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Inequalities in early uptake of HIV testing among pregnant women and in infant HIV exposure in South African public antenatal care settings, 2012

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ABSTRACT

Objectives: Wealth-related inequality across the South African antenatal HIV care cascade has not been considered in detail as a potential hindrance to eliminating infant HIV infections. We aimed to measure wealth-related inequalities in early uptake of HIV testing (before enrolling into antenatal care) and infant HIV exposure (by six weeks postpartum) and to identify the contributing determinants.

Design: Cross-sectional survey

Settings: South African primary public health facilities in 2012

Participants: A national-level sample of 8618 pregnant women

Outcome measures: Wealth-related inequalities in early uptake of HIV testing and infant HIV exposure were measured using the Erreygers concentration index. Determinants contributing to the observed inequalities were identified using the Erryegers decomposition method.

Results: Pro-poor wealth-related inequalities were observed in both variables. The concentration index for early HIV testing was: -0.03 (SE= 0.027) and that for infant HIV exposure was: -0.07 (SE= 0.024). The proportions of early HIV testing and infant HIV exposure were both significantly higher in the lower 40% wealth group compared to the higher 40% wealth group (p-values =0.040 and <0.0001, respectively). Underlying inequalities in province, educational qualification, transport means and source of income contributed the most to the wealth-related inequalities.

Conclusions: The higher burden of HIV exposure in the poorer sub-population could be contributing to delayed elimination of HIV vertical transmission in South Africa. However, early uptake of HIV testing is improving among pregnant women from poorer backgrounds. The high contribution of provinces to inequality highlights a need to shift from relying on national-level estimates alone to rather context specific interventions at provincial level.

Strengths and Limitations of the study

- Although socio-economic inequalities are known to exist in South Africa, this is the first study to use analytical models to accurately measure wealth-related inequalities in infant HIV exposure and in early uptake of antenatal HIV testing on a large nationally-representative sample.

- The external validity of the study is restricted to public health-care users who are in the majority in South Africa hence the observed inequalities exclude the minority private health care users.

- This is a cross-sectional study and causality inferences about the observed results could not be ascertained but the observed associations were indicative of areas to be investigated in future.

BACKGROUND

In most low-middle income countries, unfair inequalities in health care are still a challenge[1 2]. Maternal and child health (MCH) is one health area which has received high attention towards improved service and coverage but wealth-related disparities remain present[1 3 4]. Immunization for example has good coverage even in the poorer countries but despite this, wealth-related inequalities such as in immunization against measles have been reported[5]. High wealth-related inequality in skilled birth attendance is another example common in many low-middle income countries[3 5]. Such disparities in uptake of health services lead to the continuing problem of high child-mortality especially amongst the poorest[6].

Mathematical models have been developed specifically to give accurate measures of health inequalities due to disparities in wealth. The concentration index is one of the measures used in the study of socioeconomic inequality in health[7]. This index provides a measure of the extent of inequalities in health that are systematically associated with socio-economic status (SES). It reflects the experiences of the entire population (rather than just for example two classes) and it is sensitive to changes in the distribution of the population across socioeconomic groups[8]. A decomposition technique was further developed to enable researchers to unravel the causes of socioeconomic health inequalities[9]. Socioeconomic inequalities in a health outcome are caused by inequalities in the determinants of the health outcome. The decomposition method allows assessing the relative importance of these different inequalities in generating inequalities in the health outcome[10].

Data gathered from prevention of mother-to-child transmission of HIV (PMTCT) services demonstrate that SES mostly affects the number of antenatal visits[3 11 12]. However, the effect of background SES on other parameters of the antenatal PMTCT cascade has not been widely studied. A 2011 study on a small South African sample employed the mathematical models of the concentration index and found pro-poor inequalities in infant mortality and HIV transmission to infants[13]. Socio-economic factors are well known to be driving forces behind health-related disparities in South Africa but the application of the concentration index to specifically display the extent of the disparities due to wealth has been minimal[2]. It becomes important to evaluate the potential impact of SES across the PMTCT cascade, using the appropriate methodology, at a time when countries have adopted targets to eliminate mother-to-child transmission of HIV (MTCT), to identify key sticking points and population groups for intervention.

At present, South Africa has high coverage of PMTCT services yet still experiences vertical transmission incidences of more than 2.5% per annum, which is higher than the 2% target for 2016[14]. Maternal HIV prevalence has remained stagnant and high around 30% in the most recent years[14 15], due to improved uptake of antiretroviral treatment. This stagnant and high exposure rate to unborn, new-born and breastfeeding infants challenges attempts to completely eliminate MTCT[16]. The other challenge is the starkly unequal health care system which is dualistically divided, with 68% of the population using the public health system which is serviced by only 30% of doctors and specialists[17]. Recent attempts to improve public health care are borne out by the revised PMTCT consolidated guidelines[18].

Here we investigated wealth-related inequality as a potential barrier to eliminating MTCT within the public health system in South Africa. We evaluated the impact that SES background could have on the two main entry point indicators of the PMTCT cascade, i.e., early uptake of HIV-testing and infant HIV exposure. We further considered whether certain determinants contributed to any observed wealth-related inequalities. Unpacking the SES disparities in PMTCT services could provide additional clues to eliminating MTCT within the public health care system.

METHODS

Data

Data were taken from a national cross-sectional survey conducted in 2012 to evaluate the South African PMTCT program[19]. The survey was conducted at public primary health care clinics and community health centres offering immunisation services countrywide. A national-level sample was selected through a multistage probability proportional to size sampling approach. Health facilities were the primary sampling units selected proportionate to size (small, medium, large), which was measured using the mid-year maternal HIV prevalence and expected number of immunizations. Health facilities were then randomly selected within each size stratum leading to a total of 580 facilities across the 9 South African provinces. Finally, caregiver-infant pairs were invited to enrol into the study during the 6-weeks immunization visit using either random or consecutive selection depending on facility size. Ultimately, 10533 infants were screened and 9120 met inclusion criteria (aged 4-8 weeks and receiving 6 week immunisation). Consent to enrol into the study, to be interviewed and to take infant blood for laboratory HIV tests was sought from infant caregivers. Ethics approval was granted by the South African Medical Research Council Ethics Committee in 2009 (IRB identifier- FWA00002753). Information about socio-demographic characteristics and uptake of antenatal and PMTCT programs was collected through interviews. Two HIV tests were performed on the infants; (i) an enzyme-linked immunosorbent assay (ELISA) for passively transferred maternal anti-HIV antibodies to confirm maternal HIV infection and infant HIV exposure and (ii) an HIV total nucleic acid polymerase chain reaction to confirm infant HIV infection. Data from 8618 out of 9120 consented caregiver-infant pairs were used for analysis, the rest had missing information to establish socio-economic status.

The main outcome variables were binary: (i) early uptake of HIV testing, i.e., self-initiated HIV testing before enrolment to antenatal care versus PMTCT program-influenced testing after enrolling into antenatal care during pregnancy and (ii) infant HIV exposure, i.e., infants confirmed to have positive HIV ELISA results. Independent variables with potential to influence inequalities in the two outcomes were chosen: Highest education achieved, either primary school and lower or high school and above; Marital status, also a binary with single women (i.e., not married, not in a relationship, widows, divorced) in one group and married or co-habiting women in another; Transport to health facility categorised into own car, public transport and walking; Prior knowledge about PMTCT as either 'yes' or 'no'; A categorical variable of the nine South African provinces; lastly, source of income with four categories of women namely employed, dependent on extended family (which is usually forced by financial struggles), dependent on spouse or partner and fourthly those with irregular sources of income such as government grants.

Defining the socio-economic status

The wealth scores to measure socio-economic status were generated from household living conditions and household assets (i.e., house building material, sanitation, water, domestic fuel source and household appliances) using principal component analyses[20]. The wealth scores are only based on household assets because information on actual value of household income was not available. However these assets in the current South African context do give a good indication of wealth status.

Measuring wealth-related inequality

Wealth-related inequality measures were performed in R Statistical package v3.1.0 and in STATA SE 2013. Wealth-related inequalities were determined using the concentration index measure which has been described in detail elsewhere[21 22]. Briefly, the concentration index (CI) is used to measure wealth-related inequality and ranges from -1 to 1. It is calculated from twice the area under a curve (which is a relative measure of the co-variation between the health outcome and the SES ranking, formula shown in Equation 1), the concentration curve, which deviates from a line of equality (the diagonal straight line). Along this diagonal line, CI=0, meaning that there is no inequality caused by wealth differences, i.e., the distribution of the variable of interest across the SES groups is not influenced by wealth.

Equation 1: $CI = \frac{2}{\mu} cov(h,r)$

, in which *h* is the health outcome of interest, *r* the SES ranking and *μ* the mean of the health outcome. In this study for example *h* would be either 'early uptake of HIV testing' or 'infant HIV exposure'. A positive CI (and curve below the diagonal line) indicates that a variable is favourable among the higher wealth groups (the wealthy) otherwise it is more prevalent amongst the lower wealth groups (the poor, when the curve is above the diagonal line).

Contribution of determinant variables to wealth-related inequality can be calculated using a regression-based decomposition analyses shown in Equation 2.

Equation 2: $RCI = \sum_k \left(\frac{\beta_k \bar{x}_k}{\mu} \right) C_k$

, where for 1 to *k* determinant variables, β_k is the coefficient of a determinant variable, $\bar{x}_k$ the mean of the determinant, *μ* mean of the health outcome and C_k the concentration index of the determinant. An error term would also be included in equations 1 and 2 for continuous outcomes [21]. In this study, *k* would represent the six independent variables described earlier.

The concentration index formulas were initially designed for continuous variables therefore are limited in handling the bounded nature of binary variables. Since the outcome variables of this study are binary, we applied the commonly used Erreygers correction[23] on the CI (Equation 3) to correct for the linearity assumptions in the above equations.

Equation 3: *Erreygers correction E of the CI:* $E(CI) = \frac{CI \times \mu \times 4}{range(h)}$

, where *h* is the health outcome of interest and *μ* mean of the health outcome. Therefore in Erreygers correction, the concentration index of the health outcome is multiplied by 4 times the mean of the outcome, then divided by the range of the outcome. Similarly the wealth-related inequality decomposition by contributing determinant factors was adjusted using the Erreygers method (Equation 4)[9].

Equation 4: *Erreygers decomposition* = $E(RCI) = 4\left[\sum \beta_k C_k \bar{x}\right]$

The target strata sample sizes for the survey were not all fully attained hence all analyses were adjusted using appropriate sampling weights.

RESULTS

Sample characteristics and distribution of outcome variables

The study sample comprised women aged between 13 and 49 years, with most (56,6%) aged 20-29 years and 13.7% being adolescents. Many of them (85.6%) completed their primary education. Only 18.4% (95% CI 17.5-19.3) were employed, similar to 17.8% (16.9-18.7) dependent on extended family for income whilst the majority (52.9%) depended on their spouses/partner. A quarter of the sample reported to be legally married.

Table 1 shows the distribution of each outcome per determinant variable. A total of 22.4% of the women had their first HIV test before enrolling into antenatal care. This early HIV testing appeared to be higher in the lower 40% wealth group (23.4%) compared with the higher 40% wealth group (20.6%), p=0.040. Sample infant HIV exposure was 33.2% and significantly higher in the lower wealth group (34.9% versus 29.0%, p-value<0.0001). Compared to high school achievers, mothers with primary school education appeared to be better at testing early for HIV (p=0.0001) and had higher infant HIV exposure (p=0.0001). Both outcome variables were significantly different between income groups. Highest infant HIV exposure (43.2%) as well as early HIV testing (31.4%) were observed among mothers with unstable income sources, seconded by employed mothers, while extended family dependents had the least for both. PMTCT knowledge, marital status and means of transport were not associated with HIV testing. Yet infant HIV exposure was significantly common among those who had prior PMTCT knowledge (p-value=0.003), were single (p-value =0.011) and used public transport (p-value =0.003). There were significant differences regarding uptake of early HIV testing and infant HIV exposure by province (Table 1, p<0.0001).

Table 1: Proportion of early HIV testing and exposed infants in total and by socio-demographic characteristics

Characteristic	Early HIV testing = Yes		Infant Exposure = Positive		n
	% (95% CI)	p-value	% (95% CI)	p-value	
Total	22.4 (21.4-23.4)		33.2 (32.1;34.3)		8618
Wealth groups		**0.040**		**<0.0001**	
Lower 40%	23.4 (21.8;25.0)		34.9 (33.1;38.1)		3411
middle	24.1 (22.0;26.3)		37.9 (35.4;40.4)		1753
higher 40%	20.6 (19.2;22.1)		29.0 (27.3;30.6)		3454
Mother's Education		**0.0001**		**0.0001**	
Primary school	27.7 (25.1;30.5)		43.3 (40.3;46.2)		1277
High school	21.6 (20.5;22.6)		31.5 (30.3;32.7)		7341
Income source		**0.0001**		**0.0001**	
Employed	25.9 (23.6;28.3)		36.5 (33.9;39.1)		1596
Spouse	21.2 (19.9;22.5)		32.0 (30.5;33.5)		4538
Family member	17.2 (15.3;19.4)		27.1 (24.8;29.6)		1543
Unstable/Grant	31.4 (28.2;34.7)		43.2 (39.8;46.7)		941
PMTCT knowledge		0.710		**0.003**	
No	23.3 (19.0;28.3)		23.6 (19.3;28.4)		392
Yes	22.4 (21.4;23.4)		33.6 (32.4;34.7)		8226
Marital Status		0.560		**0.010**	
Married/Cohabit	21.9 (20.1;23.8)		30.3 (28.2;32.3)		2257
Single/widow/divorced	22.6 (21.5;23.8)		34.1 (32.9;35.4)		6361
Transport		0.060		**0.003**	
Own car	17.8 (14.5;21.5)		21.6 (18.0;25.8)		498
Public transport	23.6 (22.0;25.2)		36.6 (34.8;38.4)		3171
Walked	22.1 (20.9;23.4)		31.8 (30.4;33.3)		4949
Province		**0.0001**		**0.0001**	
WC	25.0 (22.6;27.7)		22.3 (20.0;24.8)		1141
EC	24.8 (22.0;27.8)		29.7 (26.8;32.8)		939
FS	19.3 (16.7;22.2)		33.8 (30.6;37.2)		811
GP	18.3 (16.4;20.4)		33.7 (31.4;36.1)		1595
KZN	28.2 (25.5;31.1)		43.6 (40.5;46.7)		1015
LP	18.6 (16.4;20.9)		25.9 (23.5;28.6)		1144
MP	20.8 (18.2;23.7)		37.5 (34.2;40.8)		822
NC	29.3 (25.0;34.0)		20.7 (17.0;25.0)		396
NW	20.9 (18.2;24.0)		31.6 (28.4;35.1)		755

The p-values are from the chi-squared tests for differences between sub-groups of a variable. Significant values at $p<0.05$ are in bold. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West.

Wealth-related inequalities and decomposition of determinant variable contributions

The Erreygers' corrected concentration indexes, E(CI), are given in Table 2. The E(CI) for taking the first HIV test before pregnancy was negative, -0.03, indicating a pro-poor inequality, i.e., early HIV testing is unequally common among women of lower SES ranking. A negative E(CI) (-0.07) for infant HIV exposure was also observed indicating that HIV prevalence tends to be higher among pregnant women in the lower SES ranking.

Table 2: Erreygers-corrected Concentration indexes for early uptake of HIV testing and infant HIV exposure

	Early HIV testing	Infant HIV exposure
Concentration index, E(CI) (95% CI)	-0.03 (-0.05;-0.01)	-0.07 (-0.09;-0.04)
Standard error for E(CI)	0.027	0.024
p-value for E(CI)	0.363	0.011

The contributions of secondary determinants to these inequalities are given in Table 3. Each contribution is measured from the underlying wealth-related inequality within the determinant alone (the E(CI) of the determinant) and the direct influence which the determinant has on the outcome (given by the decomposition regression coefficient). Province (55% contribution) and wealth group (41% contribution) were the highest contributors to wealth-related inequality in early HIV testing and infant HIV exposure, respectively. Provincial results varied widely between provinces with highest contributions from the KwaZulu Natal and Gauteng provinces. The next high contributors to both inequalities were mother's education, means of transport and source of income. Achieving high school reduced uptake of HIV testing by a factor of 0.29 and reduced infant HIV exposure by a factor of 0.049 with pro-poor E(CI)s. Within means of transport, the strongest effect was from public transport users from which high pro-poor E(CI)s and regression coefficients were seen. Source of income was the only high negative contributor implying that it effected a decrease in the E(CI)s of the outcome variables. Marital status and PMTCT knowledge had negligible contributions.

Disaggregation of inequalities by province

The highest overall contribution to inequalities was from underlying provincial disparities. Therefore we disaggregated the national data and recalculated the E(CI)s and outcome prevalence by province (Figures 1 and 2). Inter-provincial differences varied widely without any consistence between magnitudes of the outcome prevalence and wealth-related inequality. The highest pro-poor wealth-related inequalities for early uptake of HIV testing were observed in North West and Western Cape (E(CI)< -0.09) provinces whilst the highest pro-rich inequalities were in Northern Cape and Eastern Cape. KwaZulu Natal was the only province with a very high pro-rich inequality for infant HIV exposure (E(CI)=0.108). High pro-poor wealth-related inequalities were in Northern Cape, North West, Gauteng and Western Cape.

Table 3: Determinant associations with each outcome, wealth-related inequalities and contributions to wealth-related inequalities

(a) Early HIV testing			
Determinant	**Regression-decomposition coefficient**	**E(CI)**	**% contribution to wealth-related inequality**
Wealth Group (ref: lower 40%**)**			(total= 8.83)
middle	0.14	0.001	-1.75
higher 40%	-0.02	-0.004	10.58
Mother's Education (ref: Primary school**)**			(total = 27.53)
High school	-0.29*	-0.012	27.53
Income source (ref: Employed)			(total=-17.52)
Spouse	-0.34*	0.001	-1.94
Family member	-0.60*	-0.101	-25.41
Unstable/Grant	0.18	-0.004	9.82
PMTCT knowledge (ref: No)			
Yes	0.01	0.000#	-0.09
Marital Status (ref: Married/Cohabit)			
Single/widow/divorced	-0.01	0.000#	-0.3
Transport (ref: Own car)			(total=26.87)
Public transport	0.27	-0.012	32.84
Walked	0.21	0.002	-5.97
Province (ref: WC)			(total=54.69)
EC	-0.01	0.000#	-1.65
FS	-0.36*	-0.002	4.73
GP	-0.41*	-0.029	69.40
KZN	0.16	-0.008	17.07
LP	-0.42*	0.013	-30.51
MP	-0.25	0.001	-1.33
NC	0.22	0.002	-3.81
NW	-0.30*	0.000#	0.79

(b) Infant Exposure			
Determinant	**Regression-decomposition coefficient**	**RCI**	**% contribution to wealth-related inequality**
Wealth Group (ref: lower 40%**)**			(total=40.71)
middle	0.18*	0.001	-1.24
higher 40%	-0.14	-0.049	41.95
Mother's Education (ref: Primary school)			(total = 25.3)
High school	-0.49*	-0.020	25.30

Income source (ref: Employed)			(total=-10.00)
Spouse	-0.33*	0.001	-0.99
Family member	-0.56*	0.010	-12.69
Unstable/Grant	0.12	-0.003	3.68
PMTCT knowledge (ref: No)			
Yes	0.40*	0.001	-1.39
Marital Status (ref: Married/Cohabit)			
Single/widow/divorced	0.07	-0.001	1.58
Transport (ref: Own car)			(total=28.55)
Public transport	0.48*	-0.022	34.37
Walked	0.35*	0.003	-5.82
Province (ref: WC)			(total=15.24)
EC	0.25	-0.009	11.05
FS	0.52*	0.003	-3.60
GP	0.53*	0.038	-47.42
KZN	0.84*	-0.041	51.13
LP	0.04	-0.001	1.40
MP	0.60*	-0.001	1.72
NC	-0.15	-0.001	1.43
NW	0.32	0.000#	-0.47

*significant regression coefficient. #no wealth related inequality - 95% confidence interval includes zero. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West.

DISCUSSION

This work shows that early uptake of HIV testing and infant HIV exposure are affected by wealth-related inequality within the public health system in South Africa. There is improved uptake of self-initiated early HIV testing amongst mothers of relatively lower wealth groups, but a higher burden of infant HIV exposure amongst them. HIV testing services are now benefiting the poor in the country. This differs from countries like Burkina Faso, Kenya, Malawi and Uganda where self-initiated testing appeared more prevalent among higher wealth groups[24]. The reasons why uptake of HIV testing has become disproportionately lower among women in higher SES are unknown and need investigation. Overall, the wealth-related inequality scores are not very high, both less than 0.1, likely due to data being limited to public healthcare users alone. The wealthiest 20% in South Africa largely use private health facilities. However, obtaining significant inequality score within the public health facility users alone is of concern as it indicates that disparities exist even within the public health service. The majority of the population in the country uses these public health facilities hence efforts are needed to ensure that there is no inequity in PMTCT programs.

In decomposing determinant contributions, source of income was the only determinant whose underlying inequalities contributed to lowering the overall wealth-related inequalities of both outcomes. Depending on extended family member in particular, had very high negative decomposition regression coefficients indicating negative associations with both outcomes, which pulled the overall contribution to be negative. Not much detailed work has been reported regarding disparities between different income sources and the cross-sectional nature of this study limits our explanation for this observation. Women who reached High School had a reduced risk of HIV infant exposure and a relatively lower odds of testing early for HIV. The HIV testing result is contrary to observations reported in low-income countries[25 26]. However, it echoes improved service provision for marginalised populations in South Africa. Providing high school education could serve as a potential platform to increase HIV testing. Also, education about HIV-related health issues within communities and health facilities should be an ongoing process so that health outcomes improve equally between the well-educated and those who received little formal education.

Transport contributed to increased wealth-related inequality with largest effect from public transport users. The E(CI) scores indicate that public transport users were largely from lower SES groups while those who walked were mostly from higher SES groups. This could indirectly reflect the distance from facilities which need to be travelled, wherein poorer communities live further away from health facilities while the least poor live closer to health facilities with walkable distances. This result raises the importance of community-outreach and mobile clinic programs especially in remote rural settings were accessibility of facilities is difficult. The recently introduced primary health care package which includes ward-based outreach teams to improve uptake and access to care should be implemented optimally.

Disaggregating the data by province revealed complex inter-province differences in both prevalence and wealth-related inequality of each outcome. A total of 5/9 provinces had negative E(RCI) scores for uptake of HIV testing indicating an improvement among women from lower SES ranking who were previously disadvantaged and still are in other Sub-Saharan countries[24 27]. Most (7/9) of the provincial wealth-related inequality scores for infant HIV exposure were also negative, emphasising the high burden of infant HIV exposure within lower SES sub-population. Within-country disparities in health indicators have also been observed elsewhere[6 11], and indeed show the need to begin shifting focus from average national targets alone to spatial sub-regional focus.

Limitations

One limitation of this study is bias towards public health facility users. Although inequalities are evident just within this population alone, inclusion of private healthcare users would give a clearer indication of the true inequality gap between the richest and the poorest in the country. An all-inclusive national demographic health survey would be needed for such information. Another limitation is lack of qualitative data to explain why the lower SES group preferable test for HIV earlier than the higher SES group for example. The nature of a cross-sectional study also limits any causality inferences like the possibility that low uptake of HIV testing among wealthier is due to low infant HIV exposure. Future studies will require time series and inclusion of qualitative data in order to answer these questions.

Conclusion

Low self-initiated early HIV testing prevalence (22%) and high infant HIV exposure (33%) in the sample are both a concern. However, self-initiated uptake of HIV testing among the lower SES group is improving. The unequally high infant HIV exposure amongst the poorer could be reflecting differences in risk behaviour choices. These observations clearly point to a need for targeted interventions. Community health workers and outreach teams, like in many low-middle income settings[26-29], can be used effectively for such interventions. Also, in a large country like South Africa, aggregated national-level estimates can conceal hotspot geographic areas by averaging across high risk and low risk areas yet policy makers using sub-geographical approaches could find better clues to eliminating health problems[30]. Therefore inequity along the PMTCT cascade needs to be evaluated at lower geographic levels followed by context-specific and targeted interventions in order to eliminate MTCT.

DECLARATIONS

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Competing Interests

All authors declare no competing interests of any kind related to this work.

Ethics approval and consent to participate

The South African Medical Research Council Ethics Committee and the Centers for Disease Control and Prevention approved the final protocol for the PMTCT survey. Informed and written consent was obtained from participating mother/caregivers.

Data Sharing Statement

The data are bound by ethical and legal restrictions. To access the data of the South Africa's Prevention of Mother to Child Transmission Effective study, investigators that are not part of the study team should submit a concept proposal to Ameena Goga, MD, MS (South Africa Medical Research Council (MRC), Principal Investigator), Debra Jackson (University of the Western Cape/UNICEF, Principal Investigator) and Thu-Ha Dinh, MD, MS (US Centers for Disease Control and Prevention (CDC), Principal investigator) for approval. Investigators with an approved concept proposal must apply for guest researcher status to obtain access to a workstation and the data. Additionally they will need to complete data security and confidentiality training, and to sign data use and nondisclosure agreements. The data are not yet available in a stable public repository. Researchers who meet criteria to access the data should contact PI Ameena Goga at Ameena.Goga@mrc.ac.za .

Author's contribution

NKN conceptualised the manuscript aims, carried out the analyses & wrote the manuscript. CVM & NS trained and supervised the analyses methods, assisted with interpretation of the results and reviewed the manuscript drafts. AG contributed to conceptualising the manuscript aims and in writing and reviewing the manuscript drafts.

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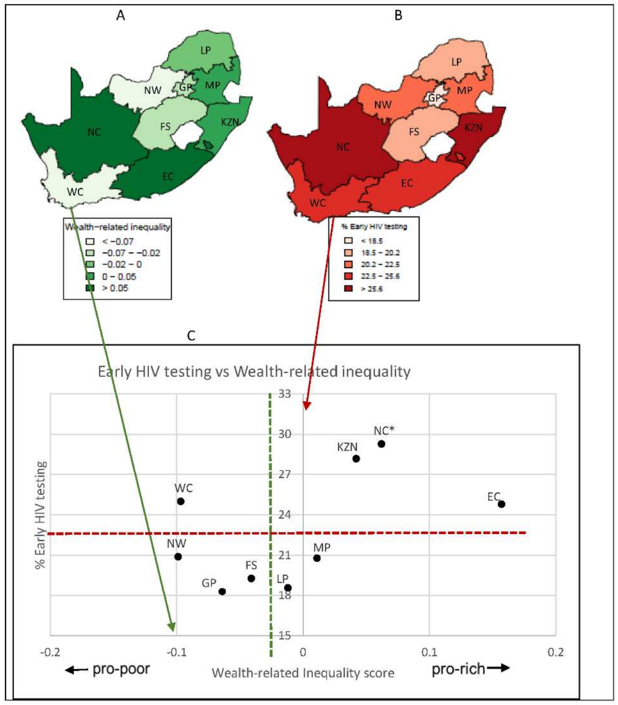
FIGURES LEGENDS

Figure 1: Provincial wealth-related inequality index versus uptake of early HIV testing

Wealth-related inequality index (A) versus (C) proportion of early HIV testing (B) per province; Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average early uptake of HIV testing on the y-axis. *small sample size for Northern Cape Province n<700.

Figure 2: Provincial wealth-related inequality index versus uptake of infant HIV exposure

Wealth-related (A) inequality index versus (C) proportions of HIV-exposed infants (B) per province. Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average infant HIV exposure on the y-axis. *small sample size for Northern Cape Province n<700.



Provincial wealth-related inequality index versus uptake of early HIV testing:
Wealth-related inequality index (A) versus (C) proportion of early HIV testing (B) per province; Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average early uptake of HIV testing on the y-axis. *small sample size for Northern Cape Province n<700.

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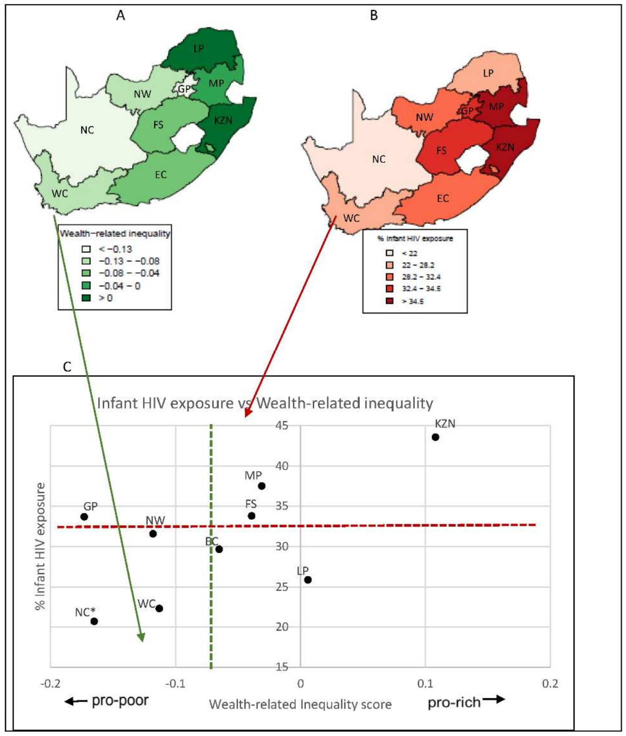

Provincial wealth-related inequality index versus uptake of infant HIV exposure: Wealth-related (A) inequality index versus (C) proportions of HIV-exposed infants (B) per province. Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average infant HIV exposure on the y-axis. *small sample size for Northern Cape Province n<700.

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Wealth-related inequalities in early uptake of HIV testing among pregnant women and in infant HIV exposure: An analysis of data from a national cross-sectional survey, South Africa

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Wealth-related inequalities in early uptake of HIV testing among pregnant women and in infant HIV exposure: An analysis of data from a national cross-sectional survey, South Africa

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Keywords: wealth-related inequality, early HIV testing, infant HIV exposure, pregnant women

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ABSTRACT

Objectives: Wealth-related inequality across the South African antenatal HIV care cascade has not been considered in detail as a potential hindrance to eliminating mother-to-child HIV transmission (EMTCT). We aimed to measure wealth-related inequalities in early uptake of HIV testing (before enrolling into antenatal care) and infant HIV exposure (by six weeks postpartum) and to identify the contributing determinants.

Design: Cross-sectional survey

Settings: South African primary public health facilities in 2012

Participants: A national-level sample of 8618 pregnant women

Outcome measures: Wealth-related inequalities in early uptake of HIV testing and infant HIV exposure were measured using the Erreygers concentration index. Determinants contributing to the observed inequalities were identified using the Erryegers decomposition method.

Results: Pro-poor wealth-related inequalities were observed in both variables. The concentration index for early HIV testing was: -0.03 (SE= 0.027) and that for infant HIV exposure was: -0.07 (SE= 0.024). The proportions of early HIV testing and infant HIV exposure were both significantly higher in the lower 40% wealth group compared to the higher 40% wealth group (p-values =0.040 and <0.0001, respectively). Underlying inequalities in province, educational qualification, transport means and source of income contributed the most to the wealth-related inequalities.

Conclusions: Our results on better early uptake of HIV testing amongst the poorer sub-population compared with the richer highlights inequity in uptake of HIV testing in South Africa. The higher burden of infant HIV exposure in the poorer sub-population may reflect this differential uptake or could illustrate increased maternal HIV prevalence amongst poor people. This socio-economic difference could delay EMTCT in South Africa. The high contribution of provinces to inequality highlights a need to shift from reliance on national-level estimates alone. Future interventions need to be context specific and tailored for different socio-economic sub-populations and sub-regional settings.

Strengths and Limitations of the study

- Although socio-economic inequalities are known to exist in South Africa, few studies have used analytical models to accurately measure wealth-related inequalities in infant HIV exposure and in early uptake of antenatal HIV testing on a large nationally-representative sample.
- The external validity of the study is restricted to public health-care users who are in the majority in South Africa hence the observed inequalities exclude the minority private health care users.
- This is a cross-sectional study and causality inferences about the observed results could not be ascertained but the observed associations were indicative of areas to be investigated in future.

BACKGROUND

In most low-middle income countries, unfair inequalities in health care are still a challenge[1 2]. Maternal and child health (MCH) is one health area that has received increased attention towards improved service coverage but wealth-related disparities remain[1 3 4]. Immunization, for example, has good coverage even in the poorer countries but wealth-related inequalities such as in immunization against measles have been reported[5]. High wealth-related inequality in skilled birth attendance is another example common in many low-middle income countries[3 5]. Such disparities in uptake of health services lead to the continuing problem of high child-mortality especially amongst the poorest[6].

Mathematical models have been developed specifically to give accurate measures of health inequalities due to disparities in wealth. The concentration index is one of the measures used in the study of socioeconomic inequality in health[7]. This index provides a measure of the extent of inequalities in health that are systematically associated with socio-economic status (SES). It reflects the experiences of the entire population (rather than just for example two classes) and it is sensitive to changes in the distribution of the population across socioeconomic groups[8]. A decomposition technique was further developed to enable researchers to unravel the causes of socioeconomic health inequalities[9]. Inequalities in the determinants of a health outcome also contribute to socioeconomic inequalities in the health outcome. The decomposition method allows assessing the relative importance of these different inequalities in generating inequalities in the health outcome[10].

Data gathered from prevention of mother-to-child transmission of HIV (PMTCT) services demonstrate that SES mostly affects the number of antenatal visits[3 11 12]. However, the effect of background SES on other parameters of the antenatal PMTCT cascade has not been widely studied. A 2011 study on a small South African sample employed the mathematical models of the concentration index and found pro-poor inequalities in infant mortality and HIV transmission to infants[13]. Socio-economic factors are well known to be driving forces behind health-related disparities in South Africa but the application of the concentration index to specifically display the extent of the disparities due to wealth has been minimal[2]. It becomes important to evaluate the potential impact of SES across the PMTCT cascade, using the appropriate methodology, at a time when countries have adopted targets to eliminate mother-to-child transmission of HIV (MTCT), to identify key sticking points and population groups for intervention.

Presently, although South Africa has more than 90% coverage of PMTCT services, the annual incidence of early vertical HIV transmission, measured at 6 weeks postpartum in 2013, was 2.5%, which was higher than the 2% target[14]. Maternal HIV prevalence has remained high (approximately 30%) and stagnant in the most recent years[14 15], due to improved uptake of antiretroviral treatment. This stagnant and high HIV exposure rate to unborn, new-born and breastfeeding infants hinder the complete elimination of mother-to-child transmission of HIV (EMTCT)[16]. The other challenge is the unequal health care system which is dualistically divided into public and private sectors. The majority (~68%) of the population use the public health care system which however is serviced by only 30% of the country's doctors and specialists[17]. The public sector has a three tier service provision system; the primary health care clinics and community health centres which serve as the first contact at no cost, for basic health and maternity care; these make referrals of complicated cases to the secondary level care – the district hospitals. Academic hospitals form the highest level and mostly serve more complicated healthcare needs. Reports of 2015, indicate a doctor-patient ratio of 1:>4000 in the public sector with still ~4% of the population living at least 5km away from the nearest health facility[18]. The private sector, smaller, comprises of private-practising healthcare professionals and private hospitals whose services are mainly remunerated through the medical aid schemes. Comparatively, the primary level of the public sector is mostly over-burdened and does experience sub-standard service provision while the private sector mainly offers high quality service. The government and some non-governmental organisations have expanded the number of primary health care clinics in an effort to decongest and improve the quality of public healthcare. Improvements for maternal and child health care have been at the forefront of attempts to improve public health care, such as the recent revisions of the PMTCT consolidated guidelines[19].

Here we investigated wealth-related inequality as a potential barrier to eliminating MTCT within the public health system in South Africa. We evaluated the impact that SES background could have on the two main entry point indicators of the PMTCT cascade, i.e., early uptake of HIV-testing and infant HIV exposure. We further considered whether certain determinants contributed to any observed wealth-related inequalities. Unpacking the SES disparities in PMTCT services could provide additional clues to eliminating MTCT within the public health care system.

METHODS

Data

A secondary analysis of data from a national cross-sectional survey conducted in 2012 to evaluate the South African PMTCT program, was conducted[20]. The methods have been explained in detail elsewhere[21]. In summary, the survey was conducted at public primary health care clinics and community health centres offering immunisation services countrywide. The primary aim was to measure national and provincial-levels MTCT amongst infants attending public health facilities for their 6 week immunisation. Infants with known and unknown HIV exposure were eligible for inclusion. The 6-weeks postpartum point was chosen because it has a 99% infant coverage for immunisation[22]. Antenatal HIV prevalence and presumed PMTCT coverage were used to estimate the sample size needed for each province at precisions of 30% to 50% and a design effect of 2. The national target sample size was 12 200, ranging between 700 and 1800 per province, proportional to provincial six week immunisation coverage. A two-stage probability proportional to size sampling approach was used. The first stage was at provincial level. In each province health facilities were stratified into medium (130-300 immunisations per year) and large (300 immunisations or more per year) facilities. Large facilities were further stratified into two groups - facilities in districts with antenatal HIV prevalence <29% or ≥29%, which was the 2009 national average antenatal HIV prevalence. Therefore facilities were grouped into three strata. The second stage was at health facility level: 580 facilities selected proportional to target facility sample size, were needed to achieve the desired provincial and national sample sizes. The target number of infants per facility was taken as the median number of infants expected in each facility within each stratum over a three week data collection period. Finally, caregiver-infant pairs were invited to enrol into the study during the 6-weeks immunization visit using either random or consecutive selection depending on facility size. Ultimately, 10533 infants were screened and 9120 provided both interview and infant blood data to measure MTCT. With respect to the data analysis for the primary outcome (6-week MTCT), sampling weights were calculated as the inverse of the realised sample size, accounting for South African live births, relative to the target sample size for each facility.

Consent to enrol into the study, to be interviewed and to take infant blood for laboratory HIV tests was sought from infant caregivers. Ethics approval was granted by the South African Medical Research Council Ethics Committee in 2009 (IRB identifier- FWA00002753). Information about socio-demographic characteristics and uptake of antenatal and PMTCT programs was collected through interviews. Two HIV tests were performed on the infants; (i) an enzyme-linked immunosorbent assay (ELISA) for passively transferred maternal anti-HIV antibodies to confirm maternal HIV infection and infant HIV exposure and (ii) an HIV total nucleic acid polymerase chain reaction to confirm infant HIV infection. Data from 8618 out of 9120 consented caregiver-infant pairs were used for analysis, the rest had missing information to establish socio-economic status.

The main outcome variables were binary: (i) early uptake of HIV testing, i.e., self-initiated HIV testing before enrolment to antenatal care versus PMTCT program-influenced testing after enrolling into antenatal care during pregnancy and (ii) infant HIV exposure, i.e., infants confirmed to have positive HIV ELISA results. Independent variables with potential to influence inequalities in the two outcomes were chosen, i.e., variables which can influence or be influenced by socio-economic background and at the same time can influence at least one of the outcomes: Education level, dichotomised as primary school and lower or high school and above was selected as education could influence attitudes towards the importance of healthcare; Marital status, dichotomised into single women (i.e., not married, not in a relationship, widows, divorced) and married (or co-habiting) women, was included as spousal support is likely to encourage uptake of healthcare; Transport to health facility categorised into own car, public transport and walking was included as a marker of ease of healthcare access, affecting the frequency and timing of uptake; Prior knowledge about PMTCT as either 'yes' or 'no' was included as prior knowledge can influence timing of HIV testing in relation to pregnancy; A categorical variable of the nine South African provinces was included as provincial differences in healthcare management and in cultural behavioural norms has been observed; lastly, source of income with four categories of women namely employed, dependent on extended family, dependent on spouse or partner and fourthly those with irregular sources of income such as government grants. The latter is not a good measure of household income but is a common structural division in South Africa, and it will be important to know whether and how it impacts on the primary outcome variables.

Defining the socio-economic status

The wealth scores to measure socio-economic status were generated from household living conditions and household assets (i.e., house building material, sanitation, water, domestic fuel source and household appliances) using principal component analyses[23]. The wealth scores are only based on household assets because information on actual value of household income was not available. However these assets in the current South African context do give a good indication of wealth status.

Measuring wealth-related inequality

Wealth-related inequality measures were performed in R Statistical package v3.1.0 and in STATA SE 2013. Wealth-related inequalities were determined using the concentration index measure which has been described in detail elsewhere[24 25]. Briefly, the concentration index (CI) is used to measure wealth-related inequality and ranges from -1 to 1. It is calculated from twice the area under a curve (which is a relative measure of the co-variation between the health outcome and the SES ranking, formula shown in Equation 1), the concentration curve, which deviates from a line of equality (the diagonal straight line). Along this diagonal line, CI=0, meaning that there is no inequality caused by wealth differences, i.e., the distribution of the variable of interest across the SES groups is not influenced by wealth.

Equation 1: $CI = \frac{2}{\mu} cov(h,r)$

, in which *h* is the health outcome of interest, *r* the SES ranking and μ the mean of the health outcome. In this study for example *h* would be either 'early uptake of HIV testing' or 'infant HIV exposure'. A positive CI (and curve below the diagonal line) indicates that a variable is favourable among the higher wealth groups (the wealthy) otherwise it is more prevalent amongst the lower wealth groups (the poor, when the curve is above the diagonal line).

Contribution of determinant variables to wealth-related inequality can be calculated using a regression-based decomposition analyses shown in Equation 2.

Equation 2: $$RCI = \sum_k \left(\frac{\beta_k \bar{x}_k}{\mu}\right) C_k$$

, where for 1 to *k* determinant variables, β_k is the coefficient of a determinant variable, $\bar{x}_k$ the mean of the determinant, μ mean of the health outcome and C_k the concentration index of the determinant. An error term would also be included in equations 1 and 2 for continuous outcomes [24]. In this study, *k* would represent the six independent variables described earlier.

The concentration index formulas were initially designed for continuous variables therefore are limited in handling the bounded nature of binary variables. Since the outcome variables of this study are binary, we applied the commonly used Erreygers correction[26] on the CI (Equation 3) to correct for the linearity assumptions in the above equations.

Equation 3: *Erreygers correction E of the CI:* $$E(CI) = \frac{CI \times \mu \times 4}{range(h)}$$

, where *h* is the health outcome of interest and μ mean of the health outcome. Therefore in Erreygers correction, the concentration index of the health outcome is multiplied by 4 times the mean of the outcome, then divided by the range of the outcome. Similarly the wealth-related inequality decomposition by contributing determinant factors was adjusted using the Erreygers method (Equation 4)[9].

Equation 4: *Erreygers decomposition* = $$E(RCI) = 4\left[\sum \beta_k C_k \bar{x}\right]$$

The target strata sample sizes for the survey were not all fully attained hence all analyses were adjusted using appropriate sampling weights.

Data analyses at provincial level

Given that the survey data are also valid for provincial level estimates and given the observed differences in the primary outcomes of the survey between provinces, we presented descriptive summaries of the outcome variables and wealth-related inequalities by province. We calculated wealth-related inequalities for each province separately using the same approach presented above. The same socio-economic ranking scores obtained from the combined national data were applied in the provincial-level calculation of wealth-related inequality. The estimates for each outcome were also calculated separately for each province.

RESULTS

Sample characteristics and distribution of outcome variables

The study sample comprised women aged between 13 and 49 years, with most (56,6%) aged 20-29 years and 13.7% being adolescents. Many of them (85.6%) completed their primary education. Only 18.4% (95% CI 17.5-19.3) were employed, similar to 17.8% (16.9-18.7) dependent on extended family for income whilst the majority (52.9%) depended on their spouses/partner. A quarter of the sample reported to be legally married.

Table 1 shows the distribution of each outcome per determinant variable. A total of 22.4% of the women had their first HIV test before enrolling into antenatal care. This early HIV testing appeared to be higher in the lower 40% wealth group (23.4%) compared with the higher 40% wealth group (20.6%), p=0.040. Sample infant HIV exposure was 33.2% and significantly higher in the lower wealth group (34.9% versus 29.0%, p-value<0.0001). Compared to high school achievers, mothers with primary school education appeared to be better at testing early for HIV (p=0.0001) and had higher infant HIV exposure (p=0.0001). Both outcome variables were significantly different between income groups. Highest infant HIV exposure (43.2%) as well as early HIV testing (31.4%) were observed among mothers with unstable income sources, seconded by employed mothers, while extended family dependents had the least for both. PMTCT knowledge, marital status and means of transport were not associated with HIV testing. Yet infant HIV exposure was significantly common among those who had prior PMTCT knowledge (p-value=0.003), were single (p-value =0.011) and used public transport (p-value =0.003). There were significant differences regarding uptake of early HIV testing and infant HIV exposure by province (Table 1, p<0.0001).

Table 1: Proportion of early HIV testing and exposed infants in total and by socio-demographic characteristics

Characteristic	Early HIV testing = Yes		Infant Exposure = Positive		n
	% (95% CI)	p-value	% (95% CI)	p-value	
Total	22.4 (21.4-23.4)		33.2 (32.1;34.3)		8618
Wealth groups		**0.040**		**<0.0001**	
Lower 40%	23.4 (21.8;25.0)		34.9 (33.1;38.1)		3411
middle	24.1 (22.0;26.3)		37.9 (35.4;40.4)		1753
higher 40%	20.6 (19.2;22.1)		29.0 (27.3;30.6)		3454
Mother's Education		**0.0001**		**0.0001**	
Primary school	27.7 (25.1;30.5)		43.3 (40.3;46.2)		1277
High school	21.6 (20.5;22.6)		31.5 (30.3;32.7)		7341
Income source		**0.0001**		**0.0001**	
Employed	25.9 (23.6;28.3)		36.5 (33.9;39.1)		1596
Spouse	21.2 (19.9;22.5)		32.0 (30.5;33.5)		4538
Family member	17.2 (15.3;19.4)		27.1 (24.8;29.6)		1543
Unstable/Grant	31.4 (28.2;34.7)		43.2 (39.8;46.7)		941
PMTCT knowledge		0.710		**0.003**	
No	23.3 (19.0;28.3)		23.6 (19.3;28.4)		392
Yes	22.4 (21.4;23.4)		33.6 (32.4;34.7)		8226
Marital Status		0.560		**0.010**	
Married/Cohabit	21.9 (20.1;23.8)		30.3 (28.2;32.3)		2257
Single/widow/divorced	22.6 (21.5;23.8)		34.1 (32.9;35.4)		6361
Transport		0.060		**0.003**	
Own car	17.8 (14.5;21.5)		21.6 (18.0;25.8)		498
Public transport	23.6 (22.0;25.2)		36.6 (34.8;38.4)		3171
Walked	22.1 (20.9;23.4)		31.8 (30.4;33.3)		4949
Province		**0.0001**		**0.0001**	
WC	25.0 (22.6;27.7)		22.3 (20.0;24.8)		1141
EC	24.8 (22.0;27.8)		29.7 (26.8;32.8)		939
FS	19.3 (16.7;22.2)		33.8 (30.6;37.2)		811
GP	18.3 (16.4;20.4)		33.7 (31.4;36.1)		1595
KZN	28.2 (25.5;31.1)		43.6 (40.5;46.7)		1015
LP	18.6 (16.4;20.9)		25.9 (23.5;28.6)		1144
MP	20.8 (18.2;23.7)		37.5 (34.2;40.8)		822
NC	29.3 (25.0;34.0)		20.7 (17.0;25.0)		396
NW	20.9 (18.2;24.0)		31.6 (28.4;35.1)		755

The p-values are from the chi-squared tests for differences between sub-groups of a variable. Significant values at p<0.05 are in bold. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West.

Wealth-related inequalities and decomposition of determinant variable contributions

The Erreygers' corrected concentration indexes, E(CI), are given in Table 2. The E(CI) for taking the first HIV test before pregnancy was negative, -0.03, indicating a pro-poor inequality, i.e., early HIV testing is unequally common among women of lower SES ranking. A negative E(CI) (-0.07) for infant HIV exposure was also observed indicating that HIV prevalence tends to be higher among pregnant women in the lower SES ranking.

Table 2: Erreygers-corrected Concentration indexes for early uptake of HIV testing and infant HIV exposure

	Early HIV testing	Infant HIV exposure
Concentration index, E(CI) (95% CI)	-0.03 (-0.05;-0.01)	-0.07 (-0.09;-0.04)
Standard error for E(CI)	0.027	0.024
p-value for E(CI)	0.363	0.011

The contributions of secondary determinants to these inequalities are given in Table 3. Each contribution is measured from the underlying wealth-related inequality within the determinant alone (the E(CI) of the determinant) and the direct influence which the determinant has on the outcome (given by the decomposition regression coefficient). Province (55% contribution) and wealth group (41% contribution) were the highest contributors to wealth-related inequality in early HIV testing and infant HIV exposure, respectively. Provincial results varied widely between provinces with highest contributions from the KwaZulu Natal and Gauteng provinces. The next high contributors to both inequalities were mother's education, means of transport and source of income. Achieving high school reduced uptake of HIV testing by a factor of 0.29 and reduced infant HIV exposure by a factor of 0.049 with pro-poor E(CI)s. Within means of transport, the strongest effect was from public transport users from which high pro-poor E(CI)s and regression coefficients were seen, although the regression coefficient for early HIV testing was not statistically significant. Source of income was the only high negative contributor implying that it effected a decrease in the E(CI)s of the outcome variables. Marital status and PMTCT knowledge had negligible contributions.

Disaggregation of inequalities by province

The highest overall contribution to inequalities was from underlying provincial disparities. Therefore we disaggregated the national data and recalculated the E(CI)s and outcome prevalence by province (Figures 1 and 2). Inter-provincial differences varied widely without any consistence between magnitudes of the outcome prevalence and wealth-related inequality. The highest pro-poor wealth-related inequalities for early uptake of HIV testing were observed in North West and Western Cape (E(CI)< -0.09) provinces whilst the highest pro-rich inequalities were in Northern Cape and Eastern Cape. KwaZulu Natal was the only province with a very high pro-rich inequality for infant HIV exposure (E(CI)=0.108). High pro-poor wealth-related inequalities were in Northern Cape, North West, Gauteng and Western Cape.

Table 3: Determinant associations with each outcome, wealth-related inequalities and contributions to wealth-related inequalities

(a) Early HIV testing			
Determinant	**Regression-decomposition coefficient**	**E(CI)**	**% contribution to wealth-related inequality**
Wealth Group (ref: lower 40%**)**			(total= 8.83)
middle	0.14	0.001	-1.75
higher 40%	-0.02	-0.004	10.58
Mother's Education (ref: Primary school**)**			(total = 27.53)
High school	-0.29*	-0.012	27.53
Income source (ref: Employed)			(total=-17.52)
Spouse	-0.34*	0.001	-1.94
Family member	-0.60*	-0.101	-25.41
Unstable/Grant	0.18	-0.004	9.82
PMTCT knowledge (ref: No)			
Yes	0.01	0.000#	-0.09
Marital Status (ref: Married/Cohabit)			
Single/widow/divorced	-0.01	0.000#	-0.3
Transport (ref: Own car)			(total=26.87)
Public transport	0.27	-0.012	32.84
Walked	0.21	0.002	-5.97
Province (ref: WC)			(total=54.69)
EC	-0.01	0.000#	-1.65
FS	-0.36*	-0.002	4.73
GP	-0.41*	-0.029	69.40
KZN	0.16	-0.008	17.07
LP	-0.42*	0.013	-30.51
MP	-0.25	0.001	-1.33
NC	0.22	0.002	-3.81
NW	-0.30*	0.000#	0.79

(b) Infant Exposure			
Determinant	**Regression-decomposition coefficient**	**RCI**	**% contribution to wealth-related inequality**
Wealth Group (ref: lower 40%**)**			(total=40.71)
middle	0.18*	0.001	-1.24
higher 40%	-0.14	-0.049	41.95
Mother's Education (ref: Primary school)			(total = 25.3)
High school	-0.49*	-0.020	25.30

Income source (ref: Employed)			(total=-10.00)
Spouse	-0.33*	0.001	-0.99
Family member	-0.56*	0.010	-12.69
Unstable/Grant	0.12	-0.003	3.68
PMTCT knowledge (ref: No)			
Yes	0.40*	0.001	-1.39
Marital Status (ref: Married/Cohabit)			
Single/widow/divorced	0.07	-0.001	1.58
Transport (ref: Own car)			(total=28.55)
Public transport	0.48*	-0.022	34.37
Walked	0.35*	0.003	-5.82
Province (ref: WC)			(total=15.24)
EC	0.25	-0.009	11.05
FS	0.52*	0.003	-3.60
GP	0.53*	0.038	-47.42
KZN	0.84*	-0.041	51.13
LP	0.04	-0.001	1.40
MP	0.60*	-0.001	1.72
NC	-0.15	-0.001	1.43
NW	0.32	0.000#	-0.47

*significant regression coefficient. #no wealth related inequality - 95% confidence interval includes zero. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West.

DISCUSSION

This work shows that early uptake of HIV testing and infant HIV exposure are affected by wealth-related inequality within the public health system in South Africa. There is improved uptake of self-initiated early HIV testing amongst mothers of relatively lower wealth groups, but a higher burden of infant HIV exposure amongst them. HIV testing services are now benefiting the poor in the country. This differs from countries like Burkina Faso, Kenya, Malawi and Uganda where self-initiated testing appeared more prevalent among higher wealth groups[27]. The reasons why uptake of HIV testing has become disproportionately lower among women in higher SES are unknown and need investigation. Overall, the wealth-related inequality scores are not very high, both less than 0.1, likely due to data being limited to public healthcare users alone. The wealthiest 20% in South Africa largely use private health facilities. However, obtaining significant inequality score within the public health facility users alone is of concern as it indicates that disparities exist even within the public health service. The majority of the population in the country uses these public health facilities hence efforts are needed to ensure that there is no inequity in PMTCT programs.

In decomposing determinant contributions, source of income was the only determinant whose underlying inequalities contributed to lowering the overall wealth-related inequalities of both outcomes. Depending on extended family member in particular, had very high negative decomposition regression coefficients indicating negative associations with both outcomes, which pulled the overall contribution to be negative. Not much detailed work has been reported regarding disparities between different income sources and the cross-sectional nature of this study limits our explanation for this observation. Women who reached High School had a reduced risk of HIV infant exposure and a relatively lower odds of testing early for HIV. The HIV testing result is contrary to observations reported in low-income countries[28 29]. However, it echoes improved service provision for marginalised populations in South Africa. Providing high school education could serve as a potential platform to increase HIV testing. Also, education about HIV-related health issues within communities and health facilities should be an ongoing process so that health outcomes improve equally between the well-educated and those who received little formal education. Even though knowledge about MTCT was significantly associated with infant HIV exposure, it had no influence on wealth-related inequality implying that national efforts on HIV education have not prioritised certain socioeconomic groups over others.

Transport contributed to increased wealth-related inequality with largest effect from public transport users. The E(CI) scores indicate that public transport users were largely from lower SES groups while those who walked were mostly from higher SES groups. This could indirectly reflect the distance from facilities which need to be travelled, wherein poorer communities live further away from health facilities while the least poor live closer to health facilities with walkable distances or choose to live far from services if they can afford private transport. The insignificant regression coefficients for HIV testing are due to a weak difference between those who walked and the rest. There were clear differences in the rate of both outcomes between those who owned cars and those who used public transport, leading to high contributions to inequality in both cases. This result raises the importance of community-outreach and mobile clinic programs especially in remote rural settings were accessibility of facilities is difficult. The recently introduced primary health care package which includes ward-based outreach teams to improve uptake and access to care should be implemented optimally.

Disaggregating the data by province revealed complex inter-province differences in both prevalence and wealth-related inequality of each outcome. A total of 5/9 provinces had negative E(RCI) scores for uptake of HIV testing indicating an improvement among women from lower SES ranking who were previously disadvantaged and still are in other Sub-Saharan countries[27 30]. Most (7/9) of the provincial wealth-related inequality scores for infant HIV exposure were also negative, emphasising the high burden of infant HIV exposure within lower SES sub-population. Within-country disparities in health indicators have also been observed elsewhere[6 11], and indeed show the need to begin shifting focus from average national targets alone to spatial sub-regional focus.

Limitations

One limitation of this study is that its findings are only valid for the South African population using public health facilities. Although inequalities are evident just within this population alone, inclusion of private healthcare users would give a clearer indication of the true inequality gap between the richest and the poorest in the country. An all-inclusive national demographic health survey would be needed for such information. Another limitation is lack of qualitative data to explain why the lower SES group preferable test for HIV earlier than the higher SES group for example. The nature of a cross-sectional study also limits any causality inferences like the possibility that low uptake of HIV testing among wealthier is due to low infant HIV exposure. Future studies will require time series and inclusion of qualitative data in order to answer these questions. Lastly the study was facility-based, but enrolled a nationally representative sample across all nine provinces of South Africa; we did not include mother and infants who were too poor to access health facility care. Thus we could have under-estimated the impact of poor socio-economic status amongst the poorest group. However, given that routine data estimate that 99% of livebirths attend health facilities for their 6 week immunisation we do not believe that this under-estimate significantly changes our overall estimate.

Conclusion

Low self-initiated early HIV testing prevalence (22%) and high infant HIV exposure (33%) in the sample are both a concern. However, self-initiated uptake of HIV testing among the lower SES group before pregnancy indicates good awareness of HIV among the economically disadvantaged and at the same time reveals inequity between the richer and poor. The unequally high infant HIV exposure amongst the poorer could be reflecting differences in risk behaviour choices or/and be a result of better uptake of HIV testing among the poorer. These observations clearly point to a need for targeted interventions. Community health workers and outreach teams, like in many low-middle income settings[29-32], can be used effectively for such interventions. Also, in a large country like South Africa, aggregated national-level estimates can conceal hotspot geographic areas by averaging across high risk and low risk areas yet policy makers using sub-geographical approaches could find better clues to eliminating health problems[33]. Therefore inequity along the PMTCT cascade needs to be evaluated at lower geographic levels followed by context-specific and targeted interventions in order to eliminate MTCT.

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Competing Interests

All authors declare no competing interests of any kind related to this work.

Ethics approval and consent to participate

The South African Medical Research Council Ethics Committee and the Centers for Disease Control and Prevention approved the final protocol for the PMTCT survey. Informed and written consent was obtained from participating mother/caregivers.

Data Sharing Statement

The data are bound by ethical and legal restrictions. To access the data of the South Africa's Prevention of Mother to Child Transmission Effective study, investigators that are not part of the study team should submit a concept proposal to Ameena Goga, MD, MS (South Africa Medical Research Council (MRC), Principal Investigator), Debra Jackson (University of the Western Cape/UNICEF, Principal Investigator) and Thu-Ha Dinh, MD, MS (US Centers for Disease Control and Prevention (CDC), Principal investigator) for approval. Investigators with an approved concept proposal must apply for guest researcher status to obtain access to a workstation and the data. Additionally they will need to complete data security and confidentiality training, and to sign data use and nondisclosure agreements. The data are not yet available in a stable public repository. Researchers who meet criteria to access the data should contact PI Ameena Goga at Ameena.Goga@mrc.ac.za .

Author's contribution

NKN conceptualised the manuscript aims, carried out the analyses & wrote the manuscript. CVM & NS trained and supervised the analyses methods, assisted with interpretation of the results and reviewed the manuscript drafts. AG contributed to conceptualising the manuscript aims and in writing and reviewing the manuscript drafts.

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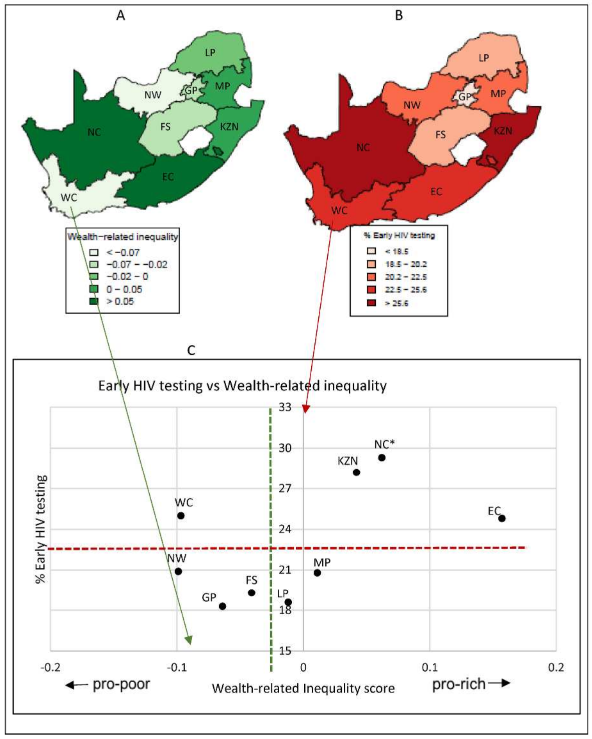
FIGURES LEGENDS

Figure 1: Provincial wealth-related inequality index versus uptake of early HIV testing

Wealth-related inequality index (A) versus (C) proportion of early HIV testing (B) per province; Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average early uptake of HIV testing on the y-axis. *small sample size for Northern Cape Province n<700.

Figure 2: Provincial wealth-related inequality index versus uptake of infant HIV exposure

Wealth-related (A) inequality index versus (C) proportions of HIV-exposed infants (B) per province. Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average infant HIV exposure on the y-axis. *small sample size for Northern Cape Province n<700.



Provincial wealth-related inequality index versus uptake of early HIV testing. ‼ ┼ Wealth-related inequality index (A) versus (C) proportion of early HIV testing (B) per province; Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average early uptake of HIV testing on the y-axis. *small sample size for Northern Cape Province n<700.

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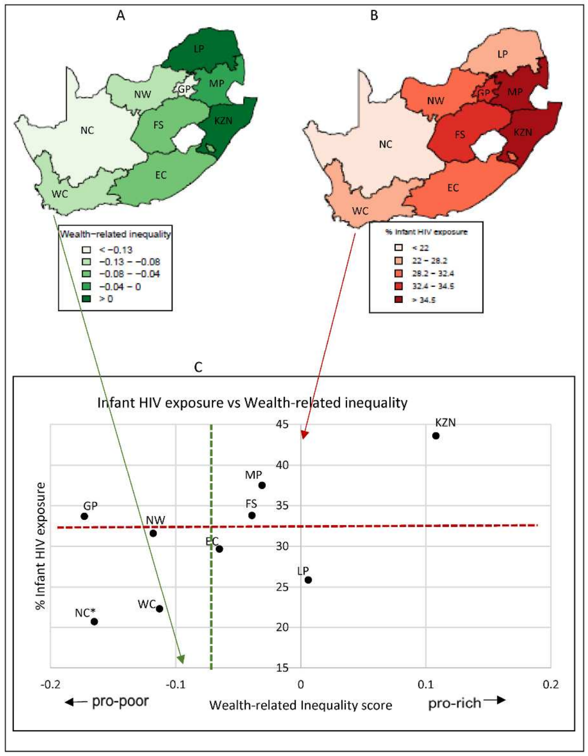

Provincial wealth-related inequality index versus uptake of infant HIV exposure. ‼ ┼ Wealth-related (A) inequality index versus (C) proportions of HIV-exposed infants (B) per province. Vertical dotted line marks the national E(CI) on the x-axis and the horizontal dotted line marks the national average infant HIV exposure on the y-axis. *small sample size for Northern Cape Province n<700.

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Wealth-related inequality in early uptake of HIV testing among pregnant women: An analysis of data from a national cross-sectional survey, South Africa

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Wealth-related inequality in early uptake of HIV testing among pregnant women: An analysis of data from a national cross-sectional survey, South Africa

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Keywords: wealth-related inequality, early HIV testing, pregnant women

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ABSTRACT

Objectives: Wealth-related inequality across the South African antenatal HIV care cascade has not been considered in detail as a potential hindrance to eliminating mother-to-child HIV transmission (EMTCT). We aimed to measure wealth-related inequality in early (before enrolling into antenatal care) uptake of HIV testing and identify the contributing determinants.

Design: Cross-sectional survey

Settings: South African primary public health facilities in 2012

Participants: A national-level sample of 8618 pregnant women

Outcome measures: Wealth-related inequality in early uptake of HIV testing was measured using the Erreygers concentration index further adjusted for inequality introduced by predicted healthcare need (i.e., need-standardized). Determinants contributing to the observed inequality were identified using the Erreygers and Wagstaff decomposition methods.

Results: Participants were aged 13 to 49 years. Antenatal HIV prevalence was 33.2%, of which 43.7% came from the lowest 40% wealth group. A pro-poor wealth-related inequality in early HIV testing was observed. The need-standardised concentration index was -0.030(95% confidence interval -0.038;-0.022). The proportion of early HIV testing was significantly better in the lower 40% wealth group compared to the higher 40% wealth group (p-value =0.040). The largest contributions to the observed inequality were from underlying inequalities in province (contribution=65.27%), age (-44.38%), wealth group (24.73%) and transport means (21.61%).

Conclusions: Our results on better early uptake of HIV testing amongst the poorer sub-population compared with the richer highlights inequity in uptake of HIV testing in South Africa. This socio-economic difference could contribute to fast-tracking EMTCT given the high HIV prevalence among the lower wealth group. The high contribution of provinces and age to inequality highlight a need to shift from reliance on national-level estimates alone but identify sub-regional specific and age-specific bottle-necks. Future interventions need to be context specific and tailored for specific sub-populations and sub-regional settings.

Strengths and Limitations of the study

- Although socio-economic inequalities are known to exist in South Africa, few studies have used analytical models to accurately measure wealth-related inequalities in early uptake of HIV testing among pregnant women on a large nationally-representative sample.
- The external validity of the study is restricted to public health-care users who are in the majority in South Africa hence the observed inequalities exclude the minority private health care users.
- This is a cross-sectional study and causality inferences about the observed results could not be ascertained but the observed associations were indicative of areas to be investigated in future.

BACKGROUND

In most low-middle income countries, unfair inequalities in health care are still a challenge[1 2]. Maternal and child health (MCH) is one health area that has received increased attention towards improved service coverage but wealth-related disparities remain[1 3 4]. Immunization, for example, has good coverage even in the poorer countries but wealth-related inequalities such as in immunization against measles have been reported[5]. High wealth-related inequality in skilled birth attendance is another example common in many low-middle income countries[3 5]. Such disparities in uptake of health services lead to the continuing problem of high child-mortality especially amongst the poorest[6].

Mathematical models have been developed specifically to give accurate measures of health inequalities due to disparities in wealth. The concentration index is one of the measures used in the study of socioeconomic inequality in health[7]. This index provides a measure of the extent of inequalities in health that are systematically associated with socio-economic status (SES). It reflects the experiences of the entire population (rather than just for example two classes) and it is sensitive to changes in the distribution of the population across socioeconomic groups[8]. A decomposition technique was further developed to enable researchers to unravel the causes of socioeconomic health inequalities[9]. Inequalities in the determinants of a health outcome also contribute to socioeconomic inequalities in the health outcome. The decomposition method allows assessing the relative importance of these different inequalities in generating inequalities in the health outcome[10].

Data gathered from prevention of mother-to-child transmission of HIV (PMTCT) services demonstrate that SES mostly affects the number of antenatal visits[3 11 12]. However, the effect of background SES on other parameters of the antenatal PMTCT cascade has not been widely studied. A 2011 study on a small South African sample employed the mathematical models of the concentration index and found pro-poor inequalities in infant mortality and HIV transmission to infants[13]. Socio-economic factors are well known to be driving forces behind health-related disparities in South Africa but the application of the concentration index to specifically display the extent of the disparities due to wealth has been minimal[2]. It becomes important to evaluate the potential impact of SES across the PMTCT cascade, using the appropriate methodology, at a time when countries have adopted targets to eliminate mother-to-child transmission of HIV (MTCT), to identify key sticking points and population groups for intervention.

Presently, although South Africa has more than 90% coverage of PMTCT services, the annual incidence of early vertical HIV transmission, measured at 6 weeks postpartum in 2013, was 2.5%, which was higher than the 2% target[14]. Maternal HIV prevalence has remained high (approximately 30%) and stagnant in the most recent years[14 15], due to improved uptake of antiretroviral treatment. This stagnant and high HIV exposure rate to unborn, new-born and breastfeeding infants hinder the complete elimination of mother-to-child transmission of HIV (EMTCT)[16]. The other challenge is the unequal health care system which is dualistically divided into public and private sectors. The majority (~68%) of the population use the public health care system which however is serviced by only 30% of the country's doctors and specialists[17]. The public sector has a three tier service provision system; the primary health care clinics and community health centres which serve as the first contact at no cost, for basic health and maternity care; these make referrals of complicated cases to the secondary level care – the district hospitals. Academic hospitals form the highest level and mostly serve more complicated healthcare needs. Reports of 2015, indicate a doctor-patient ratio of 1:>4000 in the public sector with still ~4% of the population living at least 5km away from the nearest health facility[18]. The private sector, smaller, comprises of private-practising healthcare professionals and private hospitals whose services are mainly remunerated through the medical aid schemes. Comparatively, the primary level of the public sector is mostly over-burdened and does experience sub-standard service provision while the private sector mainly offers high quality service. The government and some non-governmental organisations have expanded the number of primary health care clinics in an effort to decongest and improve the quality of public healthcare.

Improvements for maternal and child health care have been at the forefront of attempts to improve public health care, such as the recent revisions of the PMTCT consolidated guidelines[19].

Here we investigated wealth-related inequality as a potential barrier to eliminating MTCT within the public health system in South Africa. We evaluated the impact that SES background could have on one of the main entry point indicators of the PMTCT cascade, i.e., early uptake of HIV-testing. We further considered whether certain determinants contributed to the observed wealth-related inequality. Unpacking the SES disparities in PMTCT services could provide additional clues to eliminating MTCT within the public health care system.

METHODS

Data

A secondary analysis of data from a national cross-sectional survey conducted in 2012 to evaluate the South African PMTCT program, was conducted[20]. The methods have been explained in detail elsewhere[21]. In summary, the survey was conducted at public primary health care clinics and community health centres offering immunisation services countrywide. The primary aim was to measure national and provincial-levels MTCT amongst infants attending public health facilities for their 6 week immunisation. Infants with known and unknown HIV exposure were eligible for inclusion. The 6-weeks postpartum point was chosen because it has a 99% infant coverage for immunisation[22]. Antenatal HIV prevalence and presumed PMTCT coverage were used to estimate the sample size needed for each province at precisions of 30% to 50% and a design effect of 2. The national target sample size was 12 200, ranging between 700 and 1800 per province, proportional to provincial six week immunisation coverage. A two-stage probability proportional to size sampling approach was used. The first stage was at provincial level. In each province health facilities were stratified into medium (130-300 immunisations per year) and large (300 immunisations or more per year) facilities. Large facilities were further stratified into two groups - facilities in districts with antenatal HIV prevalence <29% or ≥29%, which was the 2009 national average antenatal HIV prevalence. Therefore facilities were grouped into three strata. The second stage was at health facility level: 580 facilities selected proportional to target facility sample size, were needed to achieve the desired provincial and national sample sizes. The target number of infants per facility was taken as the median number of infants expected in each facility within each stratum over a three week data collection period. Finally, caregiver-infant pairs were invited to enrol into the study during the 6-weeks immunization visit using either random or consecutive selection depending on facility size. Ultimately, 10533 infants were screened and 9120 provided both interview and infant blood data to measure MTCT. With respect to the data analysis for the primary outcome (6-week MTCT), sampling weights were calculated as the inverse of the realised sample size, accounting for South African live births, relative to the target sample size for each facility.

Consent to enrol into the study, to be interviewed and to take infant blood for laboratory HIV tests was sought from infant caregivers. Ethics approval was granted by the South African Medical Research Council Ethics Committee in 2009 (IRB identifier- FWA00002753). Information about socio-demographic characteristics and uptake of antenatal and PMTCT programs was collected through interviews. Two HIV tests were performed on the infants; (i) an enzyme-linked immunosorbent assay (ELISA) for passively transferred maternal anti-HIV antibodies to confirm maternal HIV infection and infant HIV exposure and (ii) an HIV total nucleic acid polymerase chain reaction to confirm infant HIV infection. The ELISA results for infant HIV exposure were used here as a proxy for antenatal HIV prevalence. Data from 8618 out of 9120 consented caregiver-infant pairs were used for analysis, the rest had missing information to establish socio-economic status.

The main outcome variable was binary: early uptake of HIV testing, i.e., self-initiated HIV testing before enrolment to antenatal care versus PMTCT program-influenced testing after enrolling into antenatal care during pregnancy. Independent variables with potential to influence inequality in the outcome were chosen, i.e., variables which can influence or be influenced by socio-economic background and at the same time can influence at least one of the outcomes: Education level, dichotomised as primary school and lower or high school and above was selected as education could influence attitudes towards the importance of healthcare; Marital status, dichotomised into single women (i.e., not married, not in a relationship, widows, divorced) and married (or co-habiting) women, was included as spousal support is likely to encourage uptake of healthcare; Transport to health facility categorised into own car, public transport and walking was included as a marker of ease of healthcare access, affecting the frequency and timing of uptake; Prior knowledge about PMTCT as either 'yes' or 'no' was included as prior knowledge can influence timing of HIV testing in relation to pregnancy; A categorical variable of the nine South African provinces was included as provincial differences in healthcare management and in cultural behavioural norms has been observed; lastly, source of income with four categories of women namely employed, dependent on extended family, dependent on spouse or partner and fourthly those with irregular sources of income such as government grants. The latter is not a good measure of household income but is a common structural division in South Africa, and it will be important to know whether and how it impacts on the primary outcome variables.

Three healthcare need-based variables were included, maternal age, a positive syphilis diagnosis result during pregnancy and a positive TB diagnosis result during pregnancy. These were used to predict and adjust for inequality due to differences in need for ill-health related healthcare, therefore allowing for a better prediction of inequality under equal needs. Age is not ill-health itself but different age groups have pre-existing differences in risk of ill-health which thus introduces inequity in need for healthcare.

Defining the socio-economic status

The wealth scores to measure socio-economic status were generated from household living conditions and household assets (i.e., house building material, sanitation, water, domestic fuel source and household appliances) using principal component analyses[23]. The wealth scores are only based on household assets because information on actual value of household income was not available. However these assets in the current South African context do give a good indication of wealth status.

Measuring wealth-related inequality

Wealth-related inequality measures were performed in R Statistical package v3.1.0 and in STATA SE 2013. Wealth-related inequalities were determined using the concentration index measure which has been described in detail elsewhere[24 25]. Briefly, the concentration index (CI) is used to measure wealth-related inequality and ranges from -1 to 1. It is calculated from twice the area under a curve (which is a relative measure of the co-variation between the health outcome and the SES ranking, formula shown in Equation 1), the concentration curve, which deviates from a line of equality (the diagonal straight line). Along this diagonal line, CI=0, meaning that there is no inequality caused by wealth differences, i.e., the distribution of the variable of interest across the SES groups is not influenced by wealth.

Equation 1: $CI = \frac{2}{\mu} cov(h,r)$

, in which *h* is the health outcome of interest, *r* the SES ranking and *μ* the mean of the health outcome. In this study for example *h* would be either 'early uptake of HIV testing' or 'infant HIV exposure'. A positive CI (and curve below the diagonal line) indicates that a variable is favourable among the higher wealth groups (the wealthy) otherwise it is more prevalent amongst the lower wealth groups (the poor, when the curve is above the diagonal line).

Contribution of determinant variables to wealth-related inequality can be calculated using a regression-based decomposition analyses shown in Equation 2.

Equation 2: $RCI = \sum_k \left(\frac{\beta_k \bar{x}_k}{\mu} \right) C_k$

, where for 1 to *k* determinant variables, β_k is the coefficient of a determinant variable, $\bar{x}_k$ the mean of the determinant, *μ* mean of the health outcome and C_k the concentration index of the determinant. An error term would also be included in equations 1 and 2 for continuous outcomes [24]. In this study, *k* would represent the six independent variables described earlier.

The concentration index formulas were initially designed for continuous variables therefore are limited in handling the bounded nature of binary variables. Since the outcome variable of this study was binary, we applied the commonly used Erreygers correction[26] on the CI (Equation 3) to correct for the linearity assumptions in the above equations.

Equation 3: *Erreygers correction E of the CI:* $E(CI) = \frac{CI \times \mu \times 4}{range(h)}$

, where *h* is the health outcome of interest and *μ* mean of the health outcome. Therefore in Erreygers correction, the concentration index of the health outcome is multiplied by 4 times the mean of the outcome, then divided by the range of the outcome. Similarly the wealth-related inequality decomposition by contributing determinant factors was adjusted using the Erreygers method (Equation 4)[9].

Equation 4: *Erreygers decomposition* = $E(RCI) = 4\left[\sum \beta_k C_k \bar{x}\right]$

The target strata sample sizes for the survey were not all fully attained hence all analyses were adjusted using appropriate sampling weights.

In order to accurately measure horizontal wealth-related inequality under equal needs, we used two approaches to adjust for need-based inequality measure. Firstly we included the healthcare need-defining variables- age, syphilis diagnosis during pregnancy and TB diagnosis during pregnancy in the decomposition analyses together with non-need variables, to generate a need-standardized concentration index.[24 27] Secondly we subtracted the concentration index defined by need variables alone (inequality due to need-predicted uptake) from the standard concentration index.

RESULTS

Sample characteristics and distribution of outcome variables

The study sample comprised women aged between 13 and 49 years, with most (44.3%) aged 13-24 years, 43.2% in the 24-34 years age-groups and 12.4% being 35 years and older. Many of them (85.6%) completed their primary education. Only 18.4% (95% CI 17.5-19.3) were employed, similar to 17.8% (16.9-18.7) dependent on extended family for income whilst the majority (52.9%) depended on their spouses/partner. A quarter of the sample reported to be legally married. A third, (33.2%) of the pregnant women were HIV positive, as determined by the ELISA tests for infant HIV exposure done at 6-weeks postpartum, of which 49.3% (1345) had early uptake of HIV testing. The distribution of HIV-positive women varied significantly by wealth groups, most (43.7%) were in the lower wealth group, followed by the higher wealth group (33.9%) then the middle wealth group (22.4%), p-value<0.0001.

Table 1 shows the distribution of early uptake of HIV testing by determinant variable. A total of 22.4% of the women had their first HIV test before enrolling into antenatal care. This early HIV testing appeared to be higher in the lower 40% wealth group (23.4%) compared with the higher 40% wealth group (20.6%), p=0.040. Compared to high school achievers, mothers with primary school education appeared to be better at testing early for HIV (p=0.0001). There was a significantly different distribution of early uptake of HIV testing between income groups and between provinces. Highest early HIV testing (31.4%) was observed among mothers with unstable income sources, seconded by employed mothers, while extended family dependents had the least.

Table 1: Proportion of early HIV testing by socio-demographic and need characteristics

Characteristic	**Early HIV testing = Yes**		**N**
	% (95% CI)	**p-value**	
Total	22.4 (21.4-23.4)		8618
Wealth groups		**0.040**	
Lower 40%	23.4 (21.8;25.0)		3411
middle	24.1 (22.0;26.3)		1753
higher 40%	20.6 (19.2;22.1)		3454
Mother's Education		**0.0001**	
Primary school	27.7 (25.1;30.5)		1277
High school	21.6 (20.5;22.6)		7341
Income source		**0.0001**	
Employed	25.9 (23.6;28.3)		1596

Spouse	21.2 (19.9;22.5)		4538
Family member	17.2 (15.3;19.4)		1543
Unstable/Grant	31.4 (28.2;34.7)		941
PMTCT knowledge		0.710	
No			
Yes	23.3 (19.0;28.3)		392
	22.4 (21.4;23.4)		8226
Marital Status		0.560	
Married/Cohabit	21.9 (20.1;23.8)		2257
Single/widow/divorced	22.6 (21.5;23.8)		6361
Transport		0.060	
Own car	17.8 (14.5;21.5)		498
Public transport	23.6 (22.0;25.2)		3171
Walked	22.1 (20.9;23.4)		4949
Province		**0.0001**	
WC	25.0 (22.6;27.7)		1141
EC	24.8 (22.0;27.8)		939
FS	19.3 (16.7;22.2)		811
GP	18.3 (16.4;20.4)		1595
KZN	28.2 (25.5;31.1)		1015
LP	18.6 (16.4;20.9)		1144
MP	20.8 (18.2;23.7)		822
NC	29.3 (25.0;34.0)		396
NW	20.9 (18.2;24.0)		755
Age*		**0.0001**	
13-24 years	13.3 (12.2;14.6)		3778
25-34 years	28.6 (27.0;30.2)		3761
35+ years	33.6 (30.6-36.8)		1079
Syphilis during pregnancy*		**0.0001**	
No	21.8 (20.8;22.8)		8372
Yes	44.8 (38.1;51.6)		246
Tuberculosis during pregnancy*		**0.0001**	
No	21.8 (20.9;22.8)		8396
Yes	46.4 (39.4;53.6)		222

The p-values are from the chi-squared tests for differences between sub-groups of a variable. Significant values at p<0.05 are in bold. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West. *Need variables

Wealth-related inequalities and decomposition of determinant variable contributions

The Erreygers' corrected concentration indexes, E(CI), are given in Table 2. The need-standardized E(CI) for taking the first HIV test before pregnancy was negative, -0.03, indicating a pro-poor inequality, i.e., early HIV testing is unequally common among women of lower SES ranking. Although the inequality adjusted by directly subtracting the need-based E(CI) from the standard E(CI) was slightly stronger, it was also similarly pro-poor.

Table 2: Erreygers-corrected Concentration indexes for early uptake of HIV testing

	E(CI)	95% CI
Actual Concentration index	-0.030	-0.053 ; -0.007
Need-predicted CI	0.027	0.015 ; 0.039
Actual minus need-predicted CI	-0.057	-0.068 ; -0.046
Need-standardized CI	-0.030	-0.038 ; -0.022

The concentration index for need-based use was positive (0.027) which indicates that expected health-care use given health care need is higher among those in the higher SES ranking compared to the poorer.

The contributions of secondary determinants to the need-standardised inequality are given in Table 3. Each contribution is measured from the underlying wealth-related inequality within the determinant alone (the E(CI) of the determinant) and the direct influence which the determinant has on the outcome (given by the decomposition regression coefficient). These final contributions were obtained from the need-standardized analysis. Even after adjusting for predicted need, E(CI) values for non-need variables were not zero indicating that horizontal inequity exists with respect to these variables. Province (65% contribution) and age (-44% contribution) were the highest contributors to wealth-related inequality in early HIV testing. Provincial results varied widely between provinces with highest contributions from the Limpopo and Gauteng provinces. Gauteng stood out with a very high pro-poor E(CI) of -0.133. The same two provinces as well as North West and Free State also had significant regression coefficients for association with early uptake of HIV testing. Among the age-groups, nearly all the contribution to inequality was from the 25-34 years age-group and being older than 24 in overall significantly increased the chances of early uptake of HIV testing compared to being 24 years old and younger. The E(CI)s for age-groups >24 years were both pro-rich. Age was the only high negative contributor implying that it effected a decrease in the E(CI)s of the outcome variable.

The next high contributors were wealth group (25%) and means of transport (22%). The highest wealth groups had a large effect on the contribution with a pro-poor E(CI) but the regression coefficients were not significant. Within means of transport, the strongest effect was from public transport users from which a high pro-poor E(CI) but none-significant positive regression coefficient were seen. . PMTCT knowledge had a very low contribution. Although source of income and marital status had low contributions to the observed inequality in uptake of HIV testing, being a grant recipient and being single significantly increased the chances of early uptake of HIV testing by a factor of 0.25 and 0.27 respectively. In addition, both had pro-poor E(CI)s.

In addition to age, syphilis and tuberculosis were the need variables. Both syphilis and tuberculosis had extremely low contributions to horizontal inequality in uptake of HIV testing. The E(CI) for tuberculosis was negligible and that for syphilis was very low and pro-poor. However, both had significant associations with uptake of HIV testing as shown by positive regression coefficients.

Table 3: Summary of need-standardized decomposition showing variable contributions to wealth-related inequality in early uptake of HIV testing

Determinant	Regression-decomposition coefficient	E(CI)	% contribution to wealth-related inequality
Wealth Group (ref: lower 40%**)**			(total= 24.73)
middle	0.09	0.002	-1.14
higher 40%	-0.05	-0.045	25.87
Mother's Education			
(ref: Primary school**)**			11.08
High school	-0.12	0.019	
Income source (ref: Employed)			(total=-8.10)
Spouse	-0.09	0.001	-0.49
Family member	-0.14	0.010	-5.61
Unstable/Grant	0.25*	-0.025	14.20
PMTCT knowledge (ref: No)			
Yes	-0.08	-0.001	0.52
Marital Status (ref: Married/Cohabit)			
Single/widow/divorced	0.27*	-0.016	9.39
Transport (ref: Own car)			(total=21.61)
Public transport	0.26	-0.048	27.16
Walked	0.25	0.010	-5.55
Province (ref: WC)			(total=65.27)
EC	0.04	-0.005	2.96
FS	-0.39*	-0.009	4.99
GP	0.46*	-0.133	75.52
KZN	0.15	-0.030	17.08
LP	-0.45*	0.056	-31.75
MP	-0.27	0.002	-1.40
NC	0.18	0.005	-3.02
NW	-0.34*	-0.002	0.89
NEED-VARIABLES:			
Age (ref: 13-24 years)			(total=-44.38)
25-34 years	1.02*	0.077	-44.03
35+ years	1.25*	0.001	-0.35
Had syphilis in pregnancy (ref: No)			
Yes	0.91*	-0.006	3.68
Had TB in pregnancy (ref: No)			
Yes	0.86*	0.000#	-0.01

*significant regression coefficient. #no wealth related inequality - 95% confidence interval includes zero. Provinces; WC- Western Cape, EC- Eastern Cape, FS- Free State, GP- Gauteng Province, KZN- KwaZulu Natal, LP- Limpopo Province, MP- Mpumalanga, NC- Northern Cape, NW- North West.

DISCUSSION

This work shows that early uptake of HIV testing was affected by wealth-related inequality within the public health system in South Africa during the 2012-2013 period. There is improved uptake of self-initiated early HIV testing amongst mothers of relatively lower wealth groups, but a higher burden of infant HIV exposure amongst them. HIV testing services are now benefiting the poor in the country. This differs from countries like Burkina Faso, Kenya, Malawi and Uganda where self-initiated testing appeared more prevalent among higher wealth groups[28]. The reasons why uptake of HIV testing has become disproportionately lower among women in higher SES are unknown and need investigation. Overall, the wealth-related inequality scores are not very high, both from the two methods of adjusting for need-introduced inequality are less than 0.1, likely due to data being limited to public healthcare users alone. The wealthiest 20% in South Africa largely use private health facilities. However, obtaining significant inequality score within the public health facility users alone is of concern as it indicates that disparities exist even within the public health service. The majority of the population in the country uses these public health facilities hence efforts are needed to ensure that there is no inequity in PMTCT programs.

In decomposing determinant contributions, with adjustment for healthcare need factors, the non-need variables showed influence towards wealth-related inequality in early uptake of HIV testing. Two of the three need variables, syphilis and tuberculosis had negligible inequality scores and contributions to overall inequality but were significantly associated with increased early uptake of HIV testing. These women probably already knew they were at high risk of HIV infection leading them to test for HIV prior to antenatal enrolment. However age was the only need variable with high contribution to the overall inequality and the only determinant whose underlying inequalities contributed to lowering the overall wealth-related inequality. This makes sense considering that the E(CI) scores for age alone were pro-rich, thus if age had no effect on uptake of HIV testing, then uptake of HIV testing among the poor would increase by 44%. The polarised uptake of health care in general between the adolescent or young mothers and women older than 24 years is currently a challenging problem in South Africa, for various HIV and healthcare activities, and requires urgent attention [29,30].

For non-need variables, being single or being a grant recipient showed significant associations with uptake of HIV testing which led to pro-poor inequality scores even though their contribution to overall inequality of HIV testing were small. Not much detailed work has been reported regarding disparities between different income sources and the cross-sectional nature of this study limits our explanation for this observation. Even though women who reached High School had a pro-poor inequality score, there was no significant association with the study outcome nor a high contribution to its inequality. The insignificant regression result for association of education with HIV testing is contrary to observations reported in other low-income countries[31,32]. In the South African general population, evidence from data in the period around the start of this survey, showed poor uptake of HIV testing among the less educated[33]. We see the similar difference here from the chi-squared test but our findings further confirm that this difference among antenatal women is not associated with wealth-related inequality. Knowledge about MTCT was also not significantly associated with wealth-related inequality for HIV testing implying that national efforts on HIV education have not prioritised certain socioeconomic groups over others.

Transport contributed to increased wealth-related inequality with largest effect from public transport users. The E(CI) scores indicate that public transport users were largely from lower SES groups while those who walked were mostly from higher SES groups. This could indirectly reflect the distance from facilities which need to be travelled, wherein poorer communities live further away from health facilities while the least poor live closer to health facilities with walkable distances or choose to live far from services if they can afford private transport. The insignificant regression coefficients for HIV testing are due to a weak difference between those who walked and the rest. There was a clear difference in uptake of HIV testing between those who owned cars and those who used public transport, leading to a high contribution to inequality. This result is impressive in that even though the poor rely on public transport and largely live further from health facilities[34], uptake of HIV testing is better among them. This is a progress worth to note as other countries battle with accessibility to healthcare for their populations [35 36].

There were clear differences between wealth groups. Being in the highest wealth group was associated with reduced early uptake of HIV testing. Although this was not significant, it supports its pro-poor inequality index and the positive contribution percentage. That is, the wealthier have comparatively lower uptake, and there is disproportionate inequality of uptake in favour of the poor, but if wealth group had no influence, then the observed unequal uptake among the poor would decrease by 26%. There were also evident differences in regression coefficients, inequality indexes and individual contributions between provinces, hence the very high overall contribution to overall inequality in uptake of HIV testing. In a large country like South Africa, aggregated national-level estimates can conceal hotspot geographic areas by averaging across high risk and low risk areas yet policy makers using sub-geographical approaches could find better clues to eliminating health problems[37]. Within-country disparities in health indicators have also been observed elsewhere[6 11], and indeed show the need to begin shifting focus from average national targets alone to spatial sub-regional focus. In regard to wealth-related inequality in uptake of healthcare, future work would need rural-urban disaggregation in order to identify the specific geospatial areas needing attention, as there is already evidence for rural-urban disparities in healthcare delivery and uptake[38 39].

We have used a need-standardized concentration index to present a better estimate of actual inequality in early uptake of HIV testing, by accounting for predicted inequality due to healthcare need. This approach is widely preferred in reporting horizontal inequity[40-42]. In addition we used Erreyger's corrected concentration index which attempts to improve the fit of the original concentration index algorithm meant for continuous outcomes, on a binary outcome. This Erreygers correction was suggested in the recent decade and not all studies with binary outcomes use this correction. Different methods to serve the same purpose have been discussed and none has been shown to be superior over the other[43]. Here we chose to adopt the Erreygers because it is strongly biased for country-level estimates and our survey was designed to report national-level estimates.

Limitations

One limitation of this study is that its findings are only valid for the South African population using public health facilities. Although inequalities are evident just within this population alone, inclusion of private healthcare users would give a clearer indication of the true inequality gap between the richest and the poorest in the country. An all-inclusive national demographic health survey would be needed for such information. Another limitation is lack of qualitative data to explain why the lower SES group preferable test for HIV earlier than the higher SES group for example. The nature of a cross-sectional study also limits any causality inferences like the possibility that low uptake of HIV testing among wealthier is due to low infant HIV exposure. Future studies will require time series and inclusion of qualitative data in order to answer these questions. There are clearly differences at sub-regional level but our data lack rural-urban location information which could have been useful in disentangling wealth-related geographical differences more accurately. Lastly the study was facility-based, but enrolled a nationally representative sample across all nine provinces of South Africa; we did not include mother and infants who were too poor to access health facility care. Thus we could have under-estimated the impact of poor socio-economic status amongst the poorest group. However, given that routine data estimate that 99% of livebirths attend health facilities for their 6 week immunisation we do not believe that this under-estimate significantly changes our overall estimate.

Conclusion

Low self-initiated early HIV testing prevalence (22%) and high infant HIV exposure (33%) in the sample are both a concern. However, self-initiated uptake of HIV testing among the lower SES group before pregnancy indicates good awareness of HIV among the economically disadvantaged and at the same time reveals inequity between the richer and poor. Taking from the observed distribution of infant HIV exposure in the sample, higher uptake of HIV testing among the poorer could be what was needed and could contribute to fast-tracking progress towards the EMTCT targets. Wealth group, age, transport and province were the largest contributors to wealth-related inequality in early uptake of HIV testing. The wealth group and transport results simply reflect the overall pro-poor biased uptake of testing while the results seen for age and province raise a need for interventions targeted at high risk age-groups and high-risk geographic settings. Therefore inequity along the PMTCT cascade needs to be evaluated at lower geographic levels followed by context-specific and targeted interventions in order to eliminate MTCT.

DECLARATIONS

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Competing Interests

All authors declare no competing interests of any kind related to this work.

Ethics approval and consent to participate

The South African Medical Research Council Ethics Committee and the Centers for Disease Control and Prevention approved the final protocol for the PMTCT survey. Informed and written consent was obtained from participating mother/caregivers.

Data Sharing Statement

The data are bound by ethical and legal restrictions. To access the data of the South Africa's Prevention of Mother to Child Transmission Effective study, investigators that are not part of the study team should submit a concept proposal to Ameena Goga, MD, MS (South Africa Medical Research Council (MRC), Principal Investigator), Debra Jackson (University of the Western Cape/UNICEF, Principal Investigator) and Thu-Ha Dinh, MD, MS (US Centers for Disease Control and Prevention (CDC), Principal investigator) for approval. Investigators with an approved concept proposal must apply for guest researcher status to obtain access to a workstation and the data. Additionally they will need to complete data security and confidentiality training, and to sign data use and nondisclosure agreements. The data are not yet available in a stable public repository. Researchers who meet criteria to access the data should contact PI Ameena Goga at Ameena.Goga@mrc.ac.za .

Author's contribution

NKN conceptualised the manuscript aims, carried out the analyses & wrote the manuscript. CVM & NS trained and supervised the analyses methods, assisted with interpretation of the results and reviewed the manuscript drafts. AG contributed to conceptualising the manuscript aims and in writing and reviewing the manuscript drafts.

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