Hypertension Control and Cardiovascular Mortality

Projected Health Outcomes Under WHO HTN Target Scenarios, 2026–2050

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Project Context

The UW – WHO CVD Targets 2030 Project

Modelling the Burden of Disease Impact of Cardiovascular Risk-Factor Control

Evaluates the population-health impact of achieving four WHO CVD risk-factor targets by 2030, endorsed in the **2025 NCD Political Declaration**:

- **150 million** more people with hypertension under control
- $\geq$**50%** of eligible individuals receiving lipid-lowering therapy and counselling
- **80%** BP control among people with diagnosed diabetes
- **80%** availability of validated automated BP devices

Two Companion Scientific Outputs

Aim 1. Projected Health Outcomes of Achieving WHO Targets for CVD Risk-Factor Control: A Modelling Study

Aim 2. How Increasing National BP Control Contributes to the WHO 150-Million Target by 2030

This Presentation

Focuses exclusively on **Aim 2**: HTN control scenarios and their projected CVD mortality impact (2026–2050).

The CVD Burden Is Growing — and Largely Preventable

Cardiovascular disease kills ∼20 million people per year

- Leading cause of death in every world region
- Four causes modelled jointly:
  - Ischemic heart disease (IHD)
  - Ischemic stroke
  - Intracerebral hemorrhage
  - Hypertensive heart disease (HHD)
- **Hypertension** is the single largest modifiable CVD risk factor
- ∼1.28 billion adults affected; only 1 in 5 have BP under control

Why HTN Control? Why Now?

Prevalence	∼31% of adults globally
Treated	$<$50% diagnosed
Controlled	$<$20% at BP target
WHO target	80% control by 2030
Cost-eff.	Highest-value NCD action
Policy window	2025 NCD Declaration

Definition

HTN control: sustained BP $<$140/90 mmHg among treated hypertensive individuals

Study Overview — Aim 2

Aim 2: Research Questions

Central Question

How many cardiovascular deaths could be averted between **2026 and 2050** if countries achieve Progress, **Ambitious**, or Aspirational hypertension control targets by 2030?

Sub-questions driving the analysis:

1. Which **causes** of CVD death benefit most from HTN control scale-up?
2. Which **regions** stand to gain the most?
3. How do gains **accumulate over time** — and when do they begin?
4. How does benefit vary by **age and sex**?

Scope

190 countries · Ages 20–95 · 2026–2050 · 4 CVD causes

Intervention start: 2026

Model calibrated from 2019. First year of HTN scale-up effects entering the projection is **2026**.

Study Design at a Glance

Component	Detail
Model type	Discrete-time multi-state model (Well $\rightarrow$ Sick $\rightarrow$ Dead)
Calibration data	GBD 2023: incidence, case fatality, prevalence; all-cause & CVD-specific
Population data	UNWPP 2024 single-year age/sex projections
Intervention start	**2026** — first year intervention effects enter the projection
Scale-up period	Linear scale-up 2026 $\rightarrow$ 2030; rates held constant 2030–2050
Comparison	Business-as-usual: 2024 control rates, no additional scale-up
Outcome	CVD deaths averted vs. BAU; age-standardised mortality rate (ASMR)
Time horizon	2026–2050 (25-year horizon); model calibrated from 2019

Data Sources

Data Sources and Key Variables

Source	Variables extracted	Role in model
GBD 2023 (IHME)	IR, CF, prevalence, background mortality (age/sex/country)	Baseline transition rates; initial states
GBD 2019 (IHME)	Relative risks per 10 mmHg SBP increase (IHD, stroke, HHD, by age)	Anchor BP-bin incidence; normalisation factor α
Ettehad et al. 2016	Trial effect sizes per BP category; diabetes-stratified	Treatment effect sizes by BP bin $\times$ cause
UNWPP 2024 (UN)	Population projections 2019–2050 (single-year age, sex, country)	Cohort sizes; rate denominators
WHO / NCD-RisC	Baseline HTN control rates (C_0); BP distribution by country	C_0; $P(\text{BP}_{\text{cat}})$
Country-specific	HTN control targets 2030 (Progress / Ambitious / Aspirational)	C_{target} per scenario

Scenarios

Three HTN Target Scenarios

All scenarios share:

- Same GBD-calibrated baseline transition rates
- Same baseline BP distributions (2019)
- Linear scale-up **2026** $\longrightarrow$ **2030**
- Rates held constant after 2030
- Coverage applied to hypertensive bins only ($\gtrsim$140 mmHg)

They differ only in the target control rate by 2030.

Scale-up rule:

$$C_t = C_0 + \Delta C^* \cdot \min\left(\frac{t - 2026}{2030 - 2026}, \ 1\right)$$

Business-as-Usual (BAU)

No additional scale-up; 2024 control rates maintained.

Progress

Continuation of recent trends in control through 2030.

Ambitious — *headline scenario*

Accelerated scale-up toward WHO interim targets. Most credible policy-stretch goal for 2030 and the basis for the WHO 150-million commitment.

Aspirational

Full achievement of WHO 2030 HTN targets 50% — upper bound estimate.

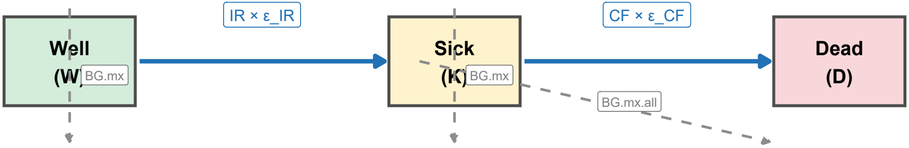
HTN Control Targets by 2030 — Country Distribution

[Figure: HTN target distribution -- data pending]

Mathematical Model

Model Architecture: Three Health States

Multi-State Transition Model | Annual time step | Ages 20-95 | 4 CVD causes



Key: $\varepsilon_{IR}, \varepsilon_{CF}$ = multiplicative effect ratios from the intervention module · BG.mx = background mortality · COVID-19 excess mortality applied 2020–2021 only

Intervention Module: 9-Step Pipeline

	Action	Output
1	Baseline BP distribution $P(\text{BP}_{\text{cat}})$ without treatment (rx $=0$)	$P(\textit{BP}_{\textit{cat}} \mid a, s, t)$
2	GBD relative risks per 10 mmHg SBP $\rightarrow$ bin-specific incidence IR_{bin}	$IR_{\textit{bin}}$
3	Diabetes-weighted Ettehad trial effect sizes E_{trial} per BP bin $\times$ cause	$E_{\textit{trial}}$
4	Linear coverage scale-up from C_0 to C_{target}, **starting 2026**	$C_t(t,\ \textit{BP}_{\textit{cat}})$
5	Coverage adjustment: $E_{\text{adj}} = E_{\text{trial}}(C_t - C_0)\,/\,(1 - E_{\text{trial}}\,C_0)$	$E_{\textit{adj}}(t)$
6	New bin incidence: $IR_{\text{bin,new}} = IR_{\text{bin}} \times (1 - E_{\text{adj}})$	$IR_{\textit{bin,new}}$
7	Aggregate: $IR_{\text{new}} = \sum IR_{\text{bin,new}} \times P(\text{BP}_{\text{cat}})$	$IR_{\textit{new}}$
8	Incidence effect ratio: $\varepsilon_{IR} = IR_{\text{new}}\,/\,IR_{\text{original}}$	$\varepsilon_{IR} \rightarrow$ *model*
9	Case-fatality effect ratio: $\varepsilon_{CF} = 1 - \rho_{CF} \times C^{\Delta}_{\text{agg}}$	$\varepsilon_{CF} \rightarrow$ *model*

Blue row = intervention start (2026). Green rows = outputs passed to state-transition model.

Key Equations

Incidence pathway

Step 2 — GBD RR anchors bin incidence:

$$IR_{\text{bin}} = \frac{RR_{\text{GBD}} \times IR}{\alpha}, \quad \alpha = \sum_{\text{cat}} P_{\text{cat}} \cdot RR_{\text{GBD}}$$

Step 5 — baseline-adjusted effect (no double-counting):

$$E_{\text{adj}}(t) = \frac{E_{\text{trial}}\,(C_t - C_0)}{1 - E_{\text{trial}}\,C_0}$$

Steps 7–8 — population-weighted effect ratio:

$$\varepsilon_{IR} = \frac{\sum IR_{\text{bin,new}} \cdot P_{\text{cat}}}{IR_{\text{original}}}$$

Case fatality pathway

Incremental coverage above baseline:

$$\Delta C_\delta(t) = \text{max}(C_t - C_0,\ 0)$$

Aggregate across hypertensive bins ($\geq$140 mmHg):

$$C_{\text{agg}}^{\Delta} = \frac{\sum_{\geq 140} \Delta C_\delta \cdot P_{\text{cat}}}{\sum_{\geq 140} P_{\text{cat}}}$$

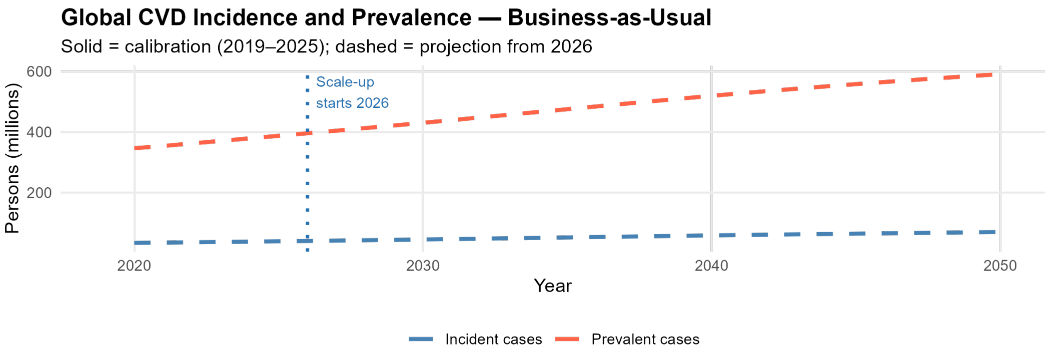
CF effect ratio:

$$\varepsilon_{CF} = 1 - \rho_{CF} \times C_{\text{agg}}^{\Delta}$$

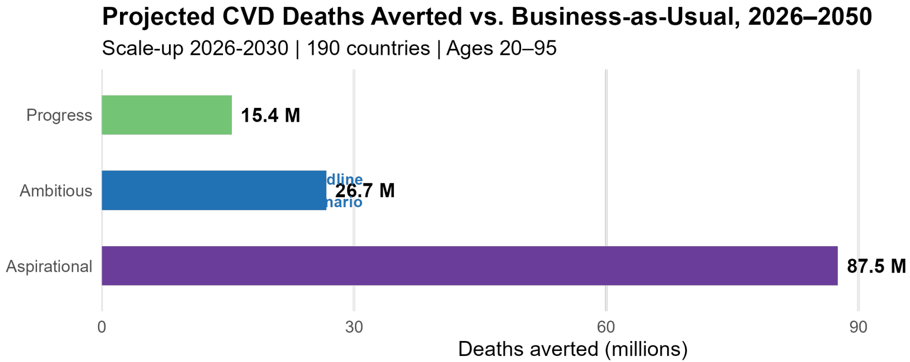
Cause	ρ_{CF}
IHD	0.24

Results

Baseline: CVD Trends Without Intervention



Key Finding: Deaths Averted by Scenario, 2026–2050



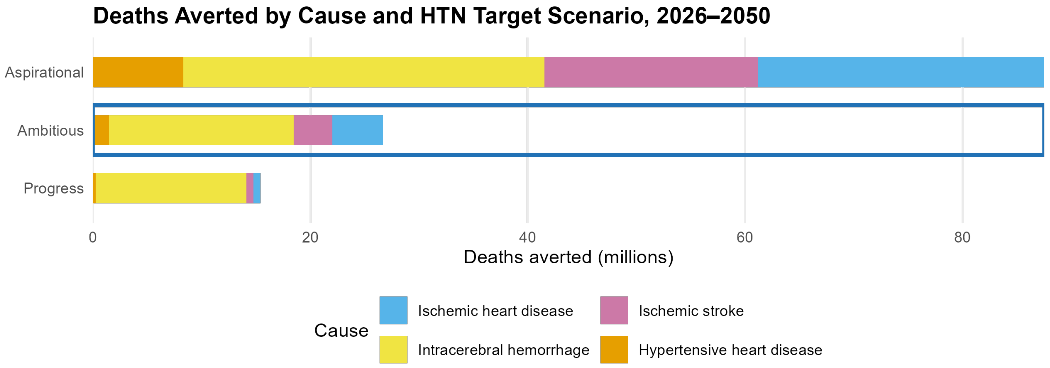
Summary Table: Deaths Averted, 2026–2050

Scenario	Deaths averted 2026–2050	Per year (thousands)	% of BAU deaths
Progress	15.42 M	617	2.3%
Ambitious	**26.68 M**	**1,067**	**3.9%**
Aspirational	87.52 M	3,501	12.9%

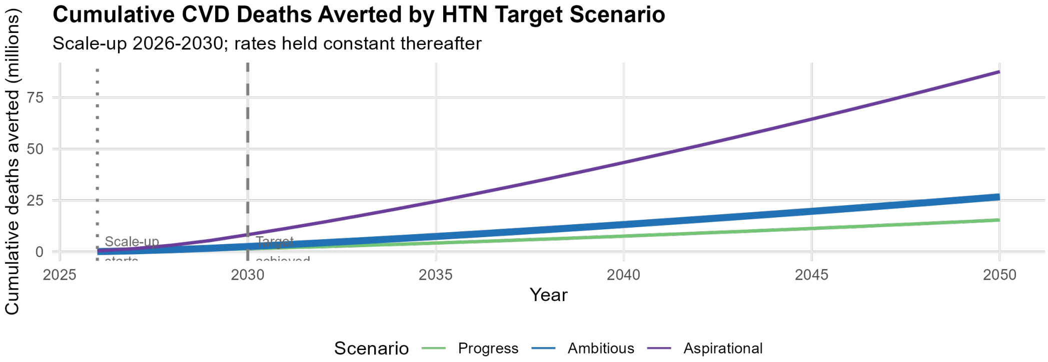
Interpretation

The **Ambitious scenario is the policy headline**: accelerated scale-up toward WHO interim targets, underpinning the 150-million commitment. Every step up in ambition saves additional lives.

Deaths Averted by Cause of Death

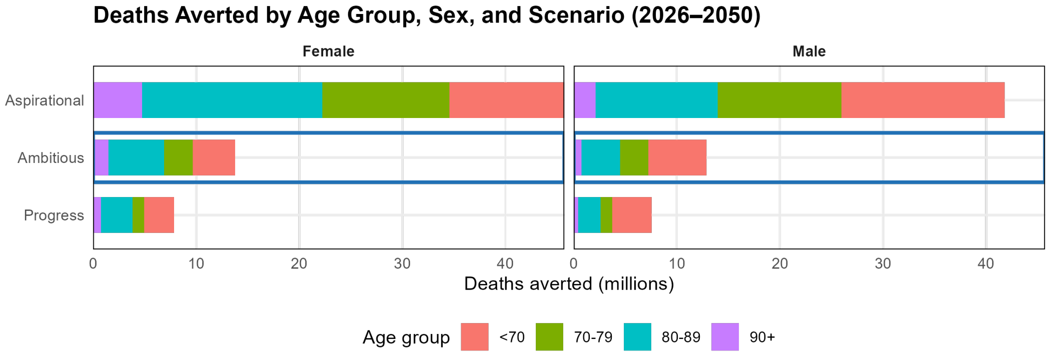


When Do Benefits Arrive? Cumulative Deaths Averted



Bold line = Ambitious (headline) scenario. Vertical lines mark start and end of scale-up.

Who Benefits? Deaths Averted by Age Group and Sex



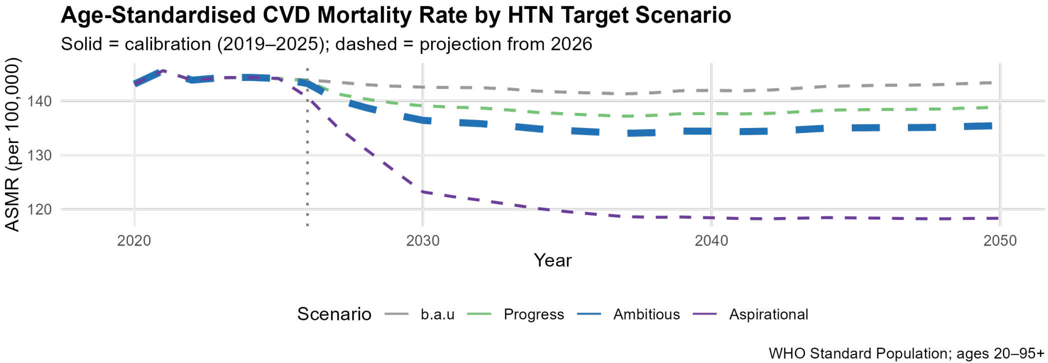
Regional Summary — All Three Scenarios

Table 1: Deaths averted (millions) by region and scenario, 2026–2050

Region	Progress	Ambitious	Aspirational
Central Europe, Eastern Europe, and Central Asia	0.60 M	**1.69 M**	7.47 M
High-income	0.66 M	**1.89 M**	3.79 M
Latin America and Caribbean	0.10 M	**0.89 M**	2.94 M
North Africa and Middle East	0.61 M	**1.45 M**	6.08 M
South Asia	3.41 M	**5.55 M**	19.23 M
Southeast Asia, East Asia, and Oceania	8.10 M	**12.39 M**	39.13 M
Sub-Saharan Africa	1.94 M	**2.81 M**	8.89 M

Column highlighted in blue = Ambitious (headline) scenario.

Age-Standardised CVD Mortality Rate by Scenario



Discussion & Limitations

Interpreting the Results

What the numbers mean:

- Deaths averted = *lives saved or meaningfully extended*, not merely deferred
- Benefits begin immediately after **2026** scale-up and compound over the 25-year horizon
- The **Ambitious–Progress gap** is the policy dividend of accelerating beyond current trends
- Geographic concentration: a few high-population countries drive global totals

Consistency with prior work:

- Direction consistent with Mills et al. 2020 *(Circulation)* and NCD Countdown 2030 *(Lancet, 2022)*
- Magnitude depends strongly on C_0: countries with lower baseline coverage gain more per unit coverage added

The Ambitious–Progress Gap

This difference quantifies the **additional lives saved by accelerating** beyond status-quo trends toward the WHO 150-million target. It is the core policy-relevant estimand of Aim 2.

Questions for Decision-Makers

- What investments move countries Progress $\rightarrow$ Ambitious?
- Which countries have the largest unmet coverage gap?
- How do these savings compare to the cost of inaction?

Limitations

Model structure

- Stable transition rates assumed; no dynamic feedback between states
- BP distributions log-normal and static — no secular trend modelled
- COVID-19 excess mortality only 2020–2021; long-term effects excluded

Data & parameters

- Ettehad ρ_{CF} values from RCTs — may overestimate real-world effectiveness at scale
- GBD 2023 uncertainty intervals not propagated
- Baseline C_0 from NCD-RisC; measurement error unquantified

Scenarios

- Linear 2026–2030 scale-up assumed; real programmes may differ
- No health-system capacity constraints modelled
- Interactions with statins, diabetes and BP device availability not included in Aim 2; planned for Aim 1 combined scenario

Next Steps

Recommendations and Next Steps

Immediate analytical priorities:

- ☐ Calibration: WHO Global Health Estimates
- ☐ Sensitivity: 2019–2025 model trend vs.observed GBD 2023
- ☐ Burden of uncontrolled HTN: compute DALYs and YLLs
- ☐ Aim 1 combined-scenario

WHO briefing package:

- ☐ WHO-formatted summary table (Ambitious, all regions)
- ☐ Policy brief for WHO NCD team with headline numbers
- ☐ Aim 2 manuscript draft

Pending decision

Confirm **Ambitious** as the WHO reporting headline scenario and align country target values with the WHO 150-million denominator methodology.

Summary: The Case for Ambitious HTN Control

Metric	Value
Countries modelled	190
Intervention period	2026–2050 (25 years)
Scale-up window	Linear, 2026 → 2030
Progress — deaths averted	15.4
Ambitious — deaths averted (headline)	**million**
Aspirational — deaths averted	**26.7 million**
Ambitious average per year	87.5
Leading beneficiary cause	million
Countries modelled	1,067 thousand / year
Intervention period	Ischemic heart disease

Bottom Line

Achieving the **Ambitious** HTN control scenario — the WHO 150-million-target trajectory — is one of the highest-return investments in global cardiovascular health. Scale-up starts **2026**; benefits compound to 2050.

Appendix

References

Ettehad D, et al. Blood pressure lowering for prevention of CVD and death. *Lancet.* 2016;387:957–967.

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WHO. HEARTS Technical Package. Geneva: WHO; 2018.

WHO. Global NCD Political Declaration. Geneva: WHO; 2025.

Mathematical Notation

IR, CF	Incidence rate; case fatality rate (GBD-calibrated baseline)
$P($**BP**$_{\textbf{cat}})$	Probability distribution across 8 BP categories
C_0, C_t	Baseline coverage and coverage at time t
ΔC^*	Incremental coverage needed to reach C_{target} above C_0
$E_{\textbf{trial}}$	Ettehad effect size (diabetes-weighted, per BP bin $\times$ cause)
$E_{\textbf{adj}}$	Coverage-adjusted effect (accounts for pre-existing baseline treatment)
α	Normalisation factor for GBD RR-weighted BP distribution
ε_{IR}, ε_{CF}	Multiplicative effect ratios passed to state-transition model
ρ_{CF}	CF reduction factor per unit incremental coverage (cause-specific)
W, K, D	Well, Sick, Dead population state counts

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