Building better HIV models: A framework for incorporating evidence on structural determinants and interventions to estimate their impacts on HIV epidemics

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Structural determinants of HIV:
The social, economic, political, cultural, organisational, and environmental factors that shape inequalities in HIV burden and access to prevention, treatment, and care. Examples: poverty, stigma, discrimination, violence.

Background

Structural determinants present significant barriers to the HIV response, especially for key populations. To address these challenges, UNAIDS introduced the 10-10-10 targets (**Fig. 1**).

<10% of countries with punitive laws and policies

<10% of key populations & PLHIV facing stigma and discrimination

<10% of women and key populations facing gender-based violence

Fig. 1. UNAIDS 10-10-10 goals for 2025.

Evidence-based models of structural determinants can:

- Evaluate progress towards these targets.
- Estimate the population-level impacts of structural determinants and interventions on HIV transmission and acquisition.

Challenges to modelling structural determinants:

- Complex to model distal factors.
- They may impact HIV through multiple mechanisms (mediators).
- Limited empirical estimates of impacts.

Aims

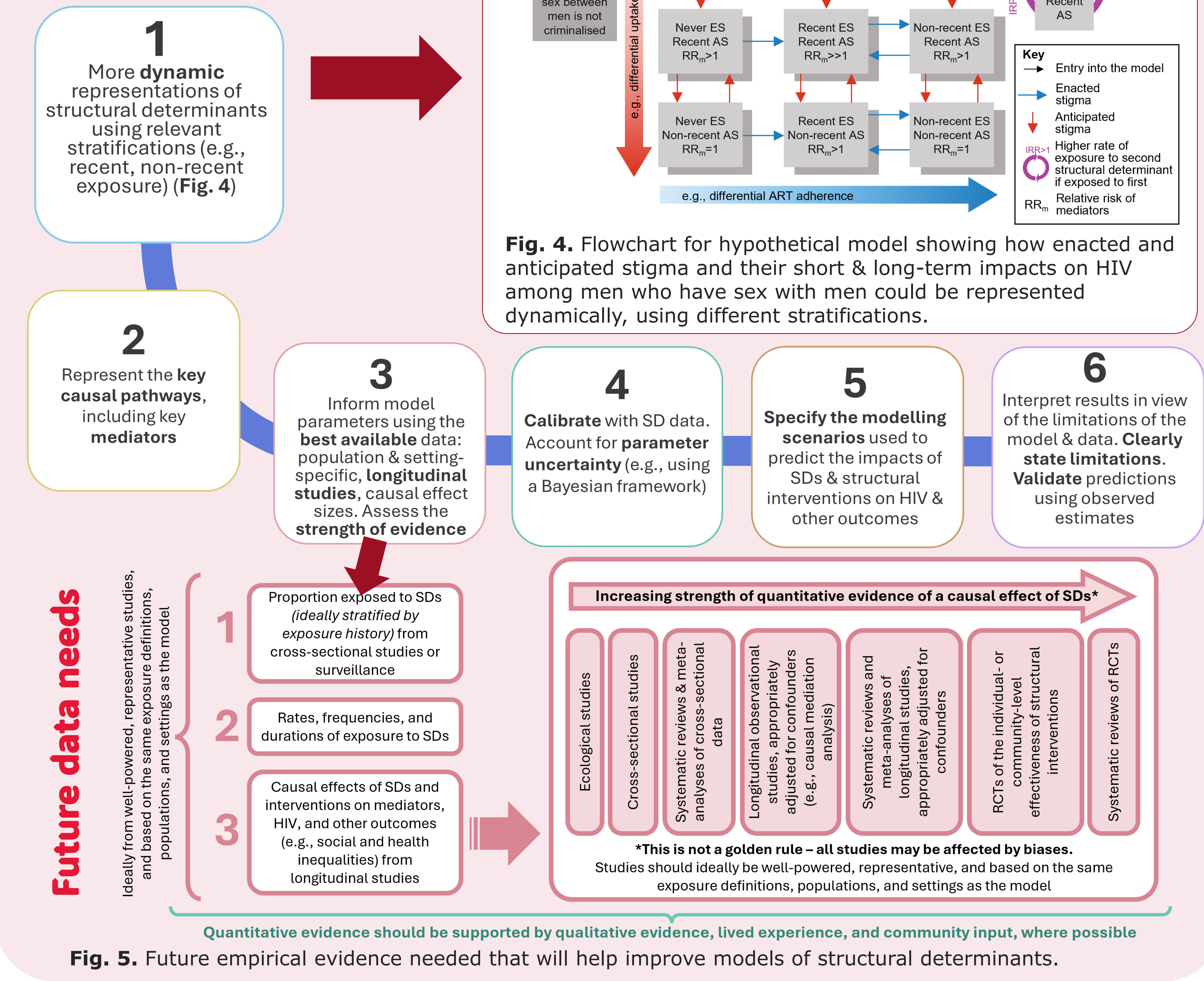**1** To **explore previous modelling** of structural determinants

2 Develop a new **framework** to support modelling and analysis of structural determinants

Methods

Scoping review of HIV transmission dynamic models addressing structural determinants, of studies up to August 28, 2023 (**Fig. 2**).

- Databases: Ovid Embase and Medline

To develop our framework, we evaluated:

- Representations of structural determinants in models.
- Causal pathways and impacts of structural determinants/interventions in models.
- Types of data on structural determinants used in models.
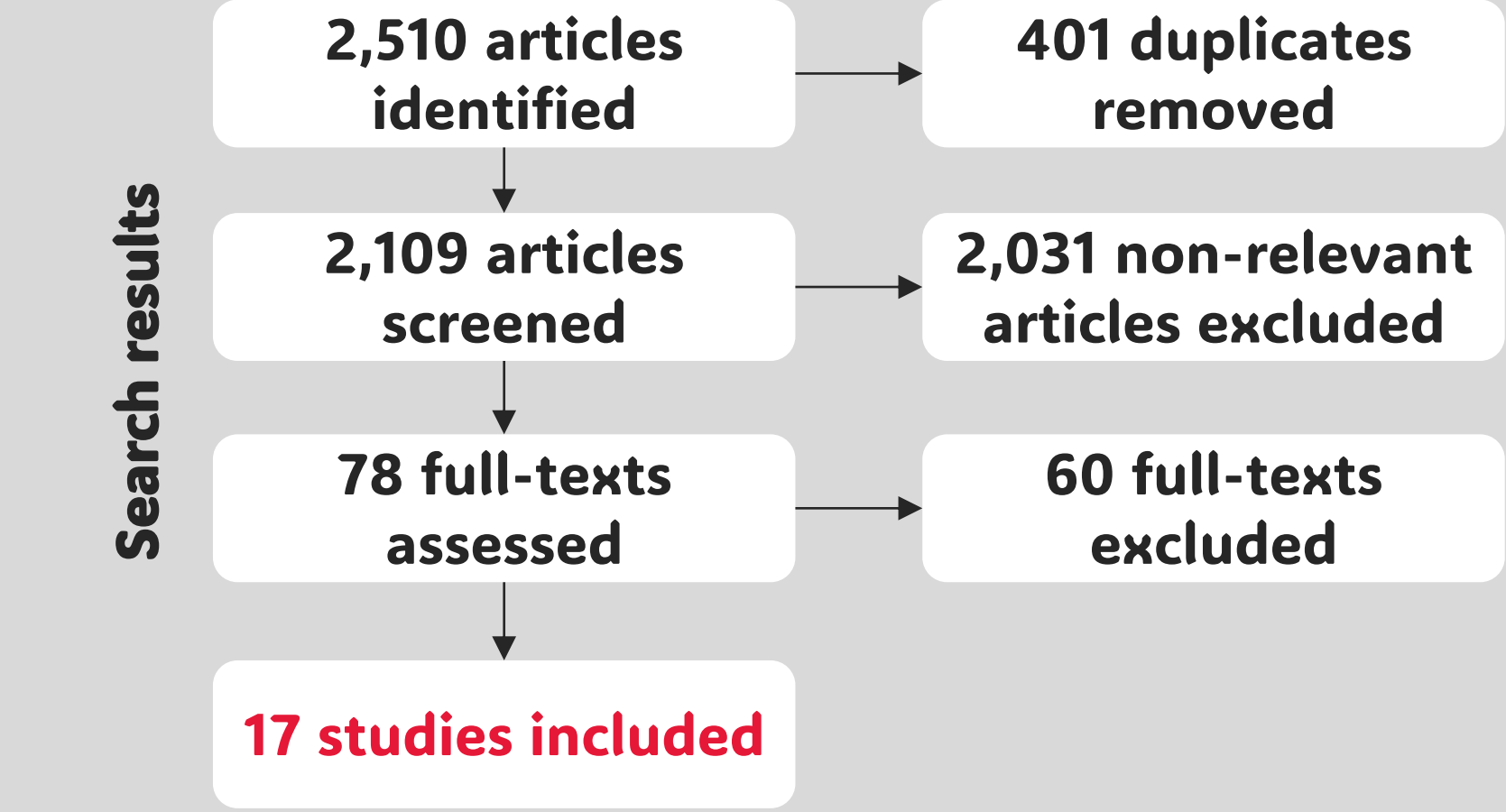
Scoping Review Results

Search results:
2,510 articles identified → 401 duplicates removed
2,109 articles screened → 2,031 non-relevant articles excluded
78 full-texts assessed → 60 full-texts excluded
17 studies included

Fig. 2. Search results of scoping review.

Exposure representations:

- Most studies modelled proximate structural determinants (**Table 1**).
- Many representations were static (**Fig. 3**).
- Few models (except of incarceration) considered long-term effects of exposure.

Dynamic, multiple exposure histories (n=8)
Static (n=7)
Dynamic, one exposure history (n=2)

- **Static**: fixed rates or probabilities were applied to parameters to account for the influence of structural determinants on mediators/HIV.
- **Dynamic**: the population was divided into compartments or states representing different exposure histories to structural determinants.
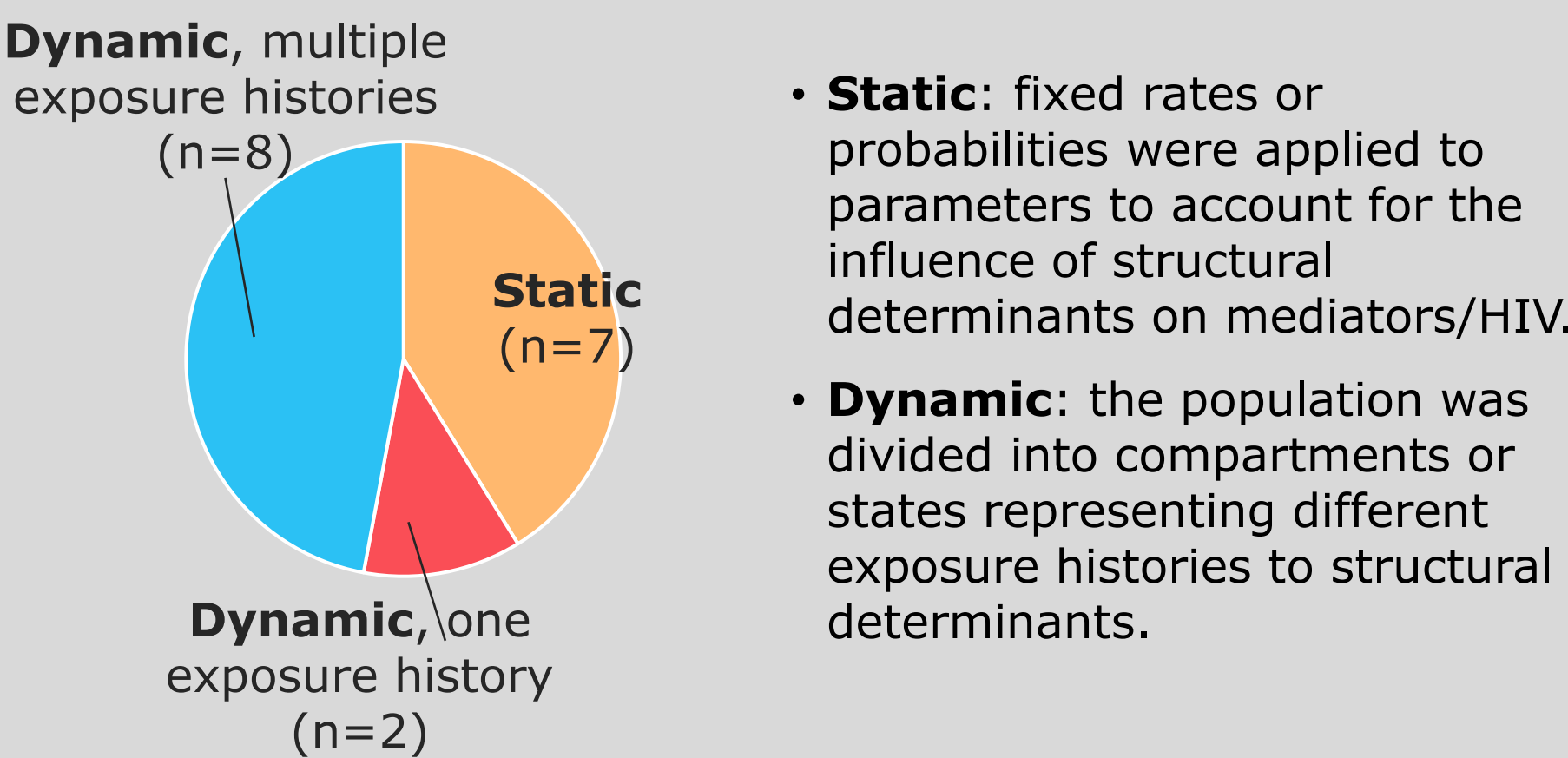
Fig. 3. Representations of exposure to structural determinants in models.

Causal pathways:

- Most effects of exposure were indirect.
- Pathways modelled had few mediating variables - mostly proximate (i.e., directly influenced HIV).
- Common mediators: contact patterns (n=8) and frequency (n=9), condoms (n=6), ART (n=5).

Model parameterisation:

- Most studies used proportions exposed (n=9) and effect sizes of exposure (n=10) to structural determinants on mediators/HIV.
- Effect sizes largely cross-sectional/non-causal.
- Structural determinants parameters were not always from the settings/populations modelled.

Recommendations

1 More **dynamic** representations of structural determinants using relevant stratifications (e.g., recent, non-recent exposure) (**Fig. 4**)

Fig. 4. Flowchart for hypothetical model showing how enacted and anticipated stigma and their short & long-term impacts on HIV among men who have sex with men could be represented dynamically, using different stratifications.

2 Represent the **key causal pathways**, including key **mediators**

3 Inform model parameters using the **best available data**: population & setting-specific, **longitudinal** studies, causal effect sizes. Assess the **strength of evidence**

4 Calibrate with SD data. Account for **parameter uncertainty** (e.g., using a Bayesian framework)

5 Specify the modelling **scenarios** used to predict the impacts of SDs & structural interventions on HIV & other outcomes

6 Interpret results in view of the limitations of the model & data. **Clearly state limitations. Validate** predictions using observed estimates

Future data needs

Ideally from well-powered, representative studies, and based on the same exposure definitions, populations, and settings as the model

1 Proportion exposed to SDs (*ideally stratified by exposure history*) from cross-sectional studies or surveillance

2 Rates, frequencies, and durations of exposure to SDs

3 Causal effects of SDs and interventions on mediators, HIV, and other outcomes (e.g., social and health inequalities) from longitudinal studies

Increasing strength of quantitative evidence of a causal effect of SDs*

Ecological studies | Cross-sectional studies | Systematic reviews & meta-analyses of cross-sectional data | Longitudinal observational studies, appropriately adjusted for confounders (e.g., causal mediation analysis) | Systematic reviews and meta-analyses of longitudinal studies, appropriately adjusted for confounders | RCTs of the individual- or community-level effectiveness of structural interventions | Systematic reviews of RCTs

*This is not a golden rule – all studies may be affected by biases. Studies should ideally be well-represented, representative, and based on the same exposure definitions, populations, and settings as the model

Quantitative evidence should be supported by qualitative evidence, lived experience, and community input, where possible

Fig. 5. Future empirical evidence needed that will help improve models of structural determinants.

Conclusions

- Estimating the impacts of structural determinants & interventions on HIV is crucial for the next phase of the global HIV response – models can help.
- Future models should dynamically model exposures and interventions using strong evidence of their effects on HIV risks.

Table 1. Models identified in our scoping review.

Study	Main structural determinant (and population) modelled
a) Static	
Stover 2021	UNAIDS 10-10-10 societal enablers: criminalisation, HIV stigma, gender-based violence (PWID, PLHIV, FSW)
Levy 2021	HIV stigma (general population)
Ronoh 2020	Positive and negative attitudes (general population aged 15-24)
Vassall 2014	Community mobilization and empowerment (FSW)
Wirtz 2014	Community empowerment (FSW)
Decker 2013	Violence (FSW)
Strathdee 2010	Police beatings (PWID)
b) Stratification-based (one level)	
Rigby & Johnson 2017	Intimate partner violence (general population)
Stone 2022	Housing instability (PWID)
c) Stratification-based (multiple levels)	
Shannon 2015	Violence (FSW)
Ward 2022	Incarceration and drug law reform (PWID)
Adams 2021	Incarceration (African-American men)
Bernard 2020	Incarceration and drug law reform (PWID)
Adams 2018	Incarceration (African-American men)
Borquez 2018	Incarceration, syringe confiscation, and drug law reform (PWID)
Altice 2016	Incarceration (PWID)
Dolan 2016	Incarceration (PWID)

FSW=female sex workers, PLHIV=people living with HIV, PWID=people who inject drugs