Mathematical modelling of male circumcision in sub-Saharan Africa predicts significant reduction in HIV prevalence

Greg Londish[1], John Murray[1,2]

[1]School of Mathematics and Statistics, University of New South Wales, Sydney, Sydney Australia
[2]National Centre in HIV Epidemiology and Clinical Research, University of New South Wales, Sydney Australia

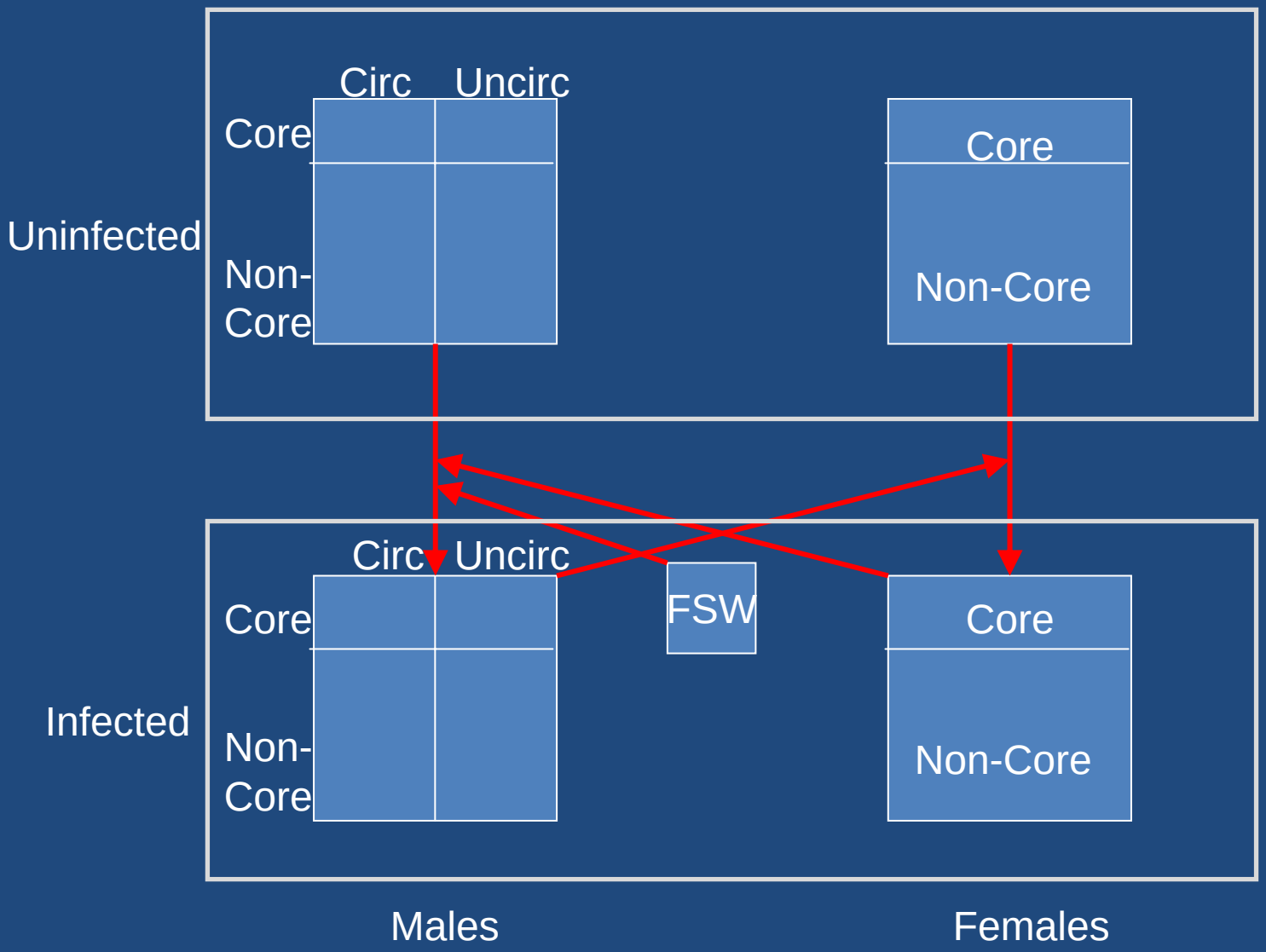
Objectives

- Provide estimates of the impact of male circumcision (MC) on established epidemics.
- Compare the effects of targeting different age groups, risk groups.
- Provide estimates for the sensitivity of a circumcision intervention to increases in risky behaviour.

Model

- The population is divided into groups based on gender, age, sexual activity, circumcision status and stage of HIV infection.
- HIV transmission is limited to heterosexual contact and mother-child.
- Sexual mixing is dependent on age alone.
- Men were also assumed to have contact with female sex workers.
- Demographics (birth, death rate, etc) were also modelled with simulations starting in 1980 and finishing in 2020.

Model



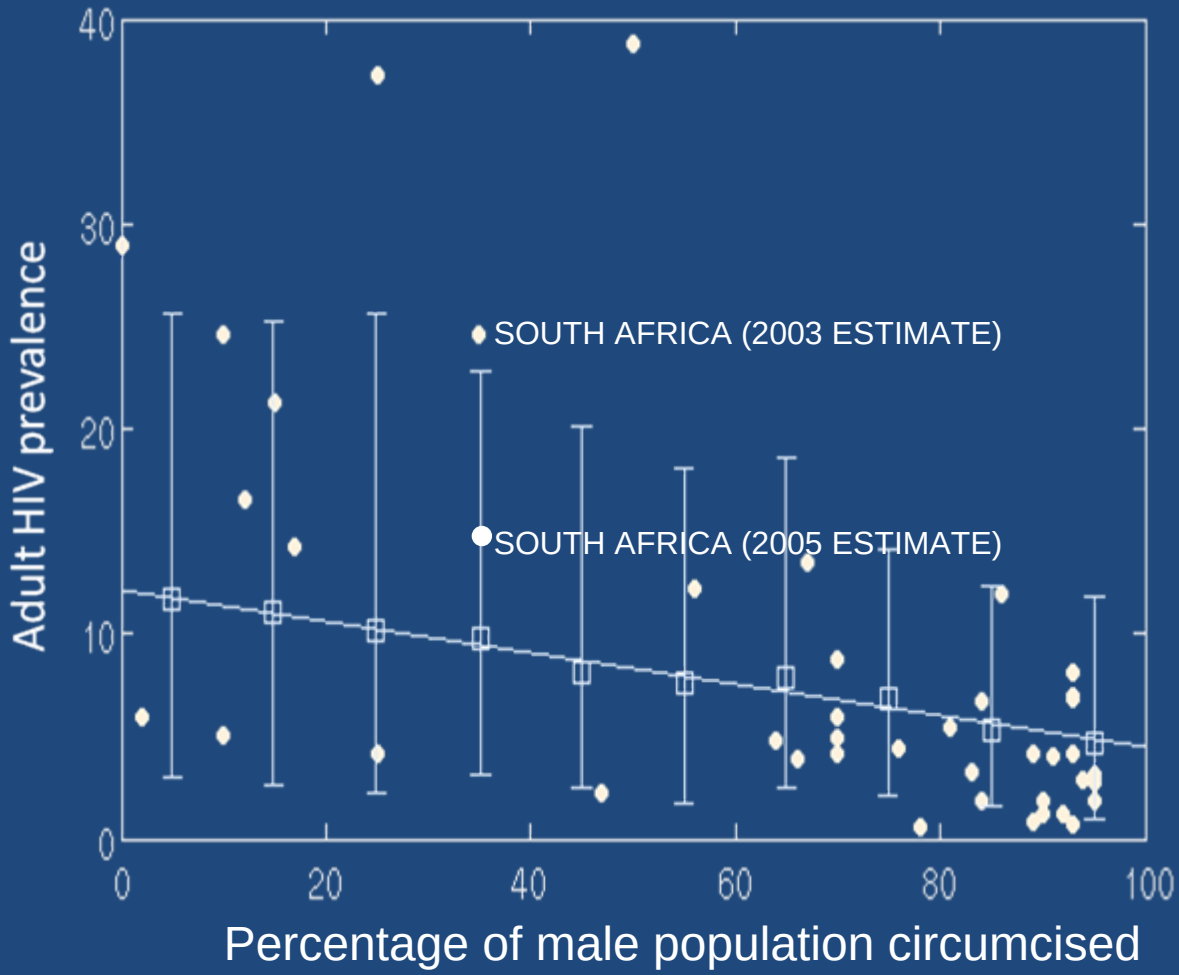
Core group is a small (0-20%) but higher sexually activity group (3-5 times the number of sexual contacts).

Key:
Red: Transmission

Simulations

- Each intervention scenario starting in 2007, consisted of two sets of simulations
  - a control set
  - an intervention set
- Reduction in prevalence is calculated by subtracting the intervention prevalence in 2020 from the control prevalence in 2020.
- Uncertainty analysis of parameters was achieved by Monte Carlo methods
  - 500 simulations
  - Latin Hypercube Sampling
- Parameter distributions were obtained from clinical trials, observational studies and other models.

Results – Comparison with Observations



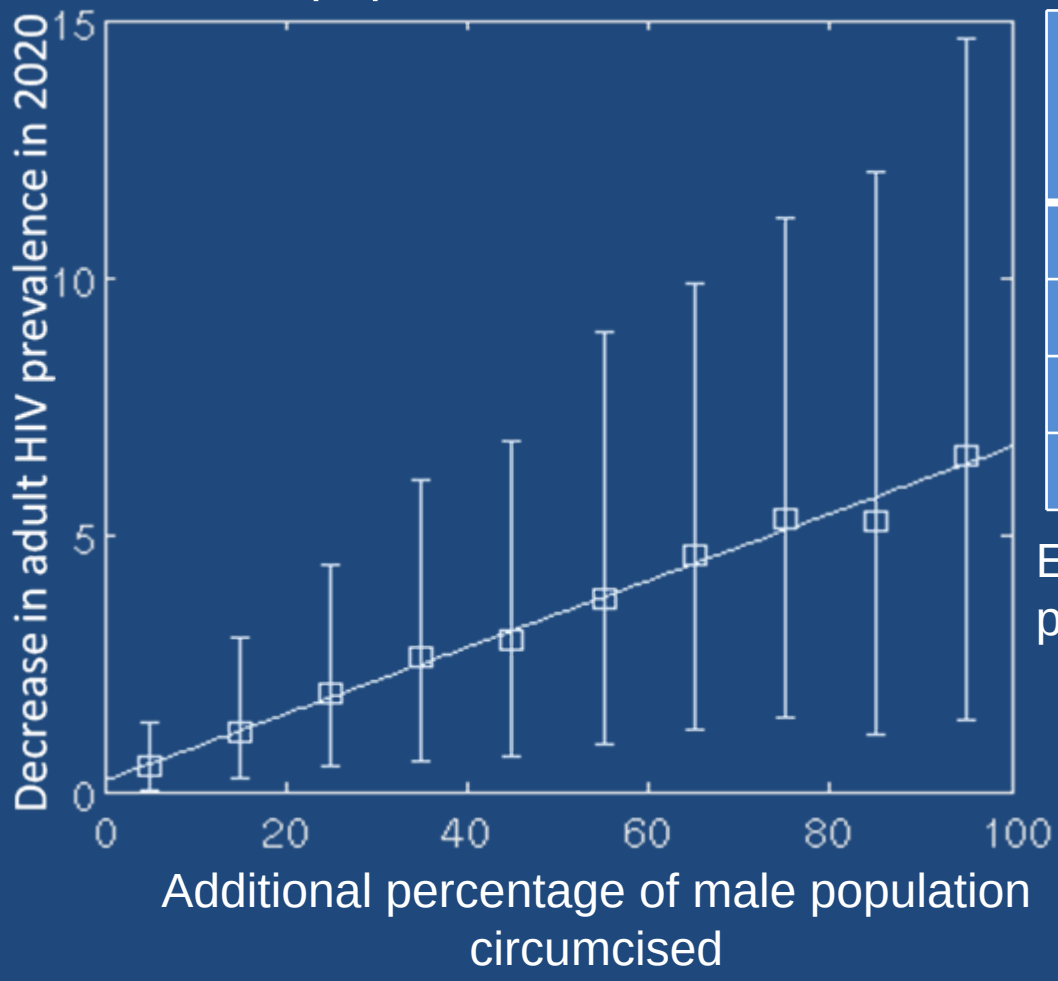
Model agrees with observations[1], but does not take into account specific regional factors.

Key:
Circles - observations
Squares – simulations
Error bars – 95% of simulations lie in this range.

[1]Williams BG, Lloyd-Smith JO, Gouws E, Hankins C, Getz WM, et al. (2006) The potential impact of male circumcision on HIV in sub-Saharan Africa. PLoS Med 3(7): e262.

Results – Partial Coverage

Starting from either low (0-20%), medium (40-60%) or high (80-100%) coverage of MC, circumcise an additional percentage of the male population.



Increase in MC Prevalence	Mean Decrease in HIV
25%	1.8%
50%	3.5%
75%	5.1%
100%	6.7%

Example: Zimbabwe (high p

Increase in	Final HIV
0%	25%
50%	18%
90%	13%

Results – Targeting Specific Age Groups

Sexual mixing patterns strongly determined by age. Therefore circumcising different age groups will lead to different impacts.

Age Group	Reduction in Adult HIV Prevalence by
10-15	0.51% (0.01 – 2.60)
15-20	1.27% (0.02 – 4.89)
20-25	1.95% (0.05 – 7.07)
25-30	2.01% (0.07 – 6.86)
30-35	1.33% (0.03 – 4.21)

Targeting 20-30 year old men leads to the largest reduction in HIV prevalence with an endpoint in 2020.

Results – Targeting Specific Risk Groups

Core group includes 0-20% of the population and has 3-5 times as many contacts as the non-core group.

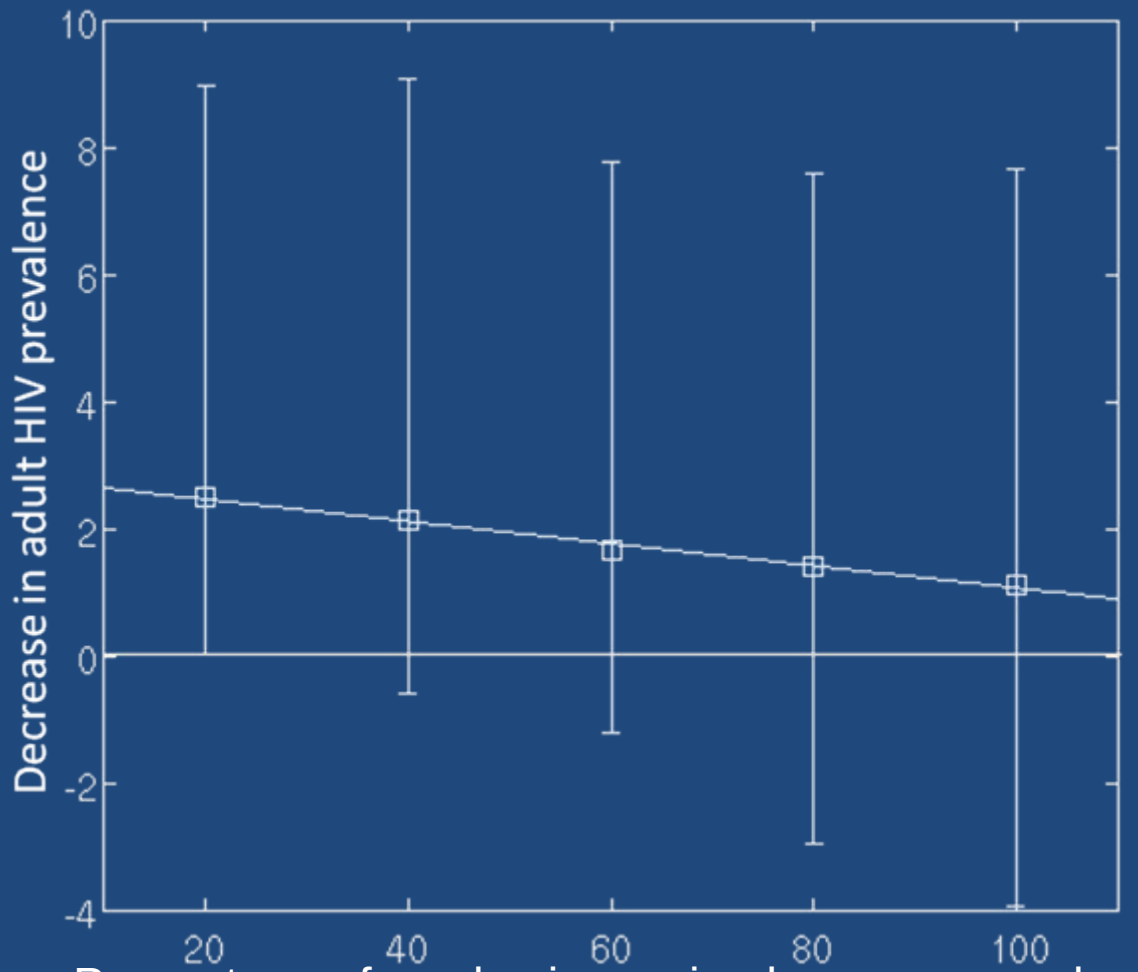
Initial level of circumcision is uniformly spread from 0 to 100%.

Risk Group	Reduction in adult HIV prevalence by
All	2.97% (0.71 - 7.02)
Core	1.10% (0.01 – 4.27)
Non-Core	2.18% (0.05 – 7.71)

Targeting the core group, if identifiable, produces a greater reduction in prevalence per circumcision.

Omitting the core group significantly decreases the effectiveness of the intervention as a whole.

Results – Sensitivity to Risky Behaviour

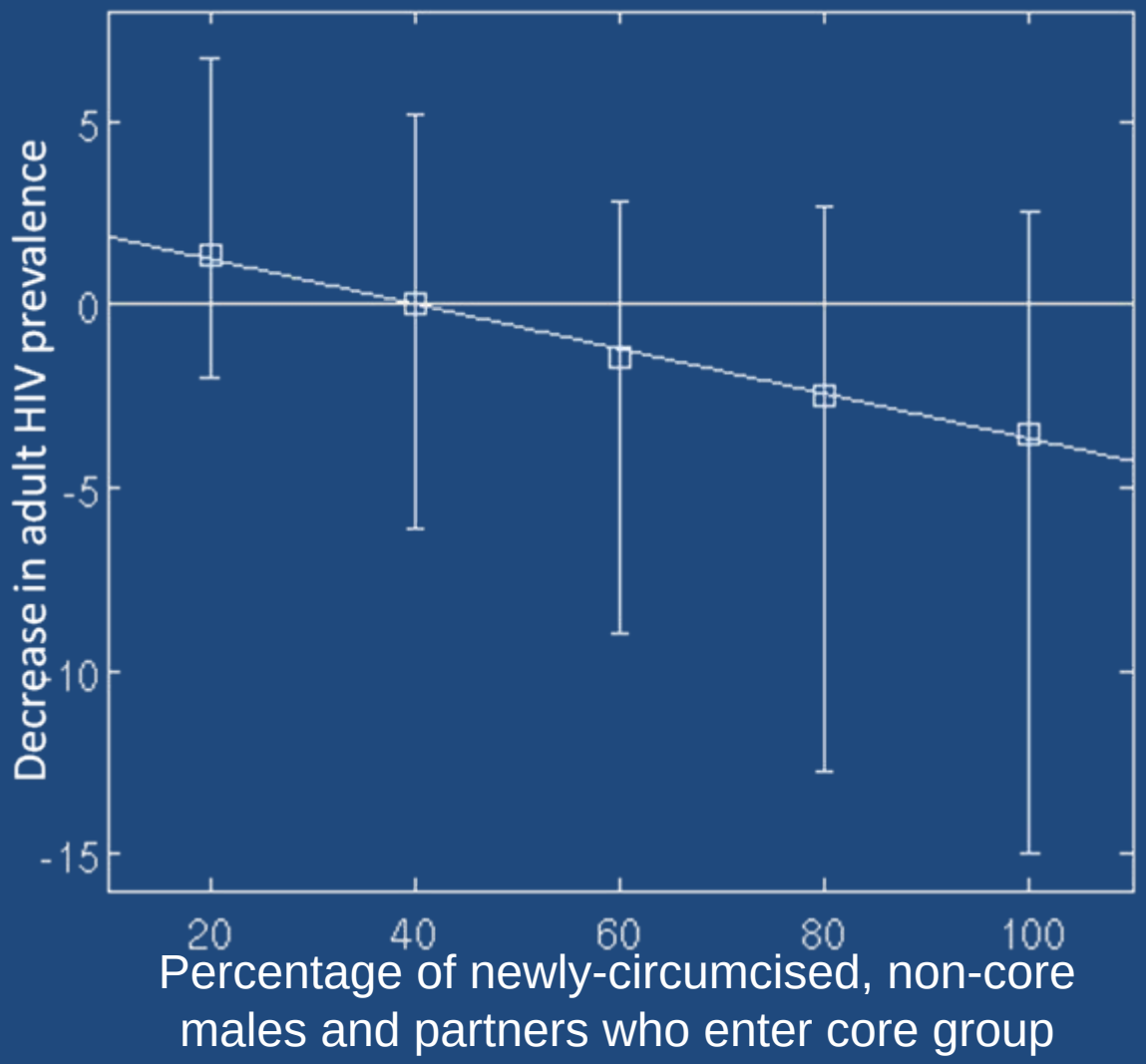


First scenario:
Starting from mean levels of MC (50%) circumcise remaining men.

Total number of partnerships conserved, but more men in high-risk group.

The intervention's effectiveness is halved if all newly circumcised, non-core men join the core group.

Results – Sensitivity to Risky Behaviour



Second scenario: Starting from mean levels of MC (50%) circumcise remaining men.

Total partnerships increase to accommodate increase in risk behaviour.

Intervention is negated if 40% of non-core, newly circumcised men and non-core women join the core group.

This is a substantial increase in individual risk.

Conclusion

- Circumcision can significantly reduce adult HIV prevalence without requiring all men to be circumcised.
- HIV prevalence reduction proportional to additional percentage population circumcised.
- Target 20-30 year old males and if identifiable, high risk men.
- Intervention is still effective despite increases in risky behaviour, but education needed to maximise impact.