Socioeconomic inequalities in child vaccination coverage in Tanzania over time: a decomposition analysis using the 2004/05, 2010 and 2015/2016 demographics and health surveys

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Background. Despite global strides to reduce child morbidity and mortality, the number of infant and child deaths from preventable causes in low-and middle-income countries remains unacceptably high. A cost-effective strategy to improve child health outcomes is through child vaccination and subsequent immunisation. Despite free child vaccination in the public healthcare sector in Tanzania, the country's vaccination rates have plateaued and remain concentrated among children from wealthier households.
Objective. To identify the factors contributing to inequality in childhood vaccination in Tanzania.
Methods. This retrospective study used secondary data from the Tanzania Demographic and Health Survey for 2004/05, 2010 and 2015/16. Inequalities were measured using the Erreygers' corrected concentration indices. These inequalities were then decomposed to gain a deeper understanding of the contributing factors.
Results. Child vaccinations are higher among children from wealthier households in Tanzania, and this disparity has intensified over time. Socioeconomic differences in wealth, residential locations, mass media exposure and maternal education have become increasingly important drivers of these inequalities among Tanzanians.
Conclusions. Socioeconomic divisions in Tanzania threaten to perpetuate inequalities in access to healthcare and subsequent health. Child vaccination should be provided equitably to all children regardless of their household's socioeconomic background. Moreover, efforts should be made to address these gaps between the vulnerable and the more privileged groups in society.

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In 2020, 5.041 million children under the age of 5 years lost their lives globally.[1] These deaths are disproportionately occurring in low-and middle-income countries (LMIC), with sub-Saharan Africa (SSA) accounting for 54% of these deaths.[1] In addition, the child mortality rate in SSA was 74 per 1 000 live births, which is double the global mortality rate of 37 per 1 000 live births.[1]

Child vaccination and subsequent immunisation are cost-effective strategies for preventing child mortality.[2] Complete basic vaccinations are estimated to prevent 2 to 3 million deaths among children under the age of five annually.[3] Vaccinations also hold important socioeconomic benefits for individuals and the broader society through gains in health, education and economic development.[4] While vaccinations decrease mortality among vaccinated children, they may also decrease infections and subsequent health consequences among unvaccinated community members.[5] There have been various initiatives to expand the coverage of child vaccination, including the Expanded Programme on Immunisation and the Global Alliance for Vaccine and Immunisation. It is reported that about 116 million (86%) infants globally were vaccinated against polio, diphtheria, tetanus, pertussis and measles in 2018.[6]

In Tanzania, the child mortality rate was estimated at 49 per 1 000 in 2020.[1] Although this figure is below the overall child mortality rate in SSA, it still falls short of the United Nations Sustainable Development Goal 3, which aims to reduce the child mortality rate to 25 per 1 000 by 2030.

Childhood immunisation programmes in Tanzania are still facing major challenges. Recent data show that the percentage of children aged 12 - 23 months who received all basic vaccinations has remained virtually unchanged between 2010 and 2015.[7] Socioeconomic inequalities in child vaccination coverage disproportionately affect the most vulnerable, specifically, in terms of urban-rural residence, variations in country regions (or zones), educational levels and wealth.[7] Disparities in childhood vaccination rates will lead to widened gaps in mortality and morbidity based on socioeconomic status, perpetuating and entrenching overall health inequalities. Therefore, programmes and policies geared toward addressing the challenges of childhood immunisation and its associated inequalities in the country are necessary. This requires a thorough understanding of the factors that contribute to inequality in childhood vaccination. Therefore, identifying the factors contributing to inequality in childhood vaccination in Tanzania is the objective of this study.

The few studies examining the barriers to vaccination in LMICs indicate that factors, such as maternal education,[8-11] household wealth and socioeconomic status,[8,12] exposure to media[10] and place of residence are associated with low levels of vaccination.[10,13] The likelihood of completing all basic vaccinations decreases with an increase in childbirth order.[13,14] In some countries, evidence suggests a sex bias in vaccination behaviour, with male children more likely to complete vaccinations compared with female children.[14,15]

Despite numerous studies conducted in developing countries,[8-10,12] there is limited evidence of child vaccination inequalities and the contributing factor among children aged 12 - 34 months in Tanzania. Therefore, in this study, we estimate the extent of wealth-related inequality in childhood vaccination and how it has changed over time. We also set out to establish the factors contributing to these inequalities. While previous studies have focused on the barriers to vaccination in Tanzania, the current study goes a step further by applying rigorous econometric techniques to gauge determinants and the contributing factors of wealth-related inequalities in childhood vaccination.

Methodology

This is a retrospective study using corrected concentration indices and decomposition analysis of secondary data obtained from three Tanzanian Demographic and Health Survey (TDHS) in 2004/05, 2010 and 2015/16 to examine inequality in child vaccination.

Data

The TDHS collects information on immunisation coverage for all children born in the five years preceding the survey. However, this study focused solely on basic vaccination information among living children aged 12 - 23 months. Only women aged 15 - 49 years with children under the age of five were eligible for questions on child vaccination. Information on vaccination coverage was collected from the children's health cards and verbal reporting from mothers. The TDHS uses a stratified two-stage cluster design, based on the 2002 (2004/05 and 2010 surveys) and 2012 (2015/16 survey) population and housing census, making it representative at both a national and residential (urban-rural) level. The final sample consisted of 1 613, 1 549 and 2 158 living children aged 12 - 23 months from the 2004/05, 2010 and 2015/16 surveys, respectively.

Variables

Dependent variable

A binary dependent variable was constructed, indicating whether the child had completed all basic vaccinations by the age of 12 - 23 months. Full basic vaccination according to the World Health Organization (WHO) recommendation include: one dose of Bacillus Calmette Guerin vaccine, three doses of DPT-HepB-Hib, three doses of polio vaccine and one dose of vaccine against measles. The binary variable is coded as one if children had completed all basic vaccinations at the time of the survey and zero if they had not.

Wealth variable

Measuring the wealth-related inequalities in vaccination rates requires a suitable variable to represent wealth. The household wealth index was created incorporating reported household assets and respondents' built environment, including dwellings, sources of drinking water and sanitation facilities. Principal component analysis was used in this process.[16] The wealth index is divided into five quintiles: poorest, poor, middle, rich and richest.

Independent variables

The dependent variables used in this study were derived from the WHO's Commission on Social Determinants of Health framework.[17] These include wealth, sex of the child (female or male), place of residence (rural or urban), zone of residence (Western, Northern, Central, Southern Highlands, Southern, South West Highlands, Lake, Eastern Zone or Zanzibar), childbirth order (1^{st}, 2^{nd}, 3^{rd} or $\geq 4^{th}$), maternal education (no education, primary, secondary or postsecondary schooling), maternal age (15 - 19, 20 - 34 or 35 - 49 years), household head sex (female or male) and exposure to the mass media (yes or no). The latter refers to whether the child's mother had access to radio, television, newspapers or magazines in the past week, and acts as a proxy for potential exposure to vaccination information.

Statistical analysis

A variety of statistical analyses were conducted in this study. The association between full basic child vaccination and its determinants was analysed using logistic regressions, and the adjusted odds ratios (aOR) were reported. The concentration curve and concentration index were used to quantify the degree and magnitude of wealth-related inequalities each year. The concentration index is a widely used measure of socioeconomic-related health inequality,[18,19] as it captures the extent to which health differs across individuals ranked by socioeconomic status. Finally, the concentration indices for each year were decomposed to explain the contribution of different socioeconomic predictors to the total inequalities.

A concentration index and concentration curve (CC) quantifies the degree of socioeconomic-related inequalities in vaccination rates. Due to the binary nature of the dependent variable, Erreygers's Corrected Concentration Index (EI)[20] was used to measure the wealth-related inequality in vaccination coverage among children aged 12 - 23 months. The EI is specified as follows:

$$EI(CV) = (1/n)\sum_{i=1}^{n}\{4CV_i(2R_i - 1)\} \quad (1)$$

Where n is the sample size, CV_i is the binary outcome variable (i.e., child vaccination) for child i and R_i is the fractional rank of child i by wealth index.[21] The EI is expressed as a value ranging between -1 and 1. A negative value indicates that the variable is concentrated among the poor and a positive value is the opposite. A value of zero indicates equality. The CC is a graphical representation of the EI and plots the cumulative percentage of the study sample ranked by their household wealth status (on the x-axis) against the cumulative percentage of the sample which has been vaccinated. If the curve is plotted above the line of equality (a 45° line), it indicates that the variable is disproportionately concentrated among the poor (similar to a negative concentration index value) and vice versa.

After calculating the EIs for each year, they are decomposed to establish the major socioeconomic and demographic factors which contribute to these inequalities in child vaccination. We draw on the Wagstaff, Van Doorslaer and Watanabe methodology[22] to conduct this decomposition. This entails calculating the linear relationship between childhood vaccination for child *i* and the set of explanatory variables (Equation).[2]

$$CV_i = \beta_o + \sum_{q=1}^{Q}\beta_q x_{iq} + \varepsilon_i \quad (2)$$

Where $x_{iq} x_{iq}$ is the set of *q* socioeconomic and demographic independent variables for child *i*, the $\beta_q \beta_q$ are the parameters or interest, and $\varepsilon_i \varepsilon_i$ is the error term. Based on equation,[2] the decomposition of the concentration index EI can be expressed as:

$$EI(CV) = 4(\sum_{q=1}^{Q}\beta_q \bar{x}_q C(x_q) + C_\varepsilon) \quad (3)$$

In equation 3, the decomposition of the EI of child vaccination is the summed product of various components, multiplied by 4. These components are the elasticity of factor x_q to changes in child vaccination (expressed as $\beta_q \bar{x}_q$,where x_q is the mean of x_q), the wealth-related inequality in factor x_q (expressed as C(x_q)) and the generalised concentration index of the error term (C_ϵ)

The analysis (equations (1) to (3)) is performed and reported for each year separately. The decomposition allows us to calculate the absolute and relative contribution of each factor x_q to the wealth-related inequality in child vaccination. We apply a robust bootstrapping technique at 500 replications to calculate the standard errors of these contributions.[23] The decomposition analysis uses a generalised linear model from the binomial family with a link function in its estimation.[24] While the full set of the decomposition analysis is reported in the supplementary material, the percentage contributions of factors x_q to EI are presented in graphs to ease interpretation and comparison. All statistical analyses were performed using Stata version 15 (StataCorp, USA). Clustering weighting is used, and results are reported at a 1%, 5% and 10% significance level.

Results

Descriptive statistics

Descriptive statistics are reported in Table 1. Data from 1 613 (2004/05), 1 549 (2010) and 2 158 (2015/16) children aged 12 - 23 months were analysed. In 2004/05, only 29% of the children had been vaccinated, which increased to 80% by 2010. The number of vaccinated children then remained at 80% between 2010 and 2015/16 (Table 1). Moreover, in 2015/2016, 79% of female children were fully vaccinated, whereas the corresponding figure was 81% for male children.

Determinants of child vaccination

The determinants of child vaccination across time periods are shown in Table 2. There was heterogeneity in the determinants of child vaccination over time. Although male children were found to be more likely to be vaccinated than female children, the distinction is only significant for the year 2015/2016. Being born second was associated with a higher likelihood of being vaccinated in 2004/05. In 2015/16, 2nd and ≥4th birth order was associated with a lower likelihood of vaccination compared with 1st birth order. Across time periods, maternal education was found to be a significant determinant of child vaccination. Indeed, women with primary education (2004 aOR 1.20, 2010 aOR 2.10*** and 2015/2016 aOR 1.53***) and secondary education (2004 aOR 1.03, 2010 aOR 2.56* and 2015/2016 aOR 1.57) had higher odds of vaccinating their children compared to those without education.

Household wealth status was also a determinant of child vaccination, with richer households more likely to vaccinate their children. The relationship was significant only for 2015/2016. The aORs for the wealth quintiles were as follows: poorer (aOR 1.36*), middle (aOR 1.91***), richer (aOR 1.81**) and richest (aOR 2.29**). Across time, we observe some variation in the odds of being vaccinated when living in a specific zone. However, the Western Zone was one of the worst performing zones across all time periods.

Wealth-related child vaccination inequalities

The CCs over time are presented in Fig. 1. The CCs lying below the line of equality indicate wealth-related inequality in access to all basic vaccination among children aged 12 - 23 months. This is true for all the years, 2004/05, 2010 and 2015/16. Access to all basic child vaccination is disproportionately higher among children from richer households compared with their counterparts from poor households. The figure also shows that the inequality in access to basic child vaccination has increased over time as the curves move further away from the line of equality.

The results from the CCs are verified by the results from the EIs presented in Table 3. The positive and statistically significant indices for 2010 and 2015/16 indicate a pro-rich distribution of children with full vaccination. The EI for 2004/05 shows a positive but insignificant difference in child vaccination by wealth status. Table 3 reveals that the wealth-related inequality in vaccination has become larger and more significant over time. Due to the insignificant EI for 2004/05, we only performed the decomposition analysis for 2010 and 2015/16.

Decomposition analysis

The percentage contributions of the various determinants to the inequality in child vaccination in 2010 and 2015/16 are shown in Fig. 2. The full set of results and their statistical significance are reported in Supplementary Material S1 (https://www.samedical.org/file/2157). In 2010, having access to media sources (43%), living in the Lake Zone (-25%), having maternal primary school level compared with no education (16%), residing in an urban area (14%), maternal age of 20 - 34 (12%) and a ≥4th birth order (10%), were the largest and significant contributors to wealth-related inequality in child vaccination.

Differences in access to media sources remained a significant and large contributor to wealth-related vaccination inequalities in 2015/16, contributing to 17% of the inequality. The same is true for urban-rural inequalities (contributing 22% in 2015/16 compared with 14% in 2010). Having a ≥4th birth order contributed 18% in 2015/16 compared with 10% in 2010. However, in contrast to 2010, wealth status made the most significant contribution to socioeconomic inequalities in full basic vaccination in 2015/16. Being in the richest wealth quintile 5 contributed 23% to wealth-related inequality in child vaccinations, whereas being in wealth quintile 4 contributed 12% (or 35% jointly).

Discussion

Tanzania has the second highest rates of childhood immunisation in the region,[25] after Burundi (85%), but higher than Kenya (71.8%), Uganda (57.4%) and Rwanda (43.1%).[8] However, the rate of vaccination among children aged 12 - 23 months has plateaued between 2010 and 2015/16 at ~80%, translating into one in five Tanzanian children missing full basic vaccination between 2010 and 2015.

The results from the logistics regressions show heterogeneity in the determinants of child vaccination over the study period. For instance, being a male child only became a significant contributor to the odds of being vaccinated by 2015/2016. This finding of male children being prioritised is similar to results from previous studies in India.[14,15] At a global level, gender inequality is negatively associated with full childhood immunisation,[26] and may reveal a worrisome trend of entrenched gender norms to the disadvantage of female children.

In 2015/2016, a child's birth order was found to be a significant determinant of the likelihood of vaccination, with the firstborn having a higher likelihood of being fully vaccinated. These results are similar across regions, and in line with studies from Ghana,[13] Nigeria[27] (both in West Africa) and India,[14] where there is also a negative probability of child vaccination with the increase in birth order. This could be attributed to heightened competition for parental care, limited resources in the family and the opportunity cost of time.[13]

The results from the logistics regression further support previous findings from East Africa,[8] sub-Saharan Africa[12] and India[11] that demonstrate a positive gradient between household socioeconomic status and the odds of a child being vaccinated. Richer households and more educated parents are more likely to vaccinate their children.

Table 1: Descriptive statistics of the TDHS 2004/05, 2010 and 2015/16

Variables	2004/05, *n* (mean)	2010, *n* (mean)	2015/16, *n* (mean)
Fully vaccinated			
Yes	460 (29)	1 244 (80)	1 724 (80)
No	1 153 (71)	305 (20)	434 (20)
Total	1 613(100)	1 549 (100)	2 158 (100)
Fully vaccinated children			
	fully vaccinated, *n* (mean)	**fully vaccinated, *n* (mean)**	**fully vaccinated, *n* (mean)**
Sex of the child			
Female	220 (28)	629 (80)	851 (79)
Male	240 (30)	615 (81)	873 (81)
Place of residence			
Rural	385 (29)	995 (79)	1 245 (77)
Urban	75 (28)	249 (87)	479 (88)
Birth order			
1	93 (28)	220 (85)	454 (86)
2	106 (32)	266 (85)	335 (81)
3	80 (32)	197 (81)	243 (80)
≥4	181 (26)	561 (77)	692 (76)
Media access			
No	103 (27)	275 (73)	296 (72)
Yes	357 (29)	969 (83)	1,428 (82)
Maternal education			
No education	105 (24)	266 (70)	301 (69)
Primary	322 (31)	807 (83)	1,004 (80)
Secondary	32 (25)	166 (90)	397 (91)
Higher	1 (9)	5 (100)	22 (92)
Maternal age, years			
15 - 19	68 (29)	143 (82)	229 (80)
20 - 34	318 (30)	837 (82)	1,117 (80)
35 - 49	74 (24)	264 (75)	378 (80)
Sex of household head			
Female	76 (32)	198 (79)	277 (82)
Male	384 (28)	1 046 (81)	1,447 (79)
Wealth index			
Poorest	100 (26)	232 (74)	327 (68)
Poorer	104 (32)	278 (77)	318 (75)
Middle	83 (27)	252 (77)	334 (82)
Richer	97 (28)	263 (87)	411 (86)
Richest	76 (30)	219 (88)	334 (91)
Zone of residence			
Western	40 (23)	89 (55)	163 (71)
Northern	32 (23)	92 (88)	130 (86)
Central	71 (33)	144 (84)	184 (88)
Southern highlands	48 (47)	82 (92)	137 (88)
Southern	28 (31)	63 (84)	69 (79)
South-West highlands	21 (15)	98 (73)	163 (69)
Lake	123 (35)	274 (79)	420 (74)
Eastern	44 (44)	128 (91)	188 (89)
Zanzibar	53 (18)	274 (84)	270 (87)

The findings from the concentration curve and index confirm that the likelihood of a child being fully vaccinated in Tanzania is concentrated among children from higher wealth-status households. The results show that although child vaccination rates improved over time, the wealth-related inequalities in child vaccination widened.

A significant contributing factor to wealth-related inequalities in childhood vaccination in 2010 and 2015/16 was the mother's access to media sources. Our results are comparable to the study

Table 2: Determinants of child vaccination over time in Tanzania

Variables	2004/05 aOR (SE)	2010 aOR (SE)	2015/16 aOR (SE)
Sex of the child			
Female		Reference category	
Male	1.11 (0.15)	1.26 (0.21)	1.30 (0.17)**
Place of residence			
Rural		Reference category	
Urban	0.892 (0.215)	1.45 (0.49)	1.37 (0.33)
Birth order			
1		Reference category	
2	1.54 (0.35)*	1.06 (0.32)	0.62 (0.14)**
3	1.32 (0.34)	0.68 (0.23)	0.84 (0.22)
≥4	1.32 (0.33)	0.74 (0.23)	0.61 (0.15)**
Media access			
No		Reference category	
Yes	0.93 (0.161)	1.45 (0.29)*	1.17 (0.19)
Maternal education			
No education		Reference category	
Primary	1.20 (0.20)	2.10 (0.40)***	1.53 (0.24)***
Secondary	1.03 (0.43)	2.56 (1.27)*	1.57 (0.44)
Higher	0.14 (0.16)*	0.03 (0.04)	1.37 (1.36)
Maternal age, years			
15 - 19		Reference category	
20 - 34	0.79 (0.19)	1.57 (0.48)	1.26 (0.29)
35 - 49	0.75 (0.23)	1.02 (0.38)	1.29 (0.38)
Sex of household head			
Female		Reference category	
Male	0.90 (0.16)	1.19 (0.27)	0.88 (0.17)
Wealth index			
Poorest		Reference category	
Poorer	1.17 (0.23)	1.08 (0.23)	1.36 (0.23)*
Middle	1.01 (0.22)	0.86 (0.21)	1.91 (0.37)***
Richer	1.23 (0.27)	1.29 (0.39)	1.81 (0.44)**
Richest	1.33 (0.43)	1.00 (0.43)	2.29 (0.78)**
Zone of residence			
Western zone		Reference category	
Northern zone	0.90 (0.25)	4.994(1.846)***	2.07 (0.63)**
Central zone	1.69 (0.41)**	4.34 (1.34)***	2.96(0.84)***
Southern highland zone	3.10 (0.89)***	5.885(2.645)***	2.114(0.666)**
Southern zone	1.54 (0.46)	5.07 (2.00)***	1.20 (0.39)
Southwest highland zone	0.67 (0.21)	1.73 (0.50)*	1.11 (0.31)
Lake zone	2.06 (0.46)***	2.697(0.649)***	1.09 (0.21)
Eastern zone	1.96 (0.62)**	8.61 (3.67)***	1.73 (0.51)*
Zanzibar zone	0.70 (0.21)	3.44 (1.03)***	1.86 (0.53)**
Constant	0.26 (0.08)***	0.40 (0.16)**	1.39 (0.47)
Observations	1 609	1 537	2 158

aOR = adjusted odds ratio; SE = standard error.
*$p<0.10$
**$p<0.05$
***$p<0.01$

in Ethiopia.[10] Mass media can be a useful way of providing information on vaccination, especially in areas where contact with the healthcare sector may be limited. It may also be effective in creating a positive disposition towards vaccination and dispelling false information regarding vaccination. Behavioural sciences have specifically focused on the heuristics and biases which may contribute to vaccine hesitancy. According to a study by Saleska and Choi,[28] negativity bias, relating to the fixation on negative information rather than positive information on vaccines, is a particularly significant contributor. Mass media campaigns

Table 3: Erreygers' corrected concentration index of wealth-related inequality in child vaccination

Variables	2004/05	2010	2015/16
Child vaccination	0.04 (0.04)	0.13 (0.03)***	0.17 (0.03)***
N	1 613	1 549	2 158

***$p<0.01$

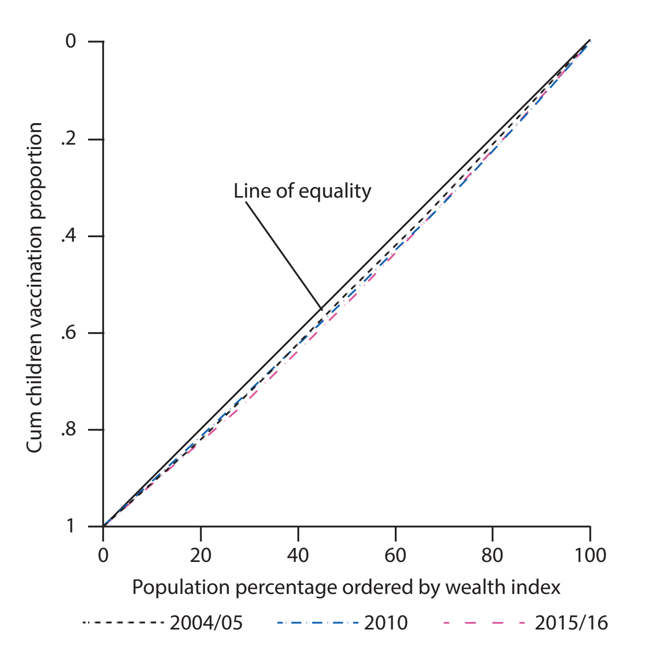

Fig. 1. Concentration curve for child vaccination status in 2004/05, 2010 and 2015/16. Source: Authors' computation from TDHS, 2004/05, 2010 and 2015/16.

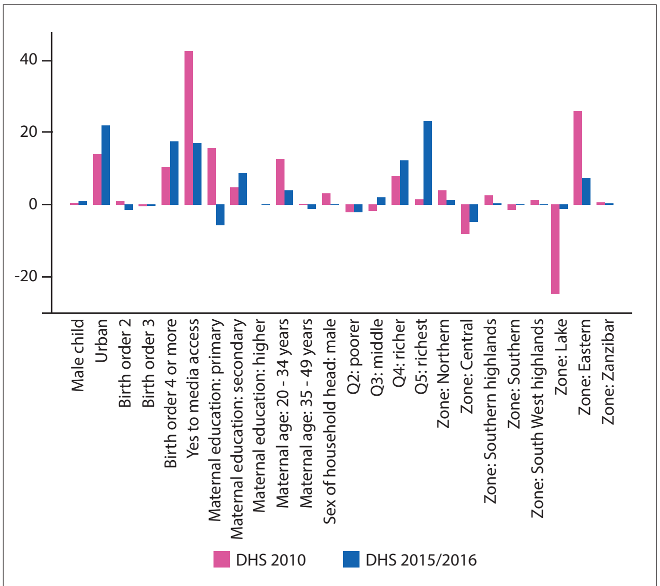

Fig. 2. Percentage contributions of determinants to wealth-related inequalities in child vaccination in 2010 and 2015/16.

reaching all sectors of society should target these perceptions to improve access to vaccines.

The difference in levels of maternal education is a significant contributor to wealth-related inequalities in vaccinations over time. These results are consistent with the findings from studies in Nigeria,[9] Ethiopia[10] and India.[11] Children whose mothers have no education are at a higher risk of missing basic vaccinations compared with their counterparts whose mothers have formal education. There are multiple mechanisms through which maternal education may influence childhood vaccination, including raising mothers' awareness, understanding and acquiring important health information and attitudes towards modern health services.[29] Maternal education may also be a proxy for other factors which may influence child immunisation rates, such as family background and community infrastructure.[30]

Household wealth status contributes significantly and increasingly to the persistence of inequalities in children's access to all basic vaccination. This is consistent with results in developing countries such as Nigeria,[9] India[15] and sub-Saharan Africa.[12] Given that vaccinations are free of cost in Tanzania, this relationship might be attributed to non-health services or indirect costs associated with getting vaccinated, such as the transport costs and ease of getting to the health facility. Urban residence as a significant contributor to widening wealth-related inequalities in vaccination confirms the important role of the socioeconomic division in vaccination inequalities. Similarly, previous studies in Ethiopia[10] and Nigeria[9] found that childhood vaccination is in favour of children residing in urban areas. This contradicts the study conducted in Ghana, which indicated changes in child vaccination from pro-urban to pro-rural.[13] This result may reflect the consequence of poor infrastructure in rural areas and long distances from homesteads to health facilities, which act as a barrier to reaching vaccination sites.

This study had several limitations. The decomposition analysis cannot explain the causality of different determinants of children's access to all basic vaccination. Moreover, the information collected from mothers regarding their children's vaccination records could be fraught with recall bias since not all children had vaccination cards and, therefore, the information was based on the mothers' verbal reports.

Conclusion

Inequalities in child vaccination by wealth status in Tanzania threaten to perpetuate existing health and wealth-related inequalities. While the Tanzanian child vaccination programme performs well relative to other countries in East Africa, our study showed that wealth-related inequalities in child vaccination have intensified between 2004/05 and 2015/2016. Intervention programmes should focus on ensuring that disadvantaged groups in society are prioritised to close the existing socioeconomic gaps in vaccination rates.

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