5% (95% CI 47.3–57.7%; I^2=99.7%), 43.5% (95% CI 37.4–49.8%; I^2=99.8%), and 21.3% (95% CI 15.4–28.8%; I^2=99.9%), respectively. These estimates are not sequential observations from one cohort and cannot be directly subtracted. Study-specific narrative findings suggested variation by sex, age, residence, and socioeconomic conditions, but these associations were not established by a pooled subgroup analysis. Funnel-plot tests did not show statistically significant asymmetry for most pools; Egger and Begg tests gave discordant findings for uncontrolled hypertension among treated participants. Extreme heterogeneity limits generalizability. **Conclusion:** In the included study populations, approximately 46% of participants with hypertension were undiagnosed and approximately 79% had uncontrolled blood pressure when all hypertensive participants formed the denominator. These separately pooled, highly heterogeneous proportions are not universal country-level estimates. Consistent hypertension definitions, standardized surveillance, and clearly specified denominators are needed to interpret diagnosis, treatment, and control gaps.

Key Words Hypertension, Undiagnosed Hypertension, Uncontrolled Hypertension, Awareness, Treatment, Blood Pressure Control, Prevalence, Meta-Analysis

INTRODUCTION

Hypertension continues to be one of the most significant preventable factors behind the development of cardiovascular morbidity and early mortality. Not only the importance of hypertension is connected to the high population prevalence, but also to its long-lasting asymptomatic nature, when damage is done to the vessels, kidneys, brain, and heart even before the treatment or detection of the condition is performed [1]. Blood pressure elevation has been shown to correlate with the development of stroke, ischemic heart disease, heart failure, chronic kidney disease, cognitive disorders, and all-cause mortality [2]. Thus, it is crucial to detect hypertension and reduce it properly since there are inexpensive diagnostic tests and effective antihypertensive treatments available [3].

In recent decades, there has been a considerable shift in the epidemiology of hypertension due to population aging, urbanization, diet change, decreased physical activity,

obesity, diabetes, and increased cardiometabolic risk burden [4]. These trends have been especially notable in low- and middle-income areas where the health-care system should be able to manage infectious diseases along with the rise of chronic diseases, lack of general practitioner availability and limited access to the drugs for long-term management [5]. In high-income settings, the detection and management of hypertension have improved, however, the control is still uneven depending on the availability to the health care, socioeconomic status, age, gender, ethnicity and continuity of care [6]. Therefore, the global hypertension burden cannot be estimated based only on the prevalence data, but it should be considered within the diagnosis-awareness-treatment-control cascade of care.

Undetected hypertension can be viewed as a failure of early detection. People with elevated blood pressure that are unaware about their condition do not enter the cardiovascular prevention program, do not receive the lifestyle advice, pharmacological treatment, and regular monitoring [7]. The burden of undetected hypertension tends to be higher in males, younger people, rural population, people with lower income, lesser education level and poor access to the health-care services [8]. This pattern suggests that the issue of undetected hypertension is not just biological but reflects the underlying structural inequities, access to the health-care service, screening coverage, and health-seeking behavior. As hypertension is usually asymptomatic, the opportunistic detection might not be enough in populations with insufficient primary care attendance and low perceived disease burden [9].

Additionally, uncontrolled hypertension is a particular public health problem that can happen among the population that was never diagnosed with hypertension, among those that were diagnosed but not treated and among those that were being treated but have insufficient blood pressure levels [10]. Poor blood pressure control might be caused by the insufficient treatment initiation, poor adherence to the drugs, therapeutic inertia, lack of follow-ups, drug cost, fragmented care or insufficient treatment intensification [11-12]. Thus, uncontrolled hypertension reflects the failures across the whole care cascade, from screening to effective treatment. The analysis of uncontrolled hypertension together with undetected hypertension allows assessing the cardiovascular prevention gaps more comprehensively.

Prior national and multinational studies have reported substantial variation in hypertension awareness, treatment, and control. Differences in sampling, blood pressure measurement, diagnostic thresholds, survey years, and outcome denominators complicate direct comparison. This review therefore aimed primarily to synthesize separately the proportions of undiagnosed hypertension among hypertensive participants and uncontrolled hypertension among (a) treated hypertensive participants and (b) all hypertensive participants. Secondary objectives were to summarize awareness/diagnosis, treatment, and blood pressure control across eligible population-based studies, and to describe study-specific demographic patterns. Because the included studies cover selected countries and multinational samples rather than every world region, the findings represent global evidence across sampled settings, not a geographically representative worldwide prevalence estimate.

METHODS

Review Design

The review protocol was designed following the PECOS design template and formulated following PRISMA 2020 reporting guidelines [13] for systematic review reporting. The population criterion was human subjects from general population, community-based, national survey, or multi-country epidemiological databases. Exposure was hypertension using measured blood pressure, prior diagnosis, use of antihypertensive drugs, or study-specific hypertension definitions. A traditional comparator was not required since the review focused on estimating pooled prevalence; however, comparative stratification was considered by country, region, income level, age group, gender, and stage of the healthcare cascade. Outcomes were undiagnosed hypertension, uncontrolled hypertension, awareness/diagnosis, treatment, and blood pressure control. Eligible study designs were original human observational studies, which included cross-sectional surveys, repeat national surveys, population-based cohort baseline analyses, and multi-country epidemiological studies since these designs had appropriate prevalence denominators and measured blood pressure data.

Protocol registration and amendments: (VERIFY WHETHER REGISTERED IN PROSPERO/OSF; PROVIDE IDENTIFIER OR STATE NOT REGISTERED). (VERIFY WHETHER ELIGIBILITY CRITERIA AND ANALYSES WERE SET BEFORE SCREENING AND DESCRIBE ANY AMENDMENTS). The review synthesizes independent outcome-specific proportions; an article contributing multiple survey rounds or populations requires assessment for overlap before inclusion in any single pool.

Inclusion and Exclusion Criteria

Outcome-specific eligibility: Undiagnosed hypertension required the number of previously unaware or undiagnosed individuals among all individuals meeting the source study's hypertension definition. Uncontrolled hypertension among treated participants required uncontrolled cases among participants currently receiving antihypertensive treatment. Uncontrolled hypertension among all hypertensive participants required uncontrolled cases among all hypertensive participants, including untreated or undiagnosed cases where the source definition allowed. Awareness/diagnosis, treatment, and control were pooled only where numerator and denominator matched the stated outcome. Mixed samples, survey-weighted percentages, age-standardized estimates, and repeated survey waves require source-by-source denominator and independence checks (VERIFY AGAINST EXTRACTION SHEET).

Included studies should have been original human studies reporting either undiagnosed hypertension, uncontrolled hypertension, or sufficient awareness, treatment, and control data from which these outcomes can be derived. Eligible studies were cross-sectional studies, national health surveys, WHO STEPS-based surveys, Demographic and Health Survey analyses, population-based cohort analyses, and multi-country community-based epidemiological studies. Included studies should report either measured blood pressure, clearly stated definition of hypertension, and an extractable denominator for at least one relevant pooled outcome. The exclusion criteria were systematic reviews, meta-analyses, narrative reviews, editorials, letter to the editor (with no new data), case reports, case series (without valid prevalence denominators), animal studies, in vitro studies, and intervention studies without baseline prevalence data. In addition, the review excluded studies that focused only on hospital inpatients, clinic-only hypertensive patients, disease-specific populations, occupation-specific samples, students only, and immigrants only because they are not appropriate for general population-level hypertension burden.

Search Reproducibility

(VERIFY EXACT SEARCH DATES, SEARCH END DATE, LANGUAGE AND DATE RESTRICTIONS, GOOGLE SCHOLAR SCREENING LIMITS, GREY-LITERATURE COVERAGE, AND DEDUPLICATION METHOD). The listed PubMed query requires both awareness-related and treatment/control-related terms and may have missed studies reporting only one outcome. This potential limitation should be considered when interpreting coverage; a corrected search and updated flow counts must not be claimed without rerunning the search. Embase, Scopus, and Web of Science were not listed among the searched databases.

Database Search Protocol

Literature was searched using database-specific Boolean combinations of hypertension, undiagnosed disease, awareness, treatment, control, prevalence, and population-based epidemiology on PubMed, Cochrane Library, Dimensions, and Google Scholar (Table 1). PubMed literature was searched using MeSH terms in conjunction with title/abstract keywords. On the other hand, Cochrane library literature search used more controlled vocabulary and trial/indexing while avoiding reviews. In addition, dimensions were used to expand literature searches for global public health and survey-based literature. Google Scholar was used with broad phrase combinations in order to find epidemiological studies, national survey reports, and multi-country databases.

Data Harmonization

For each outcome, denominators must be checked against the original publication before pooling. When numerators were reconstructed from reported percentages, rounding may have introduced error, particularly for survey-weighted or rounded estimates. Complements (for example, 100% minus awareness or control) are valid only when the original numerator and denominator refer to the same population and definitions. (VERIFY WHETHER TWO REVIEWERS EXTRACTED DATA INDEPENDENTLY AND HOW DISCREPANCIES WERE RESOLVED). A study-level extraction table should report the original or derived numerator, denominator, hypertension threshold, measurement protocol, survey weighting, and source of each estimate.

Protocol for Data Extraction and Data Items

The AXIS and Newcastle–Ottawa judgments shown in Figures 2 and 3 describe study-specific methodological concerns; they do not establish that pooled estimates are unbiased. (VERIFY INDEPENDENT ASSESSMENT, THE EXACT NOS VERSION, AND RULES USED TO CONVERT DOMAIN RATINGS INTO OVERALL JUDGMENTS). Full domain-level ratings should be supplied as supplementary material.

Data were extracted from each article using a pre-defined standard data abstraction form. Study-level variables

Table 1: Search Strings Utilised Across the Databases

Database	Search string
PubMed/MEDLINE	("Hypertension"[MeSH] OR hypertension[tiab] OR "high blood pressure"[tiab] OR "raised blood pressure"[tiab] OR "elevated blood pressure"[tiab]) AND ("Undiagnosed Diseases"[MeSH] OR undiagnosed[tiab] OR "undiagnosed hypertension"[tiab] OR unaware[tiab] OR awareness[tiab] OR diagnosis[tiab] OR diagnosed[tiab]) AND ("Blood Pressure Determination"[MeSH] OR "blood pressure measurement"[tiab] OR measured[tiab]) AND ("Prevalence"[MeSH] OR prevalence[tiab] OR epidemiology[tiab] OR "population-based"[tiab] OR "community-based"[tiab] OR "national survey"[tiab] OR "cross-sectional"[tiab]) AND (treatment[tiab] OR control[tiab] OR "blood pressure control"[tiab] OR "uncontrolled hypertension"[tiab] OR "care cascade"[tiab]) NOT (review[pt] OR meta-analysis[pt] OR editorial[pt] OR letter[pt] OR animals[mh] NOT humans[mh])
Cochrane Library	(hypertension OR "high blood pressure" OR "raised blood pressure"),ab,kw AND (undiagnosed OR unaware OR awareness OR diagnosis OR "uncontrolled hypertension" OR "blood pressure control" OR treatment),ab,kw AND (prevalence OR epidemiology OR "population based" OR "community based" OR "national survey" OR "cross sectional" OR "health survey"),ab,kw NOT ("systematic review" OR "meta-analysis" OR protocol OR animal),ab,kw
Dimensions	(hypertension OR "high blood pressure" OR "raised blood pressure" OR "elevated blood pressure") AND ("undiagnosed hypertension" OR undiagnosed OR unaware OR awareness OR "hypertension diagnosis" OR "uncontrolled hypertension" OR "blood pressure control" OR treatment) AND (prevalence OR epidemiology OR "population-based" OR "community-based" OR "nationally representative" OR "national survey" OR "WHO STEPS" OR "Demographic and Health Survey" OR "cross-sectional study") AND NOT ("systematic review" OR "meta-analysis" OR "narrative review" OR "case report" OR animal OR "in vitro")
Google Scholar	allintitle: hypertension prevalence awareness treatment control OR "undiagnosed hypertension" "population-based" OR "uncontrolled hypertension" "community-based" OR "hypertension awareness treatment control" "national survey" OR "hypertension care cascade" "measured blood pressure" OR "WHO STEPS" hypertension awareness treatment control OR "Demographic and Health Survey" "undiagnosed hypertension"

region, study design, source of data, sampling method, study period, age eligibility, sample size, mean/median age, percentage of males, setting, length of follow-up if any, and population representativeness. Methodological variables abstracted included method of blood pressure measurement, number of readings, BP averaging technique, diagnostic threshold for hypertension, definition of hypertension, definition of undiagnosed hypertension, definition of uncontrolled hypertension, definition of awareness, definition of treatment, definition of BP control, covariates of interest, and statistical methods used. Outcome variables abstracted included number of hypertensive participants, number of undiagnosed cases, number of diagnosed or aware cases, number of treated cases, number of controlled cases, number of uncontrolled cases, pooled proportion, 95% CI, and type of denominator. In cases where the articles provided proportions without the number of events, the numerators were reconstructed using the published denominator size and rounded to integers.

GRADE Interpretation

The very high inconsistency across all six outcomes and differences in definitions, survey populations, and measurement protocols warrant explicit consideration when rating certainty. Precision of a pooled confidence interval does not by itself establish high certainty. [VERIFY AND INSERT OUTCOME-SPECIFIC GRADE JUDGMENTS AND JUSTIFICATIONS FROM THE ACTUAL ASSESSMENT; DO NOT INFER FORMAL RATINGS FROM I^2 ALONE].

Assessment of Risk of Bias

Bias risk was assessed in cross-sectional evidence using the AXIS tool [14] and cohort or longitudinal evidence using the Newcastle-Ottawa Scale. The assessment criteria in the AXIS tool included clarity of study aims, appropriateness of study design, representativeness of sampling strategy, justification of sample size, validity of blood pressure measurement, clarity of outcome definitions, handling of non-responses, statistical reporting, and agreement between results and conclusion. The Newcastle-Ottawa Scale [15] assessment was based on criteria related to the selection of participants, comparability of exposed and unexposed groups, ascertaining the outcome of interest, adequacy of follow up, and controlling for potential confounders. Studies that used probability sampling, standardized blood pressure measurement, had clear diagnostic criteria, had extractable denominators, and full reporting of the outcome of interest were rated as low bias risk studies. The ones that used convenience sampling, non-standardized blood pressure measurement, did not provide denominators, and inadequate adjustment for confounders were rated as high methodological risk.

Funnel-plot asymmetry tests are difficult to interpret when heterogeneity is extreme and the number of estimates is limited. A nonsignificant result does not demonstrate absence of publication bias. For uncontrolled hypertension among treated participants, Egger's and Begg's tests gave discordant signals; these should be described as inconclusive. [VERIFY THE REPEATED EGGER INTERCEPT/P-VALUE ENTRIES FOR THE ALL-HYPERTENSIVE UNCONTROLLED AND CONTROL POOLS AGAINST ORIGINAL OUTPUT].

GRADE Certainty Assessment

Leave-one-out analysis measures the influence of omitting one estimate at a time but does not resolve incompatible outcome definitions, correlated study samples, or extreme between-study heterogeneity. The awareness and treatment pools were moderately sensitive to selected omissions. [VERIFY TABLES 5–6 ARITHMETIC, SOURCE OF INFLUENCE, AND ANY RISK-OF-BIAS OR DEFINITION-RESTRICTED SENSITIVITY ANALYSES BEFORE CLAIMING ROBUSTNESS].

The certainty of evidence was assessed using the GRADE approach [16] in combination with the AXIS [14] and NOS assessments [15] of risk of bias. Since the evidence base was dominated by observational prevalence studies, the initial certainty was taken to be low and then was graded taking into consideration risk of bias, inconsistency, indirectness, imprecision, and publication bias. Low certainty was determined by studies with unclear sampling method, non-standardized blood pressure measurement, incompatible definitions of denominator, very high heterogeneity, very large confidence interval, and asymmetric funnel plots. Certainty was not reduced by indirectness if the studies sampled the general population/community populations with measured blood pressure. Large nationally-representative and multi-country studies enhanced confidence in the findings even though heterogeneity was considerable in pooled estimates of single global pool.

Meta-Analytic Specification Requiring Verification

{INSERT EXACT SOFTWARE VERSION, RANDOM-EFFECTS TAU-SQUARED ESTIMATOR, CONFIDENCE-INTERVAL METHOD, ZERO-EVENT HANDLING, AND STUDY-WEIGHT CALCULATION FROM ORIGINAL ANALYSIS}. For a study with x events among n eligible participants, the unadjusted proportion is $p=x/n$ and its logit is $\log[p/(1-p)]$; inverse-logit back-transformation is $\exp(\theta)/(1+\exp(\theta))$. These expressions describe the transformation but do not establish which variance estimator or continuity correction the original software applied. With I^2=99.5%–99.9%, the pooled proportions are averages of markedly different settings; a prediction interval or appropriately stratified analyses would be preferable if supported by the underlying data.

Protocol for Publication Bias Assessment

Publication bias and small study effects were evaluated using the funnel plot where there were at least ten estimates available for the pool of an outcome. Each funnel plot included the individual study-specific transformed

prevalence estimate and standard error with pseudo-95% confidence intervals around the pooled effect. Asymmetry of the funnel plot was visually and statistically assessed using the Egger regression test and Begg's rank correlation test. A p-value below 0.05 was considered as evidence of statistical asymmetry.

The Study-Selection Arithmetic is Internally Consistent

725 identified minus 48 duplicates equals 677 screened; 677 minus 59 exclusions equals 618 reports sought; 618 minus 26 unretrieved equals 592 assessed; and 592 minus 567 excluded equals 25 included. The PRISMA figure should be checked for complete exclusion-reason categories, documentation of retrieval attempts, and whether each report corresponds to one independent study population. {VERIFY SEARCH END DATE AND WHETHER ANY REPEATED SURVEY POPULATIONS WERE COUNTED MORE THAN ONCE}.

Sensitivity Analysis Protocol

Leave-one-out sensitivity analysis was carried out to test the robustness of the pooled effect size. This involved taking one of the estimates for each study included in the meta-analysis model and recalculating the pooled proportion, 95% CI, and heterogeneity statistics, with each estimate being left out at once. The influence of the studies on the results was determined by comparing their recalculated estimates to the primary pooled estimates and identifying those that caused maximum change in the pooled proportion.

Meta-Analysis Protocol

Meta-analysis was conducted using the Meta-Analysis Online tool [17] for pooled proportions. Pooled random-effect models were run separately for undiagnosed hypertension, uncontrolled hypertension in those under treatment, uncontrolled hypertension in all hypertensive subjects, awareness/diagnosis, treatment, and blood pressure control. Logit transformations were applied to proportions in order to stabilize variance and the pooled estimate was back-transformed to calculate the percentage with 95% CI. The random effects model was chosen because of expected clinical and methodological heterogeneity across different countries, age groups, survey platform, blood pressure measurement protocols, and healthcare systems. Heterogeneity was quantified using Cochran's Q, I^2, and τ^2 statistics. Forest plot was generated for all pooled domains with at least three eligible study estimates. Publication bias was analyzed using funnel plots, Egger's and Begg's tests where applicable.

RESULTS

A total of 725 records were identified from PubMed, Cochrane Library, Dimensions, and Google Scholar in the initial phase of the database search, with no further records being obtained from the registers. After excluding 48 duplicates, 677 records were screened for titles and abstracts, of which 59 records were excluded due to not being in accordance with the PECOS for this review. Then, 618 records were sought for retrieval, of which 26 could not be retrieved. Out of 592 records, 567 reports were excluded due to being case reports, literature reviews, and editorials. Eventually, 25 studies [18-42] were found eligible and selected for the systematic review and quantitative synthesis (Figure 1).

Bias Assessment Observations

In the combined risk-of-bias assessment of the included cross-sectional studies (Figure 2), it was seen that most cross-sectional studies had low overall risk of bias, including [18-21,23-25,27,29,30,31-33,35-40,42]. However, there were some cross-sectional studies where there was moderate overall risk, including [22,26,34,41] since there were concerns related to target population, sampling frame, and sampling method. The most common domain-level limitation in the included cross-sectional studies was non-response or missing data, which was rated as moderate in [18,20,22,23,24,25,27,31,34,39,40,41,42]. Concerning the validity of BP measurement, most included cross-sectional studies had low risk of bias, but there were some moderate concerns, including [38,39,40]. Regarding the only longitudinal study evaluated using the Newcastle–Ottawa Scale (Figure 3), moderate overall risk was found in [28].

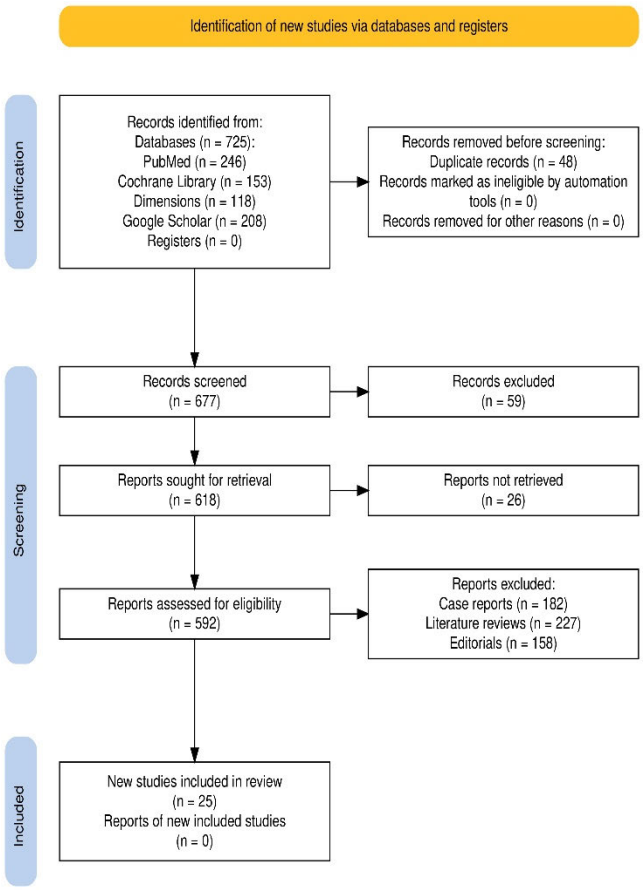


Figure 1: PRISMA Representation of Study Inclusion Process

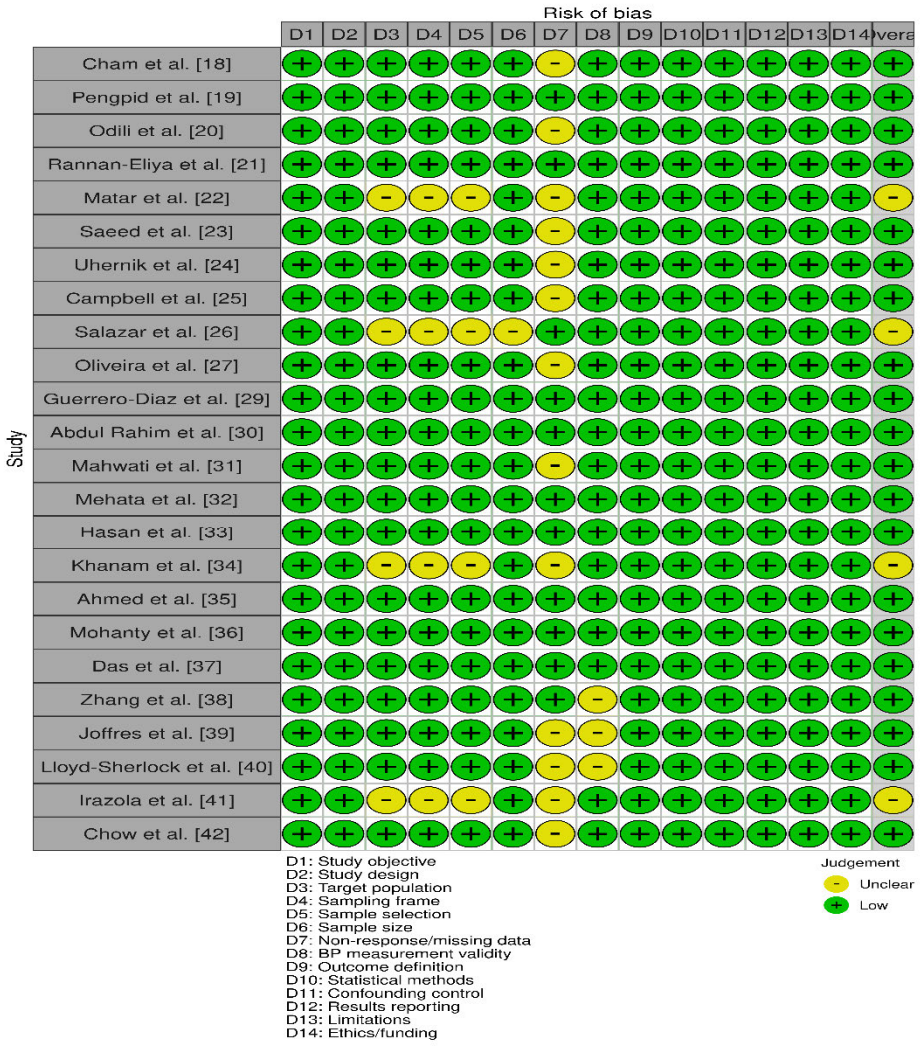


Figure 2: Bias Assessment Using AXIS Tool

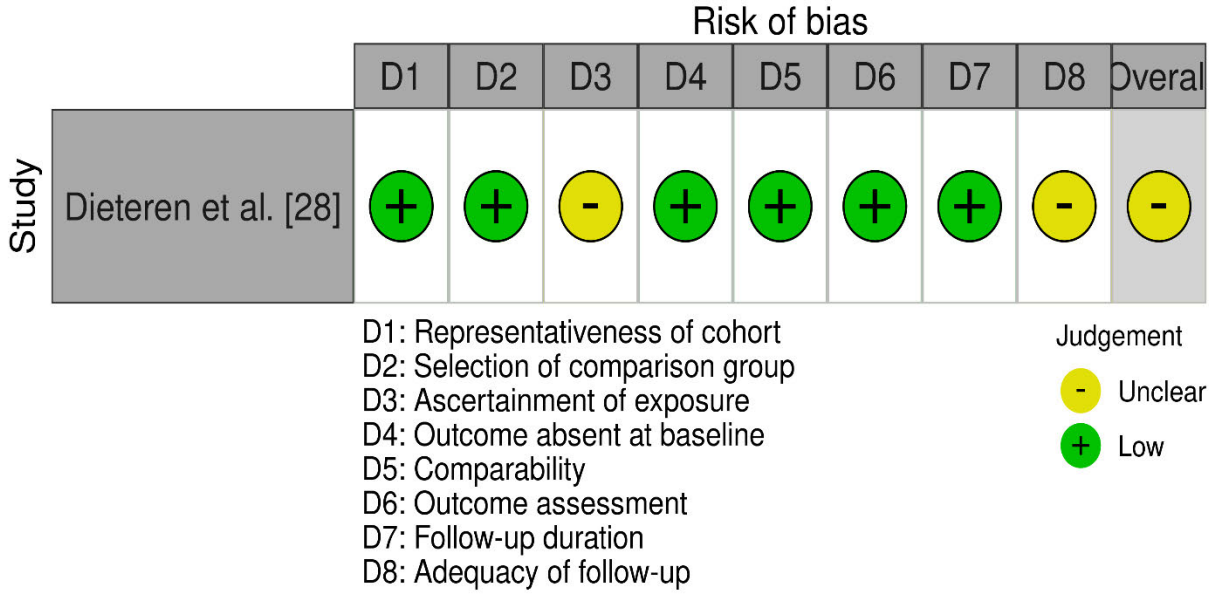


Figure 3: Bias Assessment Using NOS Tool

Table 2: Demographic Variables of the Included Studies

Author	Year	Country / region	Study design	Sample size	Mean age (years)	Male:Female ratio
Cham *et al.* [18]	2018	Gambia	National WHO STEPS cross-sectional survey	3,573	38.3 +/- 10.9	1,633:1,940
Pengpid *et al.* [19]	2022	Sudan	National STEPS cross-sectional survey	7,226	Median 37 (IQR 27-49)	2,669:4,557
Odili *et al.* [20]	2020	Nigeria	Nationwide cross-sectional survey	4,192	46.7	1,815:2,377
Rannan-Eliya *et al.* [21]	2025	Sri Lanka	Nationally representative cross-sectional baseline analysis	6,342	49.9 +/- 17.2	3,107:3,235
Matar *et al.* [22]	2015	Lebanon	Community-based cross-sectional survey	1,697	42.9 +/- 15.8	954:743
Saeed *et al.* [23]	2011	Saudi Arabia	National WHO STEPS community cross-sectional survey	4,758	15-64 age range; mean not stated	2,340:2,418
Uhernik *et al.* [24]	2023	Croatia	European Health Interview Survey cross-sectional analysis	5,461	>=15 age range; mean not stated	2,368:3,088
Campbell *et al.* [25]	2023	England	Pooled national cross-sectional cohort analysis	21,476	>=16 age range; mean not stated	9,485:11,991
Salazar *et al.* [26]	2023	Colombia	Population-based cross-sectional study	286	50.2 +/- 18.8	123:163
Oliveira *et al.* [27]	2019	Brazil	SABE population-based cross-sectional study	1,233	>=60 age range; mean not stated	approx. 486:747
Dieteren *et al.* [28]	2021	Mexico	Longitudinal cohort analysis	945	70.7 +/- 8.0	422:523
Guerrero-Diaz *et al.* [29]	2021	Peru	National survey-based cross-sectional analysis	3,697 hypertensive adults	56.7 +/- 15.5	2,157:1,540
Abdul Rahim *et al.* [30]	2025	Malaysia	National ageing-survey cross-sectional analysis	2,838	Median 57 (IQR 50-65)	1,306:1,532
Mahwati *et al.* [31]	2022	Indonesia	Cross-sectional IFLS analysis	5,914 hypertensive adults	approx. 57.4	2,504:3,410
Mehata *et al.* [32]	2018	Nepal	National population-based cross-sectional survey	13,598	15-69 age range; mean not stated	5,593:8,005
Hasan *et al.* [33]	2020	Nepal	National population-based cross-sectional analysis	3,334 hypertensive adults	49.8 (95% CI 49.1-50.5)	49.5%:50.5%
Khanam *et al.* [34]	2015	Bangladesh	Rural community-based cross-sectional study	6,094	44.2	3,061:3,033
Ahmed *et al.* [35]	2019	Bangladesh	National survey-based cross-sectional analysis	1,685 hypertensive adults from 8,835 participants	>=35 age range; mean not stated	38.3%:61.7%
Mohanty *et al.* [36]	2021	India	Nationally representative cross-sectional LASI analysis	64,427	Median 57 (IQR 49-65)	27,154:37,273
Das *et al.* [37]	2025	India	NFHS-5 secondary cross-sectional analysis	825,954 surveyed; 144,500 hypertensive subsample	15-49 age range; mean not stated	101,839:724,115
Zhang *et al.* [38]	2023	China	Six-round national repeated cross-sectional survey	642,523	18-69 age range; mean not stated	Sex distribution not tabulated in extracted main text
Joffres *et al.* [39]	2013	England, USA, Canada	Comparative national cross-sectional survey analysis	20,361	20-79 age range; mean not stated	Country-specific sex distribution
Lloyd-Sherlock *et al.* [40]	2014	China, Ghana, India, Mexico, Russia, South Africa	WHO SAGE national cross-sectional analysis	35,125	>=50 age range; mean not stated	48.0%:52.0%
Irazola *et al.* [41]	2016	Nine LMICs	Multicountry population-based cross-sectional analysis	33,660	35-74 age range; mean not stated	15,562:18,098
Chow *et al.* [42] Reviewer revision: Verify age, sex, sample size and survey-population descriptors against each original study; some entries contain approximate or inconsistent totals.	2013	17 countries	PURE baseline cross-sectional analysis	142,042	50.58 +/- 9.7	59,435:82,607

Demographic Variables Assessed

The included evidence base had predominantly cross-sectional nature [18-27, 29-42], with one longitudinal cohort component [28], and involved African [18-20], Middle Eastern [22, 23], South Asian [21,32-37], East Asian [38], Latin American [26-29], European [24, 25, 39], and multicountry settings [39-42] (Table 2). The sample size was heterogeneous, ranging from 286 individuals in Colombia [26] to 825,954 surveyed participants in India [37]. The age structure varied from younger adult samples aged 15-49 years [37] and 15-64 years [23] to older-adult samples aged ≥50 years [28, 40] and ≥60 years [27]. The female predominance was found in several samples, such as Sudan [19], England [25], Brazil [27], Malaysia [30], Indonesia [31], Nepal [32], India [36], and PURE countries [42], while the male predominance prevailed in Lebanon [22] and Peru [29].

Methodological Domains Assessed

In terms of the methodological assessment (Table 3), the majority of studies used national or population-based sampling frame [18-21, 23-25, 29-33, 35-40, 42], while some of them used community-based or municipal sampling frame [22, 26, 34, 41]. Blood pressure measurement was done based on the standardized criteria, such as two measurements [21, 24, 29, 42], three measurements [18, 19, 23, 25-28, 31, 33, 35-38, 40], five measurements [20], and six measurements in Canada [39]. Hypertension was defined by SBP ≥140 mmHg and/or DBP ≥90 mmHg [18-42], with an addition of medications intake or previous diagnosis in several cascade-based studies [18, 20-23, 27, 28, 32, 33, 36, 38-42]. Adjustment for potential confounders was done by means of age [20-22, 24, 27-29, 32-36, 38-42], sex [20-22, 24, 27-29, 32-36, 38-42], BMI [20, 22, 24, 26-29, 32-36, 38, 40, 41], socioeconomic status [21, 22, 24, 27-29, 31, 33, 35, 36, 40-42], and place of residence/region [18-21, 24, 25, 28, 29, 32, 33, 35-38, 40-42].

Outcome associated observations

The results of the outcome assessment reveal that undiagnosed hypertension was prevalent in several LMICs (Table 4): Gambia 79.0% [18]; Sudan 79.2% [19]; Peru 67.2% [29]; Bangladesh 59.9% [35]; Indonesia 56.2% [31]; Malaysia 55.9% [30]; Saudi Arabia 55.3% [23]; Nepal 50.4% [33]; and PURE countries 53.5% [42]. Awareness was relatively low in Nepal 38.0% [32]; China 38.3% [38]; Saudi Arabia 44.7% [23]; PURE countries 46.5% [42]; and WHO SAGE countries 48.3% [40]. Treatment was still not optimal in Nepal 18.0% [32]; China 34.6% [38]; Saudi Arabia 71.8% in aware adults [23]; India 50.8% [36]; and PURE countries 40.6% in all hypertensive [42]. Control was poor across the studied populations, including Gambia 4.0% [18]; Nepal approximately 9.4% [32]; China 12.0% [38]; PURE countries 13.2% [42]; Sri Lanka 20.0% [21]; India 28.8% [36]; and WHO SAGE countries 10.2% [40]. Male gender was linked to the higher hidden burden of hypertension in Sudan [19], Saudi Arabia [23], Croatia [24], Peru [29], Malaysia [30], Indonesia [31], Nepal [33], Bangladesh [35], and India [37], while older age generally increased hypertension burden but reduced underdiagnosis in Peru [29], Bangladesh [35], and Nepal [33].

Meta-Analysis Observations

Pool 1: Undiagnosed Hypertension: A total of 24 study arms contributed to the undiagnosed hypertension meta-analysis (Figures 4 and 5 respectively). The pooled percentage of undiagnosed hypertension amongst hypertensive participants was 46.4% (95 CI: 42.8 to 50.1%). There was marked heterogeneity (Q = 7960.28, df = 23, I2 = 99.7%, tau2 = 0.1327), which showed significant differences across settings. Nevertheless, the pooled value revealed that close to half of hypertensive patients were still undiagnosed and remained ignorant of their hypertensive condition.

Pool 2: Uncontrolled Hypertension

For the uncontrolled hypertension amongst treated hypertensive participants, there were 10 study arms (Figure 6). The pooled proportion was 49.6% (95 CI: 37.2 to 62.1%), and it had substantial heterogeneity (Q = 1733.35, df = 9, I2 = 99.5%, tau2 = 0.6625). This was an indication that about half of the treated hypertensive participants had not attained blood pressure control. For the uncontrolled hypertension amongst all hypertensive participants, a total of 13 study arms contributed to the analysis (Figure 7). The pooled proportion was 78.7% (95 CI: 71.2 to 84.6%), and it had substantial heterogeneity (Q = 8229.59, df = 12, I2 = 99.9%, tau2 = 0.5288). This result reflected the cumulative cascade failures of being undiagnosed, diagnosed but untreated, and treated but uncontrolled.

Pool 3: Diagnosis-Treatment-Control Cascade

For the awareness/diagnosis pool, 12 study arms contributed to the analysis (Figures 8 and 9 respectively). The pooled percentage of awareness or diagnosis was 52.5% (95% CI: 47.3 to 57.7%), and it had substantial heterogeneity (Q = 3726.11, df = 11, I2 = 99.7%, tau2 = 0.1331). For the treatment pool, there were 11 study arms and the pooled proportion was 43.5% (95 CI: 37.4 to 49.8%) (Q = 4017.34, df = 10, I2 = 99.8%, tau2 = 0.1823). The control pool had 13 study arms and the pooled proportion was 21.3% (95 CI: 15.4 to 28.8%) (Q = 8229.59, df = 12, I2 = = 99.9%, tau2 = 0.5288).

Publication Bias Assessment

The funnel plot analysis of undiagnosed hypertension included 24 estimates with a pooled proportion of 46.4% (95% CI: 42.8-50.1%) with very high heterogeneity (I^2 = 99.7%, τ^2 = 0.1327). Both Egger's test (intercept = -4.12, p = 0.441) and Begg's test (τ = -0.17, p = 0.268) were non-significant, thus, there is no statistical evidence of asymmetry (Figure 10).

In the case of uncontrolled hypertension among treated participants, there were 10 estimates with a pooled proportion of 49.6% (95% CI: 37.2-62.1%) and substantial

Table 3: Methodological Domains of the Included Studies

Author	Data platform/source	Population frame	Selection architecture	Recruitment coverage	BP acquisition	Hypertension rule	Case-status classification	Adjustment domains
Cham *et al.* [18]	WHO STEPS 2010	2003 census/EAs	Multistage stratified random	National household	3 seated automated readings; mean 2nd-3rd	SBP >=140 and/or DBP >=90 or self-report	Diagnosed vs undiagnosed HTN; treatment/control assessed	Demographic, residence, lifestyle, obesity
Pengpid *et al.* [19]	Sudan STEPS 2016	National household survey	Multistage stratified	National household	3 Omron readings after 15-min rest; mean last 2	SBP >=140 and/or DBP >=90	Raised BP + no doctor/health-worker diagnosis	Predisposing, enabling, need factors
Odili *et al.* [20]	REMAH/Nigerian national survey	Six geopolitical zones	Multistage community sampling	Rural and urban communities	5 auscultatory readings; mean of 5	SBP >=140 and/or DBP >=90 or treatment	Awareness = previous health-worker diagnosis	Age, sex, BMI, residence, zone
Rannan-Eliya *et al.* [21]	SLHAS Wave 1	National adult population	Stratified multistage probability	National non-institutionalized	2 Omron readings, 10-min interval; mean of 2	SBP >=140 and/or DBP >=90 or antihypertensive medication with diagnosis	Extended care cascade: screened, diagnosis, awareness, treatment, adherence, control	Sex, age, ethnicity, SES, province, diabetes, provider
Matar *et al.* [22]	Lebanon field survey	Public gathering venues	Multisite community recruitment	Six provinces	2 automated readings after rest; 3rd if discordant	SBP >=140 and/or DBP >=90 or medication	Awareness = doctor/healthcare professional told or medication	SES, CVD risks, BMI, smoking, alcohol
Saeed *et al.* [23]	Saudi WHO STEPS 2005	20 health regions/PHCC catchments	Multistage stratified cluster	National community	3 digital readings, 5-min intervals	Mean BP >=140/90 or known HTN	Awareness = health-professional confirmed HTN	Demographic, lifestyle, biochemical variables
Uhernik *et al.* [24]	Croatian EHIS wave 3	3,600 dwellings	Two-stage random address sampling	National household	2 BP measures >=20 min apart; mean used	Mean SBP >=140 and/or DBP >=90	No high BP in past 12 months + raised measured BP	Demographic, SES, BMI, healthcare use
Campbell *et al.* [25]	Health Survey for England 2015-2019	Private households	Multistage stratified probability	National household	3 readings; mean 2nd-3rd	Self-reported diagnosis or BP >=140/90	BP >=140/90 + no self-reported diagnosis	Ethnicity, region, rurality, education, NS-SEC, BMI, smoking
Salazar *et al.* [26]	Sabaneta population survey	Municipal households	Stratified and systematic selection	Colombian municipality	3 readings after 15-min rest, 5-min intervals	SBP >=140 and/or DBP >=90	Raised BP + no prior diagnosis or medication	Lifestyle, anthropometry, sedentary status, comorbidity
Oliveira *et al.* [27]	SABE 2010	Sao Paulo older population	Probabilistic sample	Urban older adults	3 BP readings; first excluded; mean last 2	BP >=140/90, self-report, or antihypertensive use	Diagnosed, undiagnosed, controlled, uncontrolled	SES, healthcare access, health status, CNCDs
Dieteren *et al.* [28]	WHO SAGE Mexico Waves 1 and 2	National older-adult sample	Cluster/probability sampling	National ageing cohort	3 wrist-monitor readings; mean last 2	Mean SBP >=140 and/or DBP >=90 or diagnosis	Persistent undiagnosed, untreated, uncontrolled over 5 years	Sex, age, cohabitation, rurality, wealth, insurance, BMI
Guerrero-Diaz *et al.* [29]	ENDES 2019	National demographic-health survey	Complex national survey sampling	National urban/rural	2 readings; 5-min rest then 2-min interval	Mean SBP >=140 and/or DBP >=90	Raised BP + no prior professional diagnosis	Demographic, SES, insurance, BMI, diabetes, altitude
Abdul Rahim *et al.* [30]	MARS Wave 1	2010 census enumeration blocks	Multistage random sampling	National ageing survey	Omron HEM-7120; average of 3 readings	Average SBP >=140 and/or DBP >=90	Raised BP + no doctor diagnosis	Predisposing, enabling, need factors
Mahwati *et al.* [31]	IFLS 2014-2015	Indonesian adults with BP and diagnosis data	IFLS household-based survey; analytic hypertensive subset	Nationally representative IFLS provinces	Omron HEM-7203; mean of 3 BP readings	Mean SBP >=140 and/or DBP >=90	Hypertensive + no professional diagnosis + no prescription	Education, PCE, residence, health access, symptoms, disability, health status

Table 3: Continued

Author	Data platform/source	Population frame	Selection architecture	Recruitment coverage	BP acquisition	Hypertension rule	Case-status classification	Adjustment domains
Mehata *et al.* [32]	NDHS 2016	Nepalese men and women	Stratified multistage cluster sampling	National urban/rural	Home BP measurement; NDHS biomarker module	SBP >=140 and/or DBP >=90 or medication	Awareness, treatment, controlled cascade	Age, sex, education, marital status, BMI, wealth, province, residence
Hasan *et al.* [33]	NDHS 2016	Hypertensive Nepalese adults	Two/three-stage multistage survey design	National household sample	UA-767F/FAC; 3 readings; mean last 2	SBP >=140 and/or DBP >=90, prior diagnosis, or medication	Raised BP, never diagnosed, never treated	Age, sex, BMI, wealth, province, residence, ecological zone, tobacco/alcohol/caffeine
Khanam *et al.* [34]	Rural HDSS sites, 2005	Rural Bangladeshi adults	Surveillance-site community sampling	Matlab, Abhoynagar, Mirsarai	WHO STEPS BP protocol	Measured hypertension by standard BP threshold	No self-reported HTN but measured HTN; treated but BP high for uncontrolled	Age, sex, education, wealth, smoking, chewing tobacco, BMI, physical activity
Ahmed *et al.* [35]	BDHS 2011	Bangladeshi adults with measured BP	National two-stage cluster sampling	National urban/rural	LIFE SOURCE UA-767 Plus; 3 readings; mean last 2	SBP >=140 and/or DBP >=90	Raised BP, never diagnosed, never treated	Age, sex, education, BMI, wealth, division, residence
Mohanty *et al.* [36]	LASI 2017-2018	Adults >=45 and spouses	National state-level household sample	All Indian states except Sikkim	Omron HEM-7121; 3 readings; mean last 2	BP >=140/90 or self-reported diagnosis with medication/ diet/salt restriction	Aware, treated, controlled cascade	MPCE, education, age, sex, residence, caste, religion, insurance, state
Das *et al.* [37]	NFHS-5 2019-2021	Indian men/women with biomarker BP data	Stratified two-stage national DHS sampling	National rural/urban; all states/UTs	Omron BP monitor; 3 readings; mean 2nd-3rd	Mean SBP >=140 and/or DBP >=90	Raised BP + no current HTN + no prior diagnosis + no medication	Sex-stratified rural/urban models; SES, caste, education, occupation, BMI, behaviours
Zhang *et al.* [38]	CCDRFS 2004-2018	Chinese community adults	Stratified clustered multistage national sampling	Mainland China; 6 survey rounds	3 readings; mercury in 2004, Omron from 2007; mean last 2	BP >=140/90 or antihypertensive drugs	Awareness, treatment, control; undiagnosed derivable from non-awareness	Sex, age, residence, education, region, BMI, central obesity
Joffres *et al.* [39]	HSE/NHANES/ CHMS	Non-institutionalized adults	Country-specific multistage national surveys	England, USA, Canada	England/USA: 3 readings; Canada: 6 readings	Mean BP >=140/90 or BP medication	Aware, treated, controlled, treated-uncontrolled	Sex, age, country, mortality correlation
Lloyd-Sherlock *et al.* [40]	WHO SAGE	Older adults in six LMICs	Multistage stratified random cluster sampling	National household surveys	Boso Medistar wrist device; 3 readings; mean last 2	Mean BP >=140/90 or antihypertensive use	Aware, treated, controlled, treatment efficacy	Age, sex, BMI, education, wealth, insurance, urban/rural
Irazola *et al.* [41]	NHLBI/UHG COE network	Adults from selected LMIC communities	Random population-based samples across 7 studies	9 LMICs; Africa, Asia, South America	>=2 seated readings after >=5-min rest; site-specific devices	SBP >=140 and/or DBP >=90 or medication	Awareness, treatment among aware/all HTN, control among treated/all HTN	Age, sex, education, BMI, central obesity, site
Chow *et al.* [42] Reviewer revision: Verify source definitions, BP measurement protocols and exact numerator/denominator for each study before pooling.	PURE baseline	Adults from urban/rural communities	Community household sampling	628 communities in 17 countries	Omron HEM-757; mean of 2 readings	Self-reported treated HTN or BP >=140/90	Awareness, treatment, control; undiagnosed derivable	Country income, sex, age, urban/rural, education

Table 4: Outcome-Associated Variables of the Included Studies

Author	Outcome extraction class	Main denominator	HTN burden / analytic base	Hidden hypertension estimate	Known / aware estimate	Largest diagnosis-control gap available	Gender-related signal	Age-related signal	Key adjusted / stratified signal	Overall inference drawn
Cham *et al.* [18]	Diagnosed/ undiagnosed HTN + cascade	All hypertensives; treated self-reported HTN for control	Total HTN 29.0%; raised BP 27.0%	79.0% of HTN; men 86.0%, women 71.0%	21.0% of HTN; self-reported HTN n=314	Only 4.0% of all HTN controlled; 76.0% of treated uncontrolled	Men had greater hidden burden	HTN increased with age	Rural LGA: men AOR 3.2; women AOR 2.5; obesity/smoking/inactivity relevant	National burden dominated by undetected HTN and negligible population-level control
Pengpid *et al.* [19]	Direct undiagnosed HTN	Adults 18-69 with complete BP and survey data	Total HTN 33.1% (n=2,747)	26.2% of sample; 79.2% of HTN (n=2,057)	Diagnosed HTN 6.9%; 20.8% of HTN	Diagnosis gap = 79.2% of all HTN	Male sex: undiagnosed vs diagnosed aOR 2.22	50-69 yr: aRR 2.49 vs no HTN; aOR 0.31 vs diagnosed	Obesity aRR 2.51; diabetes aRR 1.59; cholesterol aRR 1.48; health advice aRR 0.79	Around 8/10 hypertensive adults were undiagnosed, with health-contact variables protective
Odili *et al.* [20]	National HTN care cascade	All hypertensives from nationwide survey	Age-standardized HTN 38.1%	Non-awareness approx. 40.8%	Awareness approx. 59.2%	Control 12.4% of HTN; 65.4% of treated uncontrolled	Women more aware than men; control similar	HTN increased from 6.8% (<30 yr) to 63.0% (>=70 yr)	Urban treatment 40.9% vs rural 30.8%; urban awareness 62.2% vs rural 56.6%	High national prevalence with major loss between awareness, treatment, and control
Rannan-Eliya *et al.* [21]	Extended diagnosis-treatment-control cascade	All hypertensive adults in SLHAS	HTN 27.6%	Non-diagnosis 47.2%; non-awareness 50.4%	Diagnosed 52.8%; aware 49.6%	Only 20.0% of all HTN controlled; 80.0% not controlled	Females had better screening, diagnosis, treatment, and control	Cascade improved with age but control plateaued at older ages	Female diagnosis aOR 1.72; female screening aOR 1.92; diabetes/BMI improved diagnosis	Largest losses occurred at diagnosis and after treatment, despite broad screening exposure
Matar *et al.* [22]	Prevalence-awareness-treatment-control cascade	Adults with measured BP in community survey	HTN 36.9% crude; 35.9% age-sex adjusted	Non-awareness 47.0%	Awareness 53.0%	Overall control 27.0%; treated-control 54.2%; treated-uncontrolled 45.8%	Men had lower treated control: 48.9% vs women 62.3%	HTN nearly 75.0% in >=65 yr	Age, male sex, BMI, diabetes, hyperlipidemia predicted HTN	Awareness was the principal bottleneck; treated control was moderate but overall control remained low
Saeed *et al.* [23]	National STEPS HTN cascade	Saudi adults with measured BP	HTN 25.5% (n=1,213)	55.3% of HTN newly detected (n=671)	Awareness 44.7% (n=542)	37.0% of treated controlled; 63.0% of treated uncontrolled	Male HTN 27.1% vs female 23.9%; awareness male 37.3%, female 53.3%	HTN increased from 8.8% (15-24 yr) to 57.5% (55-64 yr)	Male sex, urbanization, low education, inactivity, obesity, diabetes, cholesterol predicted HTN	More than half of hypertensive adults were newly detected, with suboptimal treatment control
Uhernik *et al.* [24]	Direct undiagnosed HTN	EHIS participants with measured BP	Total HTN 44.3%; diagnosed 37.2%, undiagnosed 7.1%	7.1% population; approx. 16.0% of HTN	Approx. 84.0% of HTN diagnosed	Diagnosis gap concentrated in healthcare non-users	Undiagnosed: male 10.0% vs female 4.9%	Undiagnosed highest around 45-74 yr	Women had lower OR; older age, BMI, no family-doctor visit associated	Undiagnosed HTN was lower than in LMICs but clustered in men and healthcare non-users
Campbell *et al.* [25]	Direct undiagnosed HTN	Adults with total HTN in HSE 2015-2019	HTN: men 34.3%, women 29.7%; hypertensive n=7,997	Men 30.7%; women 27.6% of HTN	Men 69.3%; women 72.4% diagnosed/known	Hidden burden highest in low-risk younger groups	Men slightly more undiagnosed than women	Highest undiagnosed: men 16-24 yr 66.2%; women 25-34 yr 44.0%	Rural men 41.9% vs urban 32.3%; lower BMI and better self-rated health increased underdiagnosis	High-income setting still had substantial hidden HTN, especially among younger/low-risk profiles

Table 4: Continued

Author	Outcome extraction class	Main denominator	HTN burden / analytic base	Hidden hypertension estimate	Known / aware estimate	Largest diagnosis-control gap available	Gender-related signal	Age-related signal	Key adjusted / stratified signal	Overall inference drawn
Salazar *et al.* [26]	Direct undiagnosed HTN	Normotensive vs diagnosed vs undiagnosed adults	HTN 38.5%	50.9% of HTN (n=56)	49.1% of HTN diagnosed (n=54)	Diagnosis gap = about half of all HTN	Undiagnosed similar by sex; female 18.4%, male 21.1% of total sample	>60 yr prominent among HTN; RRR 0.68 reported for undiagnosed category	Elementary education RRR 1.75; physical activity RRR 1.52; no comorbidity RRR 1.42; obesity RRR 2.25	Half of hypertensive adults were undiagnosed despite measurable cardiometabolic clustering
Oliveira *et al.* [27]	Diagnosed, undiagnosed, controlled, uncontrolled HTN	Older adults in SABE 2010	HTN 79.5%	9.1% population; approx. 11.4% of HTN	Diagnosed/known approx. 88.6% of HTN	Uncontrolled 36.0% population; 51.0% of hypertensive condition	Female sex reduced uncontrolled HTN OR 0.61	Diagnosed HTN higher at 70-79 yr OR 2.02 and >=80 yr OR 2.73	Undiagnosed: nonwhite OR 1.89; uninsured OR 1.77; overweight OR 2.38; >=1 CNCD OR 0.28	In elderly adults, uncontrolled HTN exceeded undiagnosed HTN as the dominant residual burden
Dieteren *et al.* [28]	Persistent undiagnosed, untreated, uncontrolled HTN	Mexicans aged 50+ observed in two SAGE waves	HTN 64.4% at Wave 2; persistent HTN 51.1%	Persistent undiagnosed 11.3%; Wave 2 undiagnosed 22.2%	Wave 2 diagnosed approx. 77.8% of HTN	Persistent uncontrolled 34.7%; persistent untreated 15.3%	Men more likely to have persistent care gaps	Older cohort; HTN burden high across 50+ population	Singles, rural dwellers, uninsured, overweight groups had persistent gaps	Longitudinal evidence showed durable failures in diagnosis, treatment, and control
Guerrero-Diaz *et al.* [29]	Direct undiagnosed HTN	Adults with BP-compatible HTN in ENDES 2019	Hypertensive analytic base n=3,697	67.2% of HTN (n=2,549)	32.8% diagnosed (n=1,148)	Diagnosis gap = two-thirds of hypertensive adults	Men 74.7% vs women 55.7% undiagnosed	18-29 yr 94.5% vs >=70 yr 47.5% undiagnosed	Male aPR 1.15; poorest aPR 1.18; coast aPR 1.17; >=3000 m aPR 1.20; diabetes aPR 0.55	Undiagnosed HTN was very high and socioeconomically patterned toward poorer groups
Abdul Rahim *et al.* [30]	Direct undiagnosed HTN	Middle-aged/older adults with elevated BP	Elevated-BP analytic base n=2,838	55.9% overall; middle-aged 63.8%, older 45.5%	44.1% diagnosed; middle-aged 36.2%, older 54.5%	Diagnosis gap highest in middle-aged adults	Middle-aged men 69.3%; older men 53.8% undiagnosed	Middle-aged > older for underdiagnosis	Medical check-up lowered odds: middle aOR 0.28, older aOR 0.26; diabetes lowered odds: 0.39/0.26	Health-service utilization strongly explained hidden HTN in ageing Malaysians
Mahwati *et al.* [31]	Direct undiagnosed HTN	Hypertensive Indonesian adults in IFLS	Hypertensive analytic base n=5,914	56.2% of HTN (n=3,322)	43.8% diagnosed (n=2,592)	Diagnosis gap = 56.2% of HTN	Male 64.5% vs female 50.0% undiagnosed	Age distribution similar between diagnosed and undiagnosed groups	Primary/lower education OR 1.60; low PCE OR 1.28; no morning headache OR 1.97; healthy status OR 2.05	Hidden HTN predominated among poorer, less educated, and apparently healthier adults
Mehata *et al.* [32]	National HTN cascade	All hypertensive adults in NDHS	HTN 18.0%; men 22.0%, women 15.0%	Non-awareness 62.0%	Awareness 38.0%	Treatment 18.0%; controlled among treated 52.0%; approx. 90.6% of all HTN not controlled	Men had higher prevalence and weaker care cascade	HTN 34.0% in 45-69 yr	Age 45-69 AOR 7.26; male AOR 1.56; overweight AOR 3.57; obesity AOR 5.19	National Nepal data showed low awareness and treatment despite measurable HTN burden
Hasan *et al.* [33]	Direct undiagnosed HTN	Hypertensive Nepalese adults	Hypertensive analytic base n=3,334	50.4% of HTN	49.6% diagnosed/known	Diagnosis gap = 50.4%; poor-rich gap 24.6 pp	Male 54.2% vs female 46.7% undiagnosed	Undiagnosed decreased with age; >=65 yr AOR 0.65	Male AOR 1.29; overweight/obese AOR 0.80; concentration index -0.18	Undiagnosed HTN clustered among young, male, poorer, and lower-risk phenotypes

Table 4: Continued

Author	Outcome extraction class	Main denominator	HTN burden / analytic base	Hidden hypertension estimate	Known / aware estimate	Largest diagnosis-control gap available	Gender-related signal	Age-related signal	Key adjusted / stratified signal	Overall inference drawn
Khanam *et al.* [34]	Direct undiagnosed + uncontrolled HTN	Rural adults; treated self-reported HTN for uncontrolled	Self-reported HTN 14.9%; undiagnosed HTN 11.1% population-level	Undiagnosed HTN 11.1%; >=60 yr 22.7%	Self-reported HTN 14.9%; 43.0% of self-reported treated	54.9% of treated HTN uncontrolled	Undiagnosed: men 9.7%, women 12.6%	Undiagnosed 5.5% (25-39 yr) to 22.7% (>=60 yr); uncontrolled 34.5% to 67.9%	Increasing age and BMI predicted undiagnosed; age and wealth predicted uncontrolled	Rural Bangladesh had simultaneous diagnostic and treatment-control failures
Ahmed *et al.* [35]	Direct undiagnosed HTN + inequality	Hypertensive adults in BDHS	HTN n=1,685 from 8,835; approx. 19.1%	59.9% of HTN (n=978)	40.1% diagnosed/known	Diagnosis gap concentrated in poorer groups: poorest 69.7% vs richest 50.8%	Male 66.9% vs female 55.5% undiagnosed	Age >=50 less likely undiagnosed; 50-64 AOR 0.53; >=65 AOR 0.49	Female AOR 0.68; poorest AOR 1.86; concentration index -0.07	Undiagnosed HTN was concentrated among poor, male, and less educated adults
Mohanty *et al.* [36]	National HTN cascade	Adults >=45 and spouses with HTN	HTN 41.9%	Non-awareness 45.6%; undiagnosed population prevalence 19.1%	Awareness 54.4%	Treatment 50.8%; control 28.8%; uncontrolled 71.2%	Males had lower awareness, treatment, and control	Older adults had higher HTN burden; younger were less diagnosed/treated	Richest vs poorest: awareness +8.5 pp, treatment +8.9 pp, control +7.1 pp; ATC pro-rich	Older Indian adults had high HTN with incomplete and inequitable cascade performance
Das *et al.* [37]	Direct undiagnosed HTN	Working-age hypertensive adults in NFHS-5	Undiagnosed prevalence: men 11.7%, women 7.2%; HTN subsample n=144,500	Among HTN: men 66.3%, women 41.4%	Known HTN: men 33.7%, women 58.6%	Diagnosis gap substantially larger in men	Men had markedly higher underdiagnosis	Working-age analysis; younger/low-contact profiles emphasized	Urban-rural predictors differed; education, empowerment, and screening access were emphasized	Working-age India showed a major sex gap in hidden HTN, especially among men
Zhang *et al.* [38]	National repeated HTN cascade	Adults 18-69 with measured BP across 6 rounds	Standardized HTN 24.7% in 2018; crude 38.1%	Non-awareness 61.7% in 2018	Awareness 38.3% in 2018	Treatment 34.6%; control 12.0%; inadequate control 88.0%; 240M/274M uncontrolled	Prevalence decline after 2010 greater among women than men	Adult 18-69 trend across 2004-2018	Rural-control gap persisted; low education affected women's HTN prevalence	China improved modestly, but population-level diagnosis and control remained inadequate
Joffres *et al.* [39]	Three-country HTN cascade comparison	Hypertensive adults aged 20-79 in national surveys	HTN: England 30.0%, USA 29.1%, Canada 19.5%	Non-awareness: England 34.7%, USA 18.9%, Canada 16.6%	Awareness: England 65.3%, USA 81.1%, Canada 83.4%	Control: England 27.3%, USA 52.8%, Canada 65.8%; uncontrolled inverse	Women generally showed better cascade patterns	Older age had higher prevalence but more diagnosis/treatment	Country-level system differences dominated cascade performance	Canada had the strongest cascade, England the weakest, despite all being high-income settings
Lloyd-Sherlock *et al.* [40]	WHO SAGE older-adult cascade	Adults >=50 with measured BP in six LMICs	Overall HTN 52.9%; range 32.3% India to 77.9% South Africa	Non-awareness 51.7%	Awareness 48.3%; range 23.3% Ghana to 72.1% Russia	Control 10.2%; uncontrolled 89.8%; treatment efficacy 26.3%	Women had higher awareness and better control	HTN prevalence increased with age	Awareness linked to older age, female sex, overweight/obesity; control linked to age, female sex, wealth	Older LMIC adults had very high HTN and extremely weak control
Irazola *et al.* [41]	Multicountry LMIC HTN cascade	Adults 35-74 from selected LMIC communities	HTN range 19.2% Peru to 54.9% South Africa	Non-awareness range 31.0%-66.5%	Awareness range 33.5% India to 69.0% Peru	Control among all HTN 5.3% China to 45.9% Peru	Women generally had better cascade in several settings	Age-standardized 35-74 analysis	Site, education, age, sex, and cardiometabolic profiles shaped variation	LMIC communities showed heterogeneous prevalence but consistently poor control in several regions

Table 4: Continued

Author	Outcome extraction class	Main denominator	HTN burden / analytic base	Hidden hypertension estimate	Known / aware estimate	Largest diagnosis-control gap available	Gender-related signal	Age-related signal	Key adjusted / stratified signal	Overall inference drawn
Chow *et al.* [42] Reviewer revision: Verify all study-specific outcome percentages, denominators and any reconstructed counts against source publications.	PURE multinational HTN cascade	Adults 35-70 with HTN across 17 countries	HTN 40.8% (n=57,840)	Non-awareness 53.5%	Awareness 46.5%	Treatment 40.6% of all HTN; control 13.2% of all HTN; not controlled 86.8%	Women had higher awareness, treatment, and control than men	Older adults had higher prevalence and treatment exposure	LIC and rural LMIC settings had lower awareness/treatment/control; low education worsened LIC cascade	PURE provided the strongest multicountry evidence of global diagnosis and control gaps

Outcome-associated variables of the included studies (Abbreviations: AOR: Adjusted Odds Ratio, aOR: Adjusted Odds Ratio, aPR: Adjusted Prevalence Ratio, aRR: Adjusted Risk Ratio, BP: Blood Pressure, CI: Confidence Interval, CNCD: Chronic Noncommunicable Disease, DBP: Diastolic Blood Pressure, HTN: Hypertension, IQR: Interquartile Range, LMICs: Low- And Middle-Income Countries, OR: Odds Ratio, PCE: Per-Capita Expenditure, SBP: Systolic Blood Pressure, SES: Socioeconomic Status

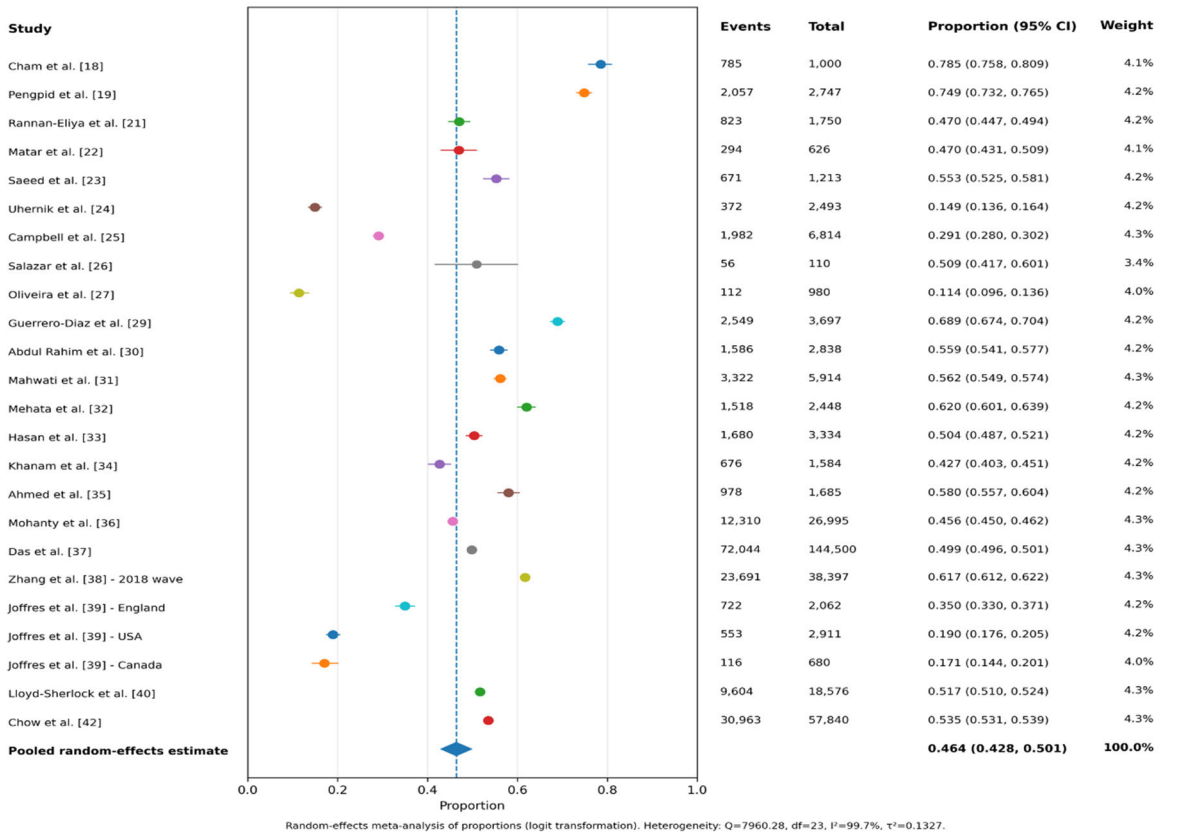


Figure 4: Pool 1: Undiagnosed Hypertension among Hypertensive Participants

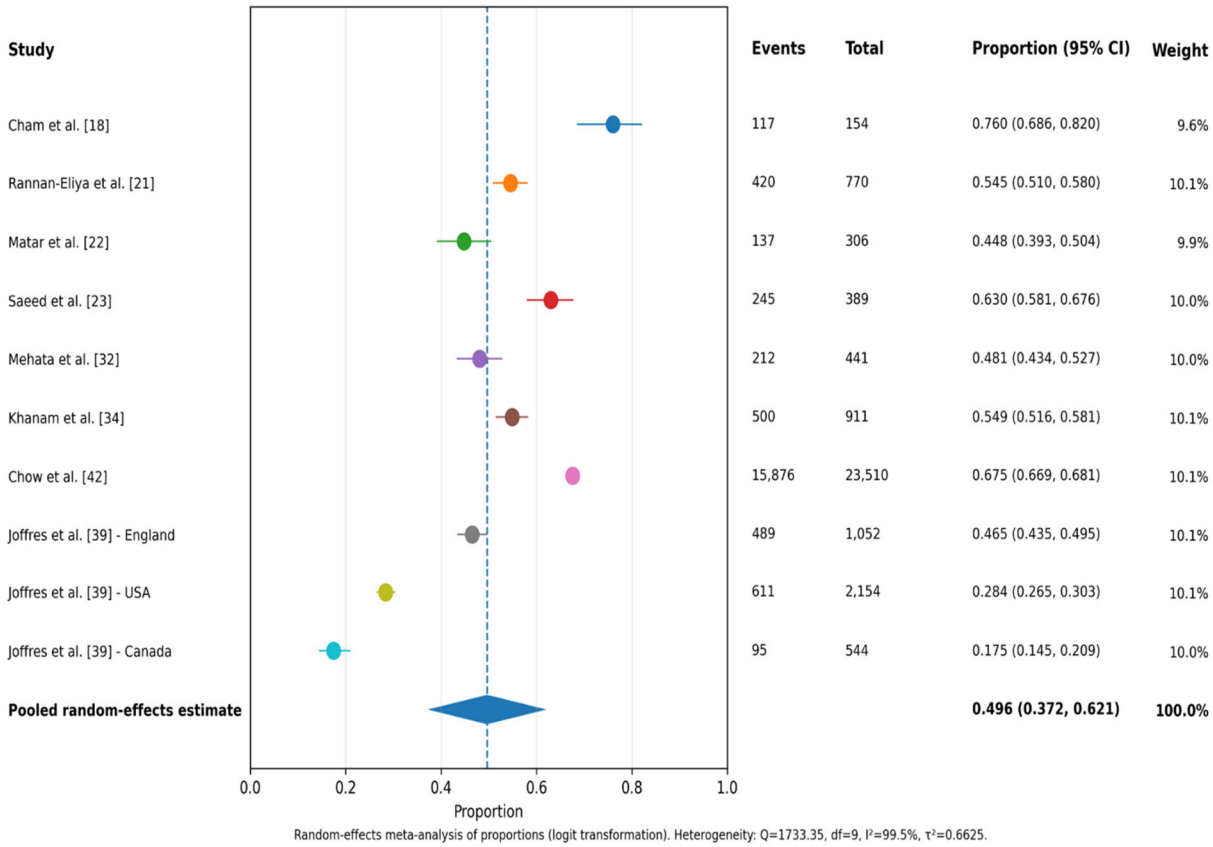


Figure 5: Pool 2A: Uncontrolled Hypertension among Treated Hypertensive Participants

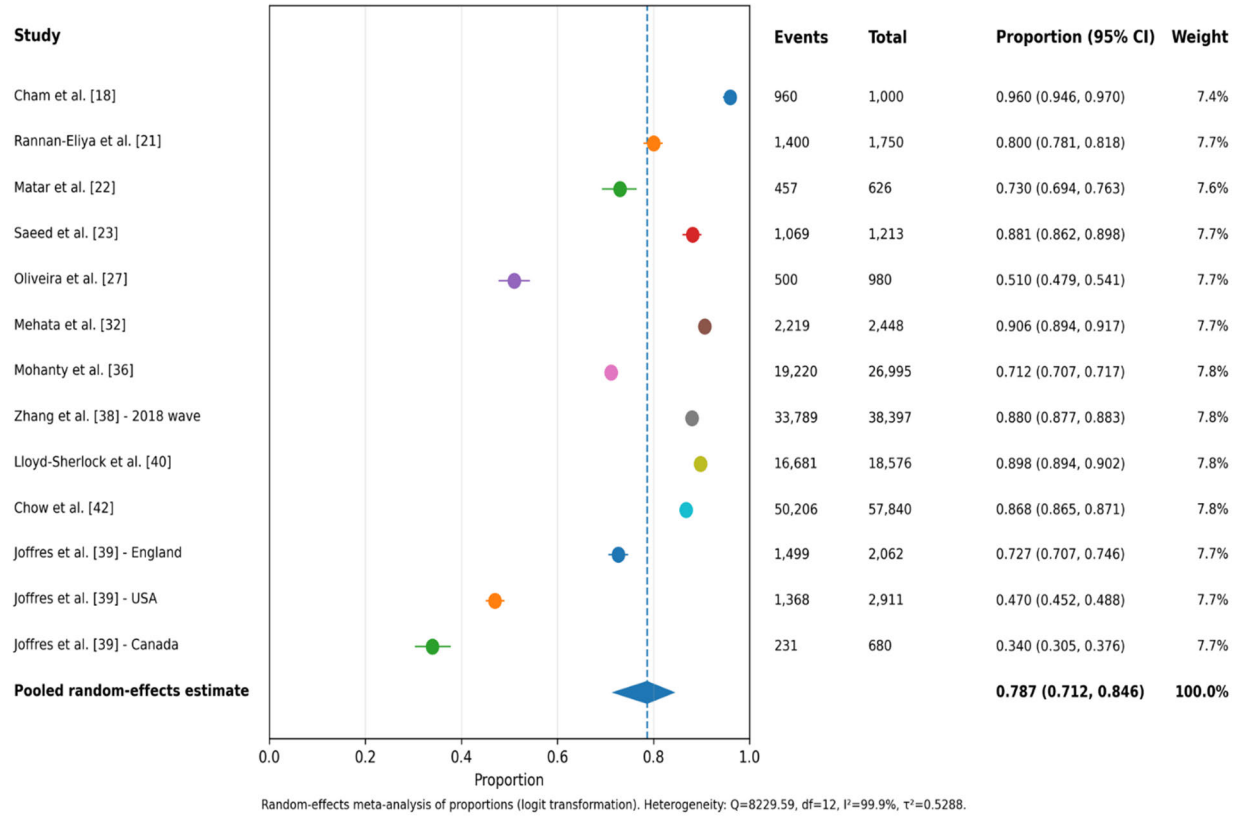


Figure 6: Pool 2B: Uncontrolled Hypertension among All Hypertensive Participants

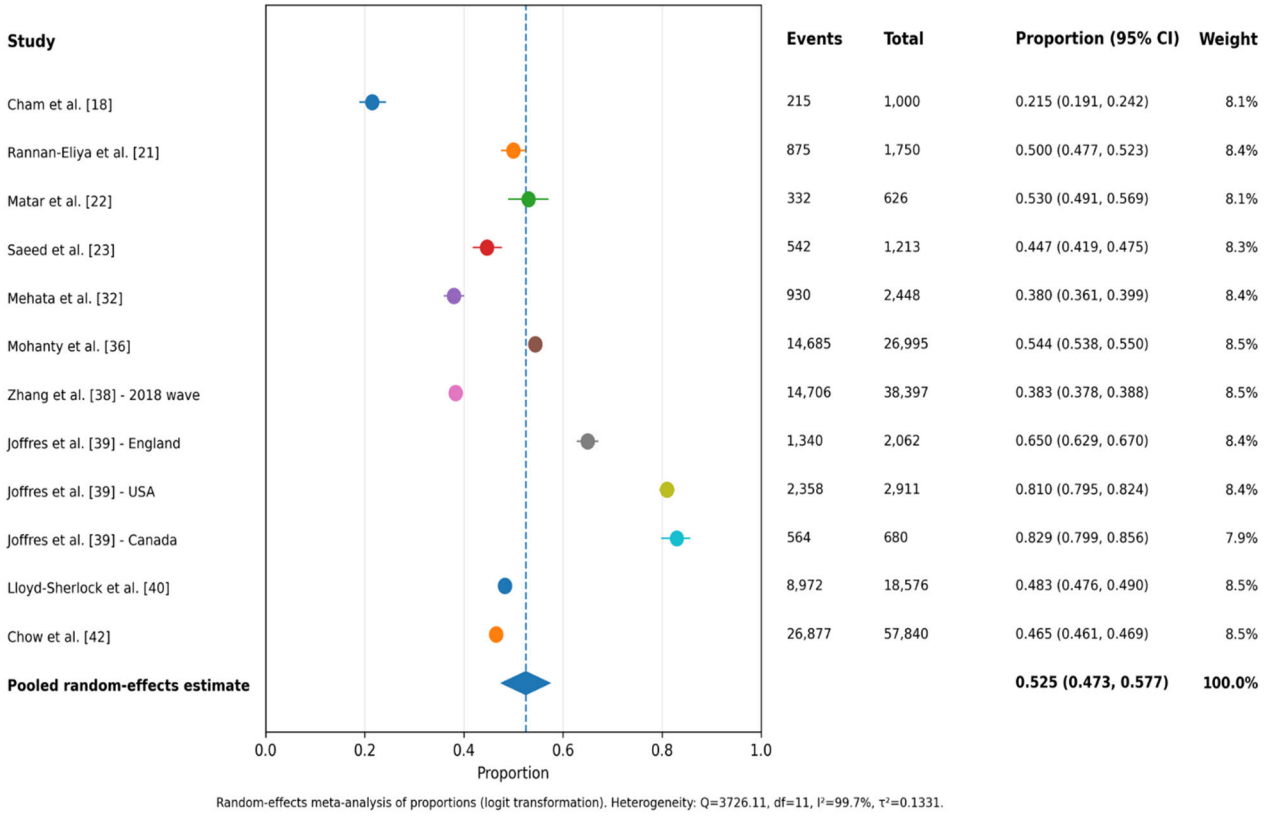


Figure 7: Pool 3A: Awareness / Diagnosis among Hypertensive Participants

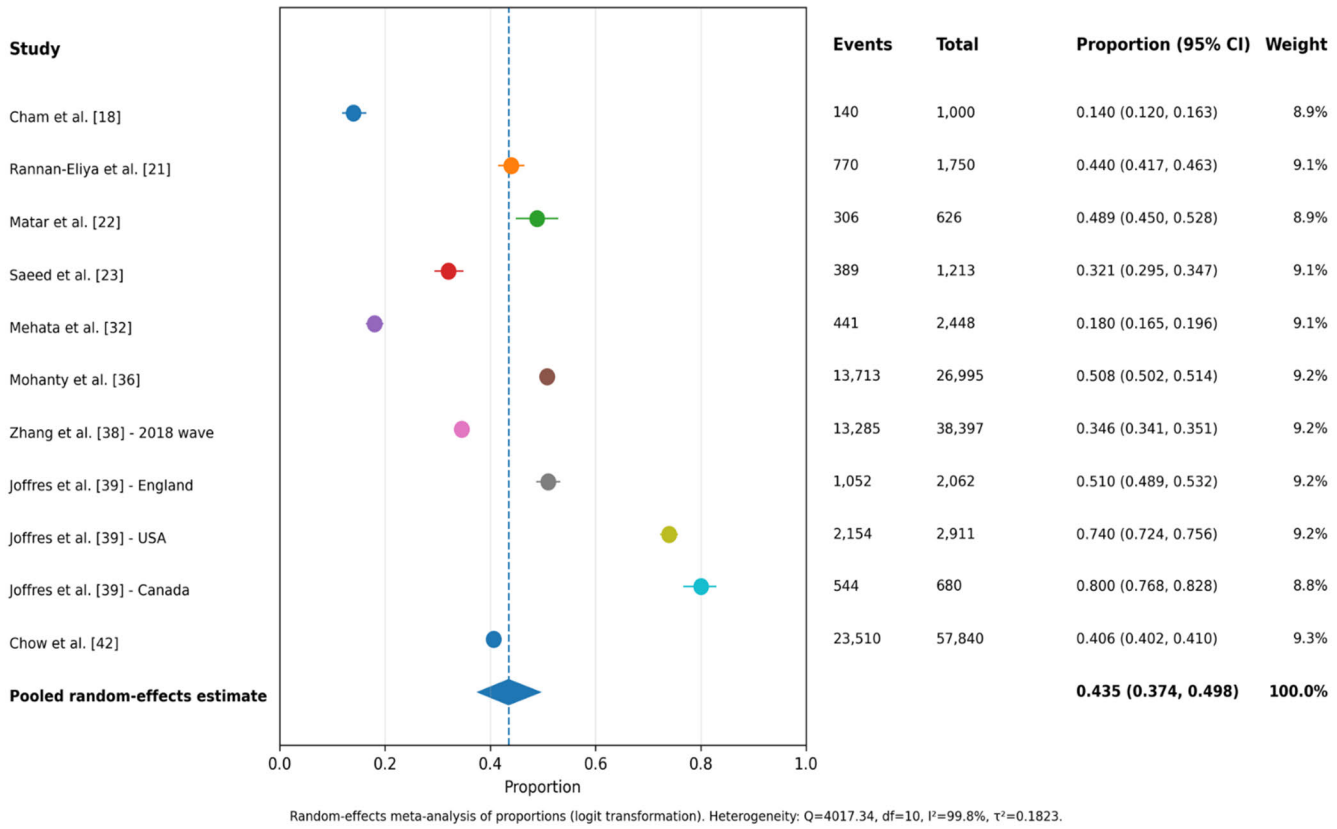


Figure 8: Pool 3B: Treatment among Hypertensive Participants

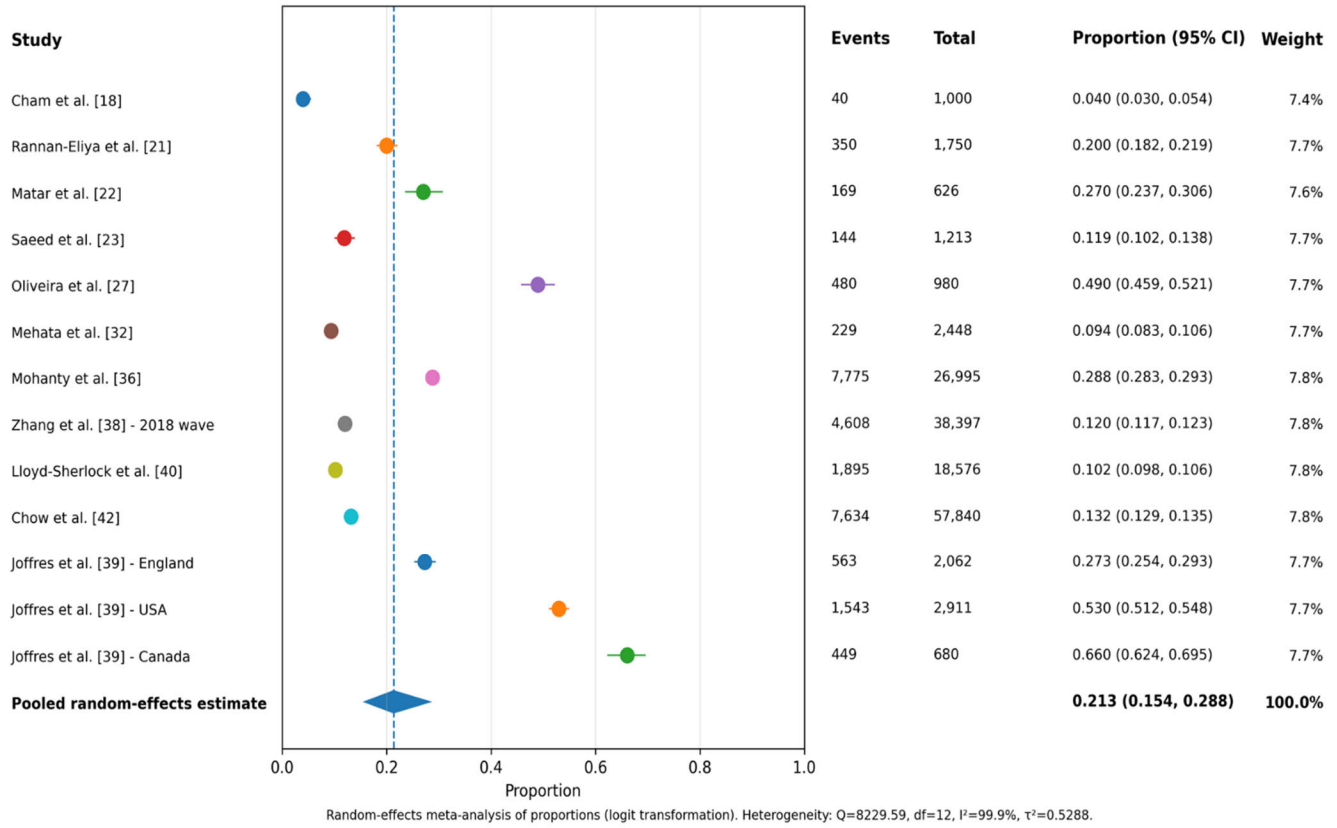
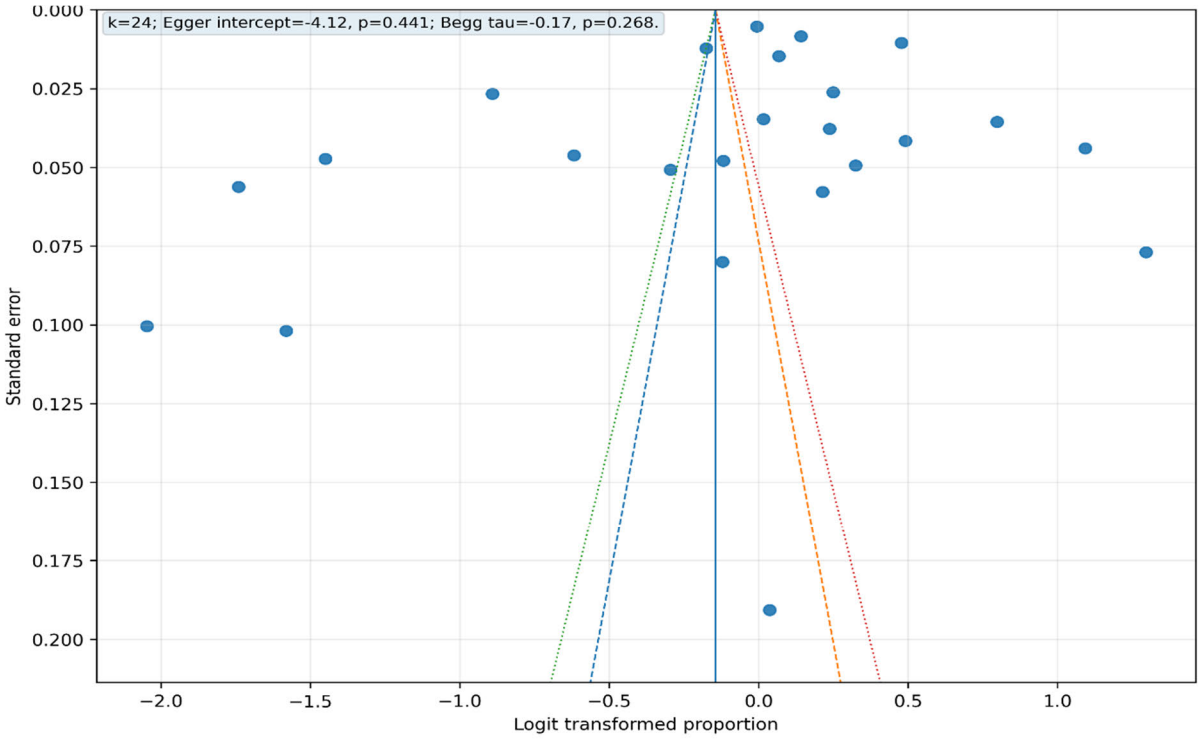


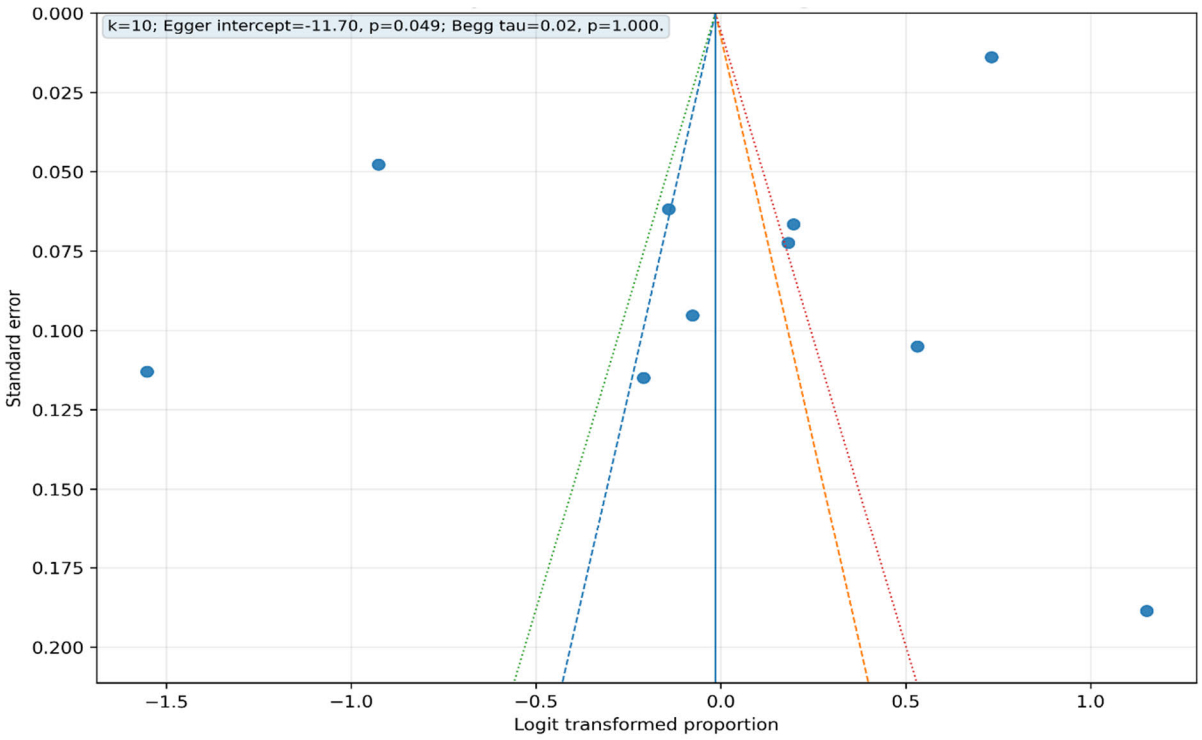
Figure 9: Pool 3C: Blood Pressure Control among Hypertensive Participants



Dashed lines: pseudo 95% limits; dotted lines: pseudo 99% limits. Funnel asymmetry was interpreted cautiously because between-study heterogeneity was substantial.

Figure 10: Funnel Plot for Undiagnosed Hypertension

Points represent study arms, dashed lines represent pseudo 95% limits and dotted lines represent pseudo 99% limits. Asymmetry was interpreted cautiously because global prevalence estimates showed high heterogeneity



Dashed lines: pseudo 95% limits; dotted lines: pseudo 99% limits. Funnel asymmetry was interpreted cautiously because between-study heterogeneity was substantial.

Figure 11: Funnel Plot for Uncontrolled Among Treated

Points represent study arms, dashed lines represent pseudo 95% limits and dotted lines represent pseudo 99% limits. Asymmetry was interpreted cautiously because global prevalence estimates showed high heterogeneity

heterogeneity (I^2 = 99.5%, τ^2 = 0.6625). Egger's test (intercept = -11.70, p = 0.049) was statistically significant, while Begg's test (τ = -0.02, p = 1.000) was not, therefore, there might be a signal of small-study asymmetry (Figure 11).

For uncontrolled hypertension among all hypertensive participants, there were 13 estimates with a pooled proportion of 78.7% (95% CI: 71.2-84.6%) with very high heterogeneity (I^2 = 99.9%, τ^2 = 0.5288). Both Egger's test (intercept = -9.10, p = 0.449) and Begg's test (τ = 0.13, p = 0.590) were non-significant, thus, there was no statistical asymmetry signal (Figure 12).

There were 12 estimates for awareness/diagnosis with a pooled proportion of 52.5% (95% CI: 47.3-57.7%) with high heterogeneity (I^2 = 99.7%, τ^2 = 0.1331). Both Egger's test (intercept = 8.32, p = 0.327) and Begg's test (τ = 0.18, p = 0.459) were non-significant, thus, there is no evidence of publication bias (Figure 13).

The treatment estimates consisted of 11, with a pooled proportion of 43.5% (95% CI: 37.4 – 49.8%) and extremely high heterogeneity (I^2 = 99.8%, τ^2 = 0.1823). The Egger's test (intercept = 3.69, p = 0.697) and Begg's test (τ = –0.05, p = 0.879) failed to yield statistically significant results, showing no statistical evidence of funnel-plot asymmetry (Figure 14).

In the case of blood pressure management, there were 13 estimates used for the pooled proportion of 21.3% (95% CI: 15.4 to 28.8%) with a very high degree of heterogeneity (I^2 = 99.9%, τ^2 = 0.5288). The Egger's test had an intercept of 9.10 (p = 0.449), and Begg's test had τ = –0.13, p = 0.590) which were non-significant, indicating no statistical evidence of publication bias.

The principal finding is that substantial gaps in hypertension diagnosis and blood pressure control were observed across the included population-based studies. The pooled estimate for undiagnosed hypertension was 46.4%, not more than half, and the pooled estimate for uncontrolled blood pressure among all hypertensive participants was 78.7%. These proportions came from outcome-specific evidence subsets and were accompanied by extreme heterogeneity (I^2 approximately 99.5–99.9%). Accordingly, they should not be interpreted as precise estimates for every country or as sequential outcomes from a single global cohort.

The six pooled indicators describe different stages and denominators: undiagnosed hypertension among hypertensive participants, uncontrolled hypertension among treated participants, uncontrolled hypertension among all hypertensive participants, awareness/diagnosis among hypertensive participants, treatment among the specified hypertensive denominator, and control among the specified hypertensive denominator. The 46.4% undiagnosed and 52.5% awareness estimates are not exact complements because they were derived from different subsets of studies. Similarly, the 49.6% treated-uncontrolled and 78.7% all-hypertensive-uncontrolled estimates must not be directly compared without accounting for different denominators.

The narrative synthesis identified study-specific associations of underdiagnosis with sex, age, rural residence, socioeconomic disadvantage, and access to healthcare. These patterns were not quantified in a common adjusted meta-analysis and should not be interpreted as universal independent predictors. Differences in survey design, blood pressure thresholds, and participant characteristics may partly explain variation, but their contribution was not formally established by subgroup or meta-regression analyses.

The pooled estimate of blood pressure control among all hypertensive participants was 21.3% (95% CI 15.4–28.8%; I^2=99.9%). Among participants receiving antihypertensive treatment, 49.6% remained uncontrolled (95% CI 37.2–62.1%; I^2=99.5%). These distinct indicators suggest important gaps in hypertension care across the sampled settings; however, the very high heterogeneity and differences in outcome definitions prevent a single representative estimate for all healthcare systems.

Comparisons with individual national surveys or previous global analyses require attention to survey year, age eligibility, diagnostic threshold, blood pressure measurement protocol, and denominator. Differences between the pooled estimates and country-specific reports should not automatically be attributed to healthcare-system performance. The added contribution of this review is the parallel synthesis of several hypertension-care indicators with explicit recognition that their contributing study sets differ.

Population-based screening and follow-up may help address gaps in hypertension detection and management, but this prevalence meta-analysis did not directly evaluate intervention effectiveness. Policy decisions should therefore be informed by local surveillance, clinical guidance, healthcare resources, and evidence from intervention studies. Consistent reporting of blood pressure measurement procedures and care-cascade denominators would make comparisons across settings more informative.

Table 5: Leave-One-Out Sensitivity Analysis of Pooled Estimates for Hypertension Indicators

Meta-analysis pool	Main pooled estimate (%)	Leave-one-out pooled range (%)	Maximum absolute change (pp)	I^2 range (%)	Sensitivity inference
Undiagnosed hypertension	46.4	44.9–48.4	1.97	99.6–99.7	Stable
Uncontrolled among treated	49.6	46.5–53.9	4.22	98.5–99.5	Moderately sensitive
Uncontrolled among all hypertensives	78.7	76.0–81.3	2.62	99.8–99.9	Stable
Awareness/diagnosis	52.5	49.3–55.6	3.17	99.6–99.7	Moderately sensitive
Treatment	43.5	39.6–47.2	3.86	99.7–99.8	Moderately sensitive
Control	21.3	18.7–24.0	2.62	99.8–99.9	Stable

Reviewer revision: Recheck leave-one-out estimates, CI and absolute percentage-point changes against statistical output

Table 6: Most Influential Leave-One-Out Exclusions

Meta-analysis pool	Most influential omitted study	Recalculated pooled estimate (%)	95% CI (%)	Change vs main estimate (pp)	Influence
Undiagnosed hypertension	Oliveira *et al.* [27]	48.4	44.7–52.0	+1.97	Low
Uncontrolled among treated	Joffres *et al.* [39] — Canada	53.9	41.6–65.7	+4.22	Meaningful
Uncontrolled among all hypertensives	Joffres *et al.* [39] — Canada	81.3	74.5–86.6	+2.61	Low
Awareness/diagnosis	Joffres *et al.* [39] — Canada	49.3	44.1–54.6	−3.17	Meaningful
Treatment	Joffres *et al.* [39] — Canada	39.6	33.7–45.9	−3.86	Meaningful
Control	Cham *et al.* [18]	24.0	17.3–32.2	+2.62	Low

Reviewer revision: Recheck leave-one-out estimates, CI and absolute percentage-point changes against statistical output

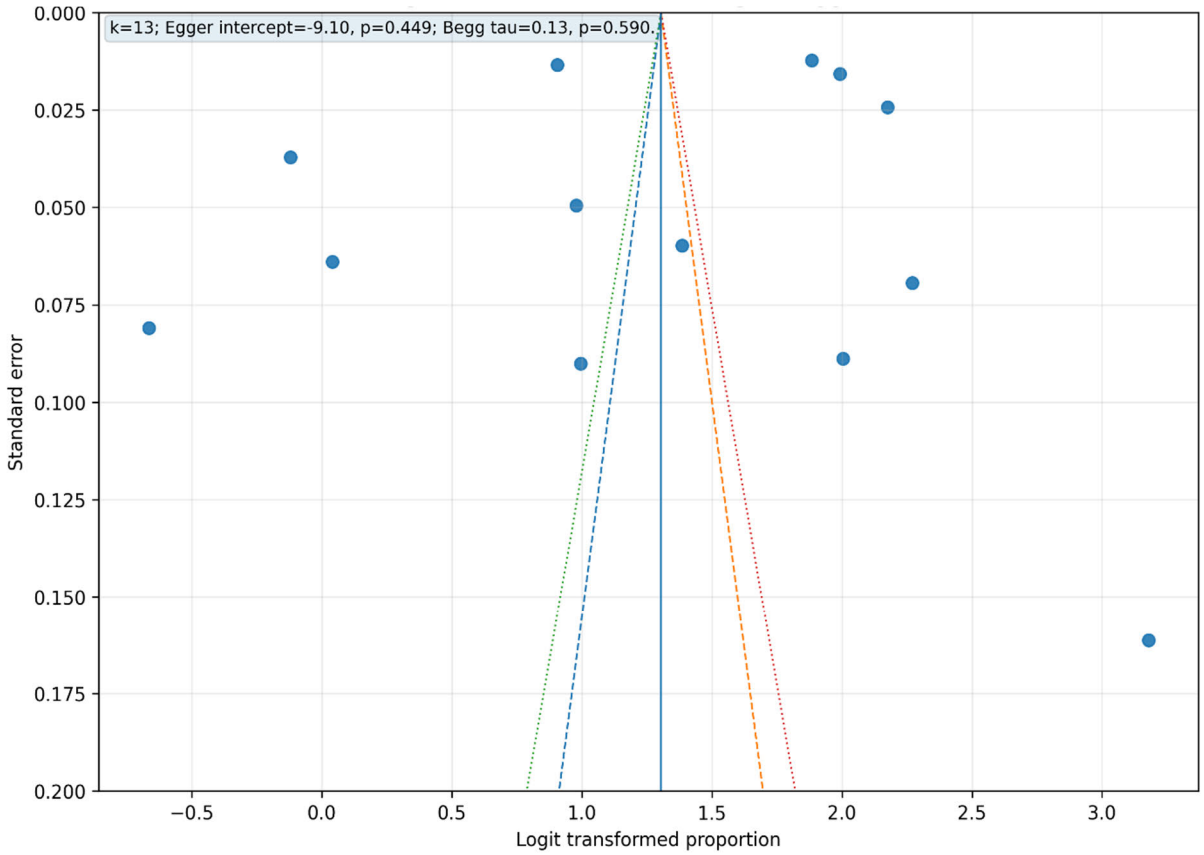
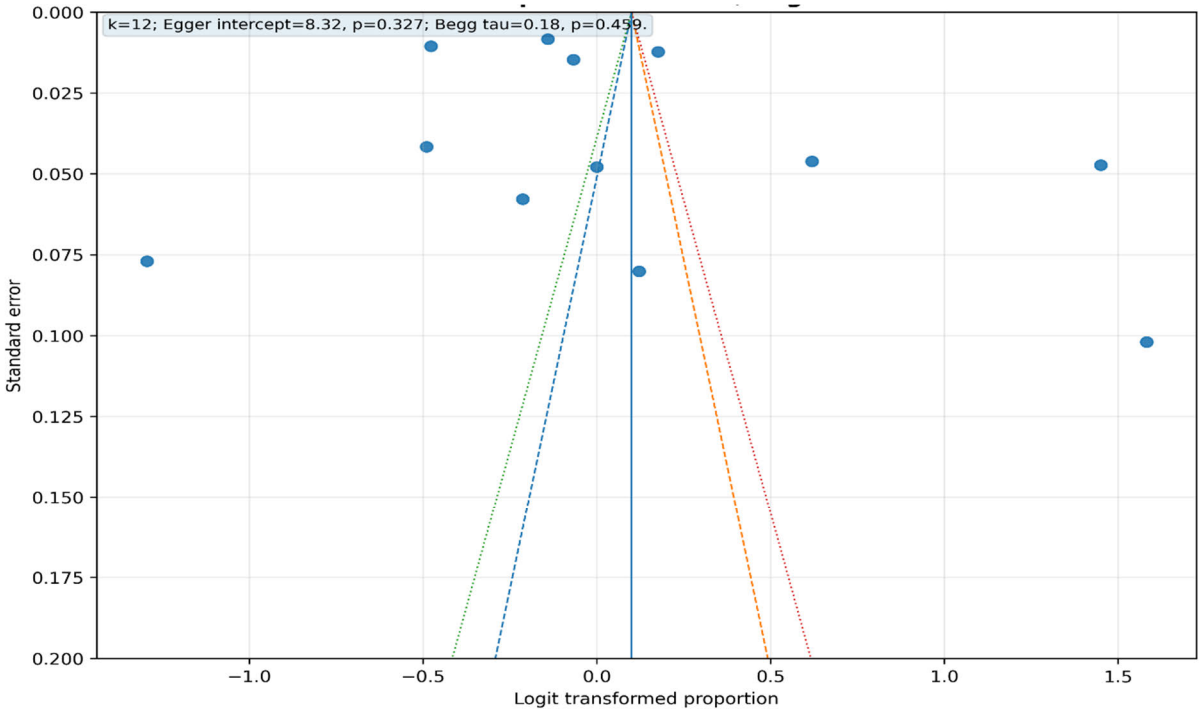


Figure 12: Funnel Plot for Uncontrolled among All Hypertensives

Possible contributors to uncontrolled blood pressure include incomplete detection, delayed treatment initiation, poor adherence, therapeutic inertia, and insufficient follow-up. However, these mechanisms were not uniformly measured or pooled in the included studies and should be regarded as hypotheses or contextual explanations rather than demonstrated causes of the observed prevalence estimates. The review cannot identify which intervention would yield the largest improvement in control.

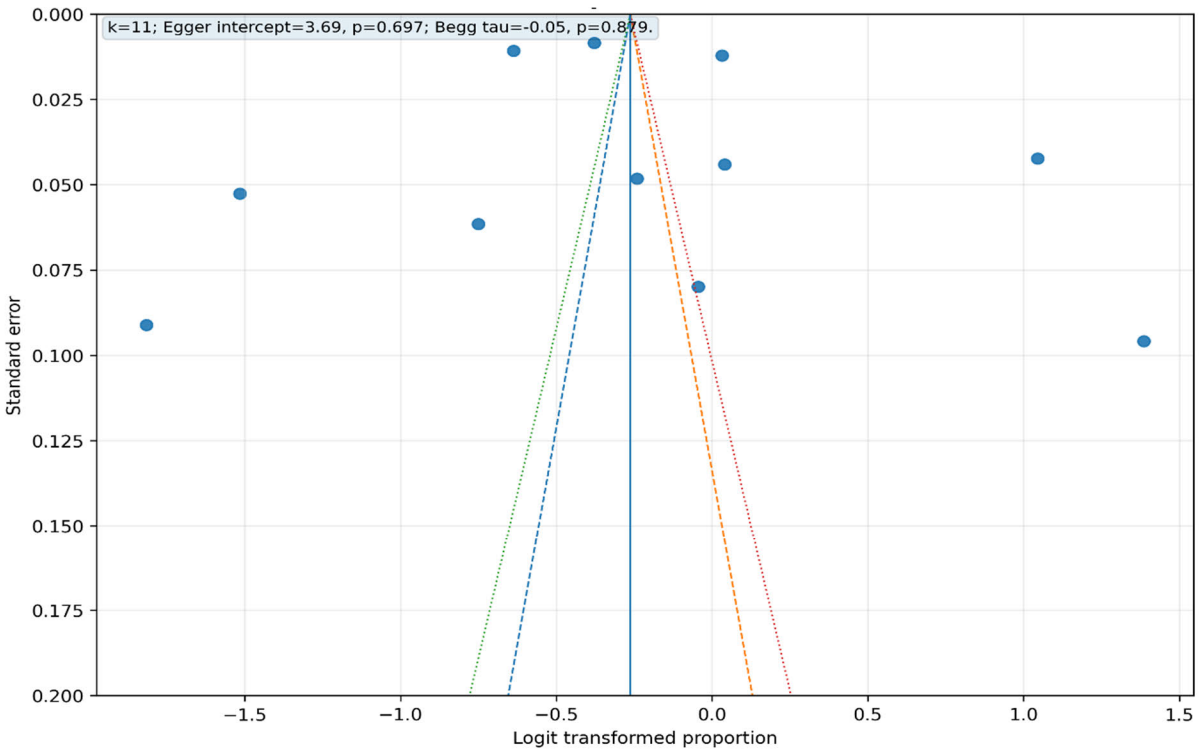
This review has several important limitations. First, the 25 included studies covered selected countries and multinational populations, leaving some regions underrepresented; the evidence is not a geographically representative worldwide sample. Second, extreme heterogeneity (I^2=99.5%–99.9%) limits the usefulness of a single pooled estimate for any individual country. Third, studies varied in diagnostic thresholds, survey years, sampling methods, blood pressure measurement devices and protocols, age ranges, and the definitions and denominators used for awareness, treatment, and control. Fourth, some numerators were reconstructed from rounded percentages, which may introduce error, particularly for survey-weighted estimates. Fifth, database coverage and the restrictive search structure may have missed relevant studies; grey literature and unretrieved reports could also affect representativeness. Sixth, predominantly cross-sectional evidence cannot establish temporal changes or causal explanations. Finally, nonsignificant funnel-plot tests cannot exclude publication bias, and leave-one-out stability does not resolve extreme heterogeneity. These limitations should guide interpretation of all six pooled outcomes.



Dashed lines: pseudo 95% limits; dotted lines: pseudo 99% limits. Funnel asymmetry was interpreted cautiously because between-study heterogeneity was substantial.

Figure 13: Funnel Plot for Awareness/Diagnosis

Points represent study arms; dashed lines represent pseudo 95% limits and dotted lines represent pseudo 99% limits. Asymmetry was interpreted cautiously because global prevalence estimates showed high heterogeneity



Dashed lines: pseudo 95% limits; dotted lines: pseudo 99% limits. Funnel asymmetry was interpreted cautiously because between-study heterogeneity was substantial.

Figure 14: Funnel Plot for Treatment

Points represent study arms; dashed lines represent pseudo 95% limits and dotted lines represent pseudo 99% limits. Asymmetry was interpreted cautiously because global prevalence estimates showed high heterogeneity

The primary observation from this review is that there are still a number of limitations within the continuum of hypertension care around the world, where more than half of people suffering from this condition had not been diagnosed and even fewer had achieved blood pressure control. This was very important since it is not due to difficult cases that cannot be controlled but rather to preventable problems at all stages from screening through to treatment and maintenance. For this reason, in the future, public health policies should focus on BP screening within the whole population, standardization of procedures, linkage to general practitioners, adherence to treatment, and monitoring.

The assessed findings in this meta-analysis suggested that failure in hypertension care was distributed throughout the entire diagnostic and control phases. Undiagnosed hypertension was estimated to be 46.4% (95% confidence interval: 42.8-50.1%), and uncontrolled hypertension in all participants with hypertension was 78.7% (95% confidence interval: 71.2-84.6%). Such results implied that global burden of hypertension consisted of not only its prevalence rate, but also of insufficient diagnostics and lack of control. This was clinically relevant because hypertension has still been one of the main determinants of cardiovascular and renal pathology [1]. On the other hand, resistant hypertension constituted a narrow clinical subpopulation within the wide group of uncontrolled hypertension [2].

This systematic review and meta-analysis identified substantial gaps in hypertension diagnosis and control across the included population-based studies. Approximately 46% of hypertensive participants were undiagnosed in one evidence subset, while approximately 79% had uncontrolled blood pressure among all hypertensive participants in a separate subset. These figures are not directly complementary or universally representative estimates, and the very high between-study heterogeneity substantially limits generalization. The awareness, treatment, and control estimates likewise reflect different study subsets and must not be interpreted as sequential stages of one unified cohort. Better harmonization of hypertension definitions, standardized blood pressure measurement, representative population surveillance, and consistent reporting of outcome denominators are needed to support more reliable comparisons and locally appropriate prevention strategies.

Control failure was even more prominent compared to diagnostic failure. Blood pressure control in all participants with hypertension pooled only to 21.3% (95% confidence interval: 15.4-28.8%), and uncontrolled hypertension in treated patients was 49.6% (95% confidence interval: 37.2-62.1%). This implied that treatment per se could not guarantee sufficient reduction in blood pressure. Poor control had been known in dialysis-related and resistant hypertension populations [7,8]. Prolonged uncontrolled blood pressure has also been linked to increased vascular, renal, cerebrovascular, and cognitive risks [9]. All this suggested that the need of stepwise treatment adjustment, standardized blood pressure measurements, and BP control programs was obvious [10-12].

As compared to the general literature on hypertension, the estimates of pooled cascade suggested weaker performance of the global healthcare system compared to organized healthcare settings. Complex phenotypes of blood pressure in diabetic and chronic disease patients had needed ongoing diagnosis and treatment [43,44]. National estimates of Spain had demonstrated higher rates of diagnosis and treatment, where about 68% of subjects had been diagnosed with hypertension and 57% had received treatment [45], while this review had revealed pooled awareness/diagnosis of 52.5% and treatment of 43.5%. Such a difference implied that the estimates of global burden were lower due to worse screening, treatment accessibility, and follow-up.

Author Verification Required before Resubmission

Original search logs and date; PRISMA checklist and exclusion records; protocol registration; full extraction sheet with denominators; risk-of-bias worksheets; GRADE ratings; statistical model and software output; funnel-plot test values; leave-one-out calculations; and bibliographic source verification. These cannot be reconstructed reliably from the manuscript alone.

The observed results were also consistent with the life-course approach to hypertension diagnostics. Even though this review focused primarily on adult population-based literature, pediatric and youth populations' literature had emphasized that high blood pressure may be under-diagnosed before the adulthood [46]. Also, high-risk pediatric populations had needed the active blood pressure surveillance [47,48]. In this review, younger adults were more frequently under-diagnosed despite their lower hypertension prevalence, which could imply the low perception of risk and rare healthcare contact.

High burden of treated-uncontrolled hypertension might have been explained by non-adherence, therapeutic inertia, follow-up, and the bias of office-based blood pressure measurement. Non-adherence had been common in resistant hypertension [49], and the national hypertension literature had emphasized the persistence of control gap even in developed healthcare systems [50]. The role of nocturnal hypertension, home monitoring, ambulatory monitoring, and asleep BP profile had been increasingly recognized in recent literature [51-54]. The very high heterogeneity across the pooled outcomes (I^2 = 99.5-99.9%) was predictable since the studies differed in terms of region, age range, survey year, blood pressure protocol, denominator definition, and healthcare system. However, the direction of evidence had been consistent enough to support the importance of standardization of BP measurement, phenotype identification, and integration of cardiometabolic care [55-59].

Limitations

Considerable statistical heterogeneity was present across majority of the included studies in this review with respect to pooled outcomes owing to variations in geography, age,

eligibility, sampling approach, data collection period, methodology for blood pressure assessment, denominators, and outcome measures. Some studies reported cascade outcomes rather than undiagnosed or uncontrolled hypertension estimates, necessitating the transformation of relevant outcomes from awareness, treatment, or control rates. Most of the included studies had cross-sectional designs, which precluded investigation of temporal consistency, compliance with the treatment, and causal factors leading to under-diagnosis or poor control. The results were also conditional upon the health care system context since national surveys, studies of older-adult populations, samples of people in the working ages, and multi-country community surveys were not entirely comparable despite the standardized pooling.

CONCLUSION

This systematic review and meta-analysis demonstrated that undiagnosed and uncontrolled hypertension were large unresolved problems in global cardiovascular disease prevention. The results of the pooled analysis implied that undiagnosed condition was prevalent among more than half of patients with hypertension, whereas effective population control rates were low. It was evident that the entire continuum of hypertension care had suffered from sequential loss to follow-up at the levels of screening, diagnosis, treatment, and control of the condition.

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