International Journal for Equity in Health

RESEARCH

Open Access

Exploring the association between multidimensional poverty and antenatal care utilization in two provinces of Papua New Guinea: a cross-sectional study

Olga P. M. Saweri[1,2*], William S. Pomat[1,2], Andrew J. Vallely[1,2], Virginia Wiseman[1,3†], Neha Batura[4†] and For the WANTAIM Study Group

Abstract

Background Although global poverty rates have declined in the last decade, the fall in the Asia-Pacific region has been slow relative to the rest of the world. Poverty continues to be a major cause of poor maternal and newborn health, and a barrier to accessing timely antenatal care. Papua New Guinea has one of the highest poverty rates and some of the worst maternal and neonatal outcomes in the Asia-Pacific region. Few studies have investigated equity in antenatal care utilization in this setting. We explored equity in antenatal care utilization and the determinants of service utilization, which include a measure of multidimensional poverty in Papua New Guinea.

Methods To explore the association between poverty and antenatal care utilization this study uses data from a ten-cluster randomized controlled trial. The poverty headcount, average poverty gap, adjusted poverty headcount, and multidimensional poverty index of antenatal clinic attendees are derived using the Alkire-Foster method. The distribution of service utilization is explored using the multidimensional poverty index, followed by multivariate regression analyses to evaluate the determinants of service utilization.

Results The poverty headcount was 61.06%, the average poverty gap 47.71%, the adjusted poverty headcount 29.13% and the average multidimensional poverty index was 0.363. Further, antenatal care utilization was regressive with respect to poverty. The regression analyses indicated that older women; being a widow (small number of widows ($n = 3$) asserts interpreting result with caution); or formally employed increase the likelihood of accessing antenatal care more often in pregnancy. Travelling for over an hour to receive care was negatively associated with utilization.

Conclusion This study indicated high levels of multidimensional poverty in PNG and that ANC utilization was regressive; highlighting the need to encourage pregnant women, especially those who are economically more vulnerable to visit clinics regularly throughout pregnancy.

[†]Virginia Wiseman and Neha Batura are joint last authors.

*Correspondence:
Olga P. M. Saweri
nsaweri@kirby.unsw.edu.au
Full list of author information is available at the end of the article

Background

Globally, 648 million people in 2019 were living in extreme poverty, or living on less than the equivalent of USD 2.15 (2017 purchasing power parity prices) per day [1]. The Asia-Pacific region has the largest share of impoverished people worldwide [2]. The most recent estimates show that in 2017, approximately 37.5% of the population in Papua New Guinea (PNG) were living on less than the equivalent of USD 2.15 (2017 purchasing power parity prices) per day [3] compared to 24.8% in Myanmar in 2017, 29.9% in Fiji in 2019, and 15.9% in Vanuatu in 2020 [4].

Studies show that ill-health is disproportionately concentrated among the poor [5]. Poverty not only causes ill health and limits access to health care; ill health can also be a major cause of poverty due, for example, to the costs of seeking health care and loss of income experienced by patients and their caregivers [5–7]. Equity analyses of health service utilization can help determine whether those who have a greater need for health care utilize services in a commensurate way [5, 8]. Further, equity analyses also help policymakers pinpoint the causes of inequity in healthcare and suggest innovations to reduce inequity [6, 8, 9].

Typically, equity analyses use the socio-economic or poverty status of individuals as a proxy for need [10–12]. Poverty describes the social and economic background of an individual or group of individuals, helping to reveal inequality within a given population [12, 13]. Traditional poverty measures tend to be unidimensional and use income, consumption expenditure, or proxies of these, to indicate the level of poverty that an individual or household experiences [14–18]. However, in many low- and middle- income countries (LMICs), such measures are not always stable in the short- to medium- run, and not considered to be an absolute determinant of the ability to support oneself or one's household [19]. Further, income- or consumption- based variables do not consider deprivation in non-monetary dimensions, (for example, education, access to hygienic sanitation, and safe drinking water). As a result, unidimensional measures often fail to recognize intra-cluster differences [12, 20, 21], especially in settings where the majority of the population may be "cash poor" [9, 13]. In contrast, measures of multidimensional poverty focus on both monetary and non-monetary deprivation [13, 20]. These more complex measures reflect the various sources of deprivation faced by individuals at the same time and demonstrate an individual's ability to support themselves and their families [12, 20]. It has been argued that a multidimensional approach to poverty, which includes measures of non-monetary poverty offers a more nuanced understanding of the determinants of health service utilization in many LMIC [22, 23].

Complications in pregnancy can be detected and subsequently mitigated when pregnant women access antenatal care (ANC) services. ANC comprises a comprehensive set number of consultations throughout pregnancy, as per the World Health Organization (WHO) guidelines [24]. The ANC policy in PNG is guided by the WHO global policy for ANC, recommending that pregnant women have at least four visits starting early in the second trimester [25]. ANC utilization is particularly low in PNG [26]. Annual average antenatal clinic attendance over the last decade has been approximately 50% for at least one visit and 30% for at least four visits throughout pregnancy [27]. Research conducted in several LMICs shows that the utilization of ANC services is associated with a range of financial, social, cultural, and geographical barriers, giving rise to inequities in maternal and neonatal health outcomes [14, 28–32]. Only a handful of studies focus on understanding the links between multiple dimensions of deprivation and ANC utilization [14, 29]. This is the first study aiming to estimate multidimensional poverty in PNG and to explore equity in ANC service utilization including whether multidimensional poverty is a determinant of service utilization in PNG. This study fills an important knowledge gap that could help shape interventions to enhance utilization of antenatal care, especially among those in greatest need.

Methods

Study setting

PNG comprises 22 provinces in four regions. Health services are primarily provided by government- and church-run health facilities decentralized at a provincial level [33]. Each province has primary healthcare facilities, which manage outpatients and minor admissions, and a single provincial hospital to manage general outpatients, and minor and major admissions. ANC is provided at nearly all health facilities; however, if complications arise, pregnant women are referred to the closest district/rural or provincial hospital for further assessment and care [34].

This study is nested within the Women and Newborn Trial of Antenatal Interventions and Management (WANTAIM); a 10 cluster-randomized cross-over trial in two provinces (East New Britain and Madang) in PNG [35]. The trial aims to determine if point-of-care testing and treatment for sexually transmitted and genital infections in pregnancy can reduce preterm birth and low birth weight [35]. The clusters consist of a health facility and its catchment population, and are a mix of urban, peri-urban, and rural locations. Recruitment of pregnant women occurs at the selected health facility in each

cluster. Trial participants are followed up throughout the remainder of their pregnancy, following birth, and up to 6 weeks after birth. Further details of the trial are available in the study protocols [35, 36].

Ethics

Ethical approval was granted by the Institutional Review Board (IRB) of the PNG Institute of Medical Research (PNGIMR) (IRB number 1608); the Medical Research Advisory Committee (MRAC) of the PNG National Department of Health (MRAC number 16.24); the Human Research Ethics Committee (HREC) of the University of New South Wales (HREC number 16708); and the Research Ethics Committee (REC) of the London School of Hygiene and Tropical Medicine (REC number 12009). Written informed consent was obtained from all trial participants.

Data sources

This study uses data from the case report forms (CRFs) administered to WANTAIM trial participants during their first antenatal clinic visit and each of their follow-up visits. The CRFs include questions on general health and well-being, obstetric history, as well as demographic and socio-economic information. The data comprises 4526 CRFs collected between 2017 and 2021 from participating antenatal clinic attendees in all 10 clusters. This analysis has 4474 observations and excludes 52 records due to incomplete information.

Analytical strategy

This analysis is a cross-sectional study and begins with estimating multidimensional poverty using the Alkire-Foster (AF) method [9], which classifies antenatal clinic attendees as either poor or not. Following the calculations of multidimensional poverty and the multidimensional poverty index (MPI), we depict how ANC utilization varies by the MPI to understand whether utilization is progressive (i.e., those with the greatest need, measured by multidimensional poverty, are utilizing ANC in proportion to their need) or regressive (i.e., those with the greatest need, are not utilizing ANC in proportion to their need). In this analysis, if utilization is progressive, we would expect to see that the least well-off pregnant women make more antenatal care visits than the best off pregnant women. In contrast, if utilization is regressive, we would expect to see that least well-off pregnant women make fewer visits than the best off pregnant women. Lastly, using the Andersen framework, which categorizes individual and contextual determinants of healthcare into predisposing, enabling, and need factors [29]; the determinants of ANC utilization are explored using ordinary least squares (OLS) regression analysis. The variables in these analyses are summarized below.

Variables

Multidimensional poverty

The AF method for estimating multidimensional poverty provides a general framework that can be adapted for application in different settings [13, 37]. The flexibility of the model means that contextual adaptations and parameter adjustments are made according to data availability [13, 37]. A detailed description of the framework and methodology can be found elsewhere [22].

The first step in measuring multidimensional poverty involves identifying indicators across three dimensions: standard of living, health, and education [9, 13]. Figure 1 presents the adaptation of the AF framework for this study. The white squares depict the indicators prescribed by the AF model and the grey are adaptations made for this study.

The second step is to assign a deprivation measure to each indicator comprising multidimensional poverty (see

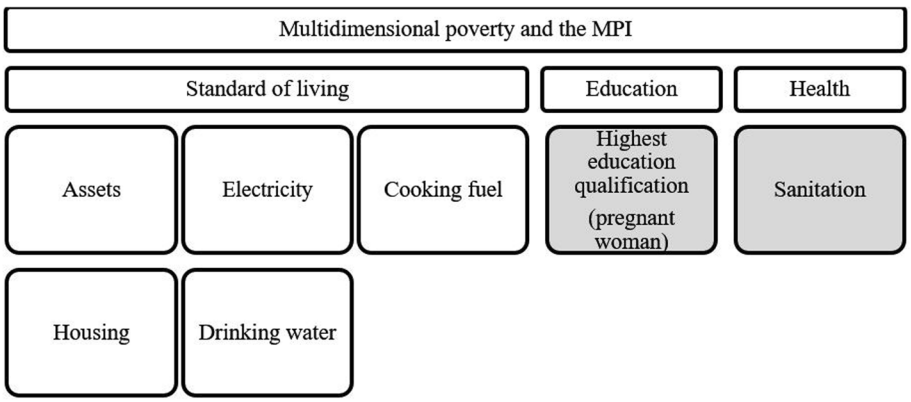

Fig. 1 Indicators estimating multidimensional poverty under the Alkire-Foster method

Table 1). The deprivation measure for each indicator is derived using the deprivation threshold [9, 22]. The deprivation threshold is defined as the cut-off point where an antenatal clinic attendee is identified as deprived or not per indicator (see Table 1) [13].

Using each deprivation threshold (see Table 1), poverty lines are applied and the number of deprived antenatal clinic attendees per indicator are counted. Multidimensional poverty is a deprivation measure, therefore poverty is determined by the number of indicators an ANC attendee does not have [9]. Specifically, when an antenatal clinic attendee is deprived of an indicator, the indicator takes the value of one (1), and when not deprived the value of the indicator is zero (0). Equal weights are then attached to each indicator [13, 22].

Next the proportion of multidimensionally poor antenatal clinic attendees is calculated using the cross-dimensional poverty threshold, K. K is the number of deprivations needed to determine whether an antenatal clinic attendee is poor [9]. K is commonly set at the global multidimensional poverty value of deprivation, which is a third of weighted indicators [19, 20, 22]. Thus, for this study K is set at 0.33; specifically, those facing more deprivations than K are considered multidimensionally poor [20, 22]. Using K, the headcount, H, which is an indicator of absolute poverty, is calculated. H is the fraction of the population that is considered poor when using K.

$$Headcount(H) = \frac{number\ of\ poor\ people\ (P)}{sample\ size\ (N)} \tag{1}$$

The penultimate step is to determine the average poverty gap, A. The average poverty gap is defined as the number of deprivations faced by poor antenatal clinic attendees on average [9] and is shown in Eq. (3). It is found by calculating the sum of deprivations divided by the number of poor people in the sample and enables the calculation of relative poverty.

$$Average\ poverty\ gap(A) = \frac{\sum_{n=i}^{d}\left(proportion\ of\ deprivations(d)_1 + d_2 + d_3 \cdots + d_{n=i}\right)}{P} \tag{2}$$

Lastly, the estimation of multidimensional poverty, or the adjusted headcount, M, is obtained by multiplying the headcount, H, by the poverty gap, A.

$$Adjusted\ Headcount(M) = H \times A \tag{3}$$

MPI

The MPI is a composite index; it is derived from the sum of all indicators given equal weights (see Table 1 for the list of indicators). Dividing the sum of all indicators by the total number of indicators ($n = 8$) produces the index, which has a value between 0 and 1. An antenatal clinic attendee that is deprived of all indicators will have an MPI of one, while an ANC attendee not deprived across all indicators has an MPI of zero.

$$MPI = \frac{\sum (Assets + Drink + Elec + Cook + Floor + Sanit + Toilet + Educ)}{8} \tag{4}$$

Table 1 Deprivation thresholds of the multidimensional poverty indicators

	Deprivation threshold
Dimension: Standard of living	
Assets[a]	Deprived if fewer than five household assets are owned
Drinking water	Deprived if water source is surface water (unimproved water source)
Electricity	Deprived if mains, generator, or biofuel are not used
Cooking fuel	Deprived if gas, an electric stove, wood, or biofuel are not used
Housing/floor material	Deprived if the house has no floor or has a natural floor
Dimension: Health	
Sanitation	Deprived if there is no toilet (defecates directly into the sea or bush)
Shared toilet facility	Deprived if toilet is shared or a communal toilet
Dimension: Education	
Highest level attained	Deprived if grade 8 not completed

[a] Assets include any of the following: mobile phone; radio; bicycle; motorcycle/ scooter; vehicle; boat; television; videocassette recorder; cassette/ cd/ dvd player; camera; stove; fridge; microwave; washing machine; fan(s); a solar water heater

Cook: Cooking fuel; Drink: Drinking water; Education: Highest educational attainment; Elec: Electricity; MPI: Multidimensional poverty index; Sanit: Type of sanitation; Toilet: Private, shared or public toilet.

Dependent variables

Determinants of ANC utilization are derived utilizing the Andersen framework for health care utilization [38]. The framework has been widely adapted for use in the ANC setting [29, 39], and conceptualizes utilization by several factors [20, 40]. For this study ANC utilization is measured using the number of antenatal clinic visits made throughout pregnancy.

Independent variables

The Andersen framework categorized independent variables as either predisposing, enabling, or need [29, 38]. Predisposing factors are pre-existing demographic and social characteristics of care seekers; enabling factors are the resources allowing individuals to seek care; and need factors are the conditions that drive individuals to seek care [29, 38]. Independent variables defined as predisposing in this study included the MPI, occupation of the antenatal clinic attendee, marital status, and age. Only one independent variable was categorized as an enabling factor, namely the distance to health facility. None of the independent variables included in this study are categorised as need variables.

Data analysis

Descriptive statistics were presented for the entire sample and by province. Multidimensional poverty was estimated for each attendee in the sample, and a Shapiro Wilk test for normality was conducted to check for skewness and kurtosis [41]. The regression analysis was conducted using bivariate and multivariate OLS regression models, accounting for clustering. Robustness checks were conducted (Appendix 3) to validate the regression results by using a household asset index and fortnightly household consumption expenditure, which are long- and short-term measures of poverty respectively [12]. Coefficients and p-values with a significance level of < 0.05 were used to interpret the results. For this study, all analyses were conducted using Stata version 13, StataCorp, TX, USA. Lastly, this study adheres to the STROBE guidelines for cross-sectional research (see Supplementary Appendix S2).

Results

Descriptive statistics

Table 2 presents the demographic characteristics of the sample by province. Most pregnant women had between five and seven antenatal clinic visits (45.55%); the proportion of visits was higher for East New Britain (51.53%) than Madang (39.84%). Most antenatal clinic attendees were aged 21–30 (61.18%); in Madang (59.72%) and in East New Britain (63.43%); most were married (93.67%); in Madang (92.84%) and East New Britain (94.55%). In East New Britain, most antenatal clinic attendees either completed grade eight (27.80%) or ten (24.55%), whereas in Madang, most either completed grade eight (25.86%) or did not complete 8 years of formal education (24.86%). For the time spent on usual activities, most antenatal clinic attendees were market vendors (60.82%) in both East New Britain (70.02%) and Madang (52.03%).

Table 2 also illustrates the proportion of antenatal clinic attendees deprived or not deprived according to the indicators that comprise the MPI. Irrespective of cluster, antenatal clinic attendees faced similar dimensions of deprivations. Most antenatal clinic attendees were deprived with respect to assets (81.54%) and cooking fuel (85.90%). However, attendees were not deprived with respect to drinking water (60.68%), electricity (75.37%), material used for house or floor (98.06%), the type of sanitation used (94.32%) and whether the toilet was shared (76.02%).

Multidimensional poverty

The headcount of poor antenatal clinic attendees was 61.06%, which means that given the cross-dimensional threshold of 0.33, 61.06% of the sample is poor. Using number of poor antenatal clinic attendees (or the headcount), an average poverty gap of 47.71% was determined. Using the average poverty gap, the adjusted headcount measuring relative poverty was 29.13%. The adjusted headcount reflects the severity of poverty as it combines both the incidence and intensity of poverty. A breakdown of the calculations is presented in Appendix 1.

Figure 2 illustrates the distribution of antenatal clinic attendees by the MPI. The MPI, as defined in the Methods section, can take a maximum value of 1 and a minimum value of 0. The MPI is a deprivation score, so therefore a lower MPI indicates a wealthier antenatal clinic attendee. Figure 2 illustrates that in this sample, the average MPI was 0.363, with a range of 0 to 0.875, and a standard deviation of 0.178 (the average, range and standard deviation are all estimated from the main dataset). Figure 2 illustrates that most antenatal clinic attendees face two to four deprivations out of eight, with MPIs ranging between 0.25 to 0.5. All antenatal clinic attendees that have an MPI of 0.375 or greater are considered poor, using the threshold K (see Table 6 in Appendix 1).

The number of antenatal clinic visits per person is explored to explore the relationship between ANC utilization and the MPI. First, the descriptive statistics of

Table 2 Descriptive statistics-frequencies and percentages of the study sample

	Total Sample N (%)	Madang N (%)	East New Britain N (%)	*P*-value
Number of participants	4474	2289	2185	
Antenatal clinic visits				0.000
Fewer than 4	1183 (26.44)	736 (32.15)	447 (20.46)	
4	945 (21.12)	535 (23.37)	410 (18.77)	
5–7	2038 (45.55)	912 (39.84)	1126 (51.54)	
8	213 (4.76)	70 (3.06)	143 (6.57)	
More than 8	95 (2.12)	36 (1.57)	59 (2.70)	
Age				0.000
16–20	827 (18.48)	492 (21.49)	331 (15.15)	
21–30	2737 (61.18)	1367 (59.72)	1386 (63.43)	
31–40	847 (18.93)	409 (17.87)	439 (20.09)	
41–50	41 (0.92)	19 (0.83)	22 (1.01)	
No age available	28 (0.63)	21 (0.92)	7 (0.32)	
Marital status				0.002
Single	197 (4.40)	127 (5.55)	70 (3.20)	
Married	4191 (93.67)	2125 (92.84)	2066 (94.55)	
Separated	53 (1.18)	26 (1.14)	27 (1.24)	
Divorced	2 (0.04)	-	2 (0.09)	
Widowed	3 (0.07)	1 (0.04)	2 (0.09)	
No marital status available	28 (0.63)	10 (0.44)	18 (0.82)	
Highest level of education (Pregnant woman)				0.000
Did not attend school	308 (6.88)	262 (11.45)	46 (2.11)	
Did not complete primary school	943 (21.08)	564 (24.64)	379 (17.35)	
Completed grade 8	1205 (26.93)	594 (25.95)	611 (27.96)	
Did not complete secondary school	298 (6.67)	163 (7.12)	135 (6.18)	
Completed grade 10	893 (19.96)	358 (15.64)	535 (24.49)	
Completed grade 12	346 (7.73)	154 (6.73)	192 (8.79)	
Completed tertiary education (tech. college/vocation/ university)	478 (10.68)	193 (8.43)	285 (13.04)	
Not available	3 (0.07)	1 (0.04)	2 (0.09)	
Main use of time (occupation)				0.000
Homemaker	462 (10.33)	367 (16.03)	95 (4.35)	
Subsistence farmer	437 (9.77)	244 (10.66)	193 (8.83)	
Market vendor (sells market produce)	2721 (60.82)	1191 (52.03)	1530 (70.02)	
Self-employed	164 (3.67)	96 (4.19)	68 (3.11)	
Formally employed	425 (9.50)	215 (9.39)	210 (9.61)	
Student	116 (2.59)	67 (2.93)	49 (2.24)	
Not Working	132 (2.95)	101 (4.41)	31 (1.42)	
Other	12 (0.27)	6 (0.26)	6 (0.27)	
Nothing listed	5 (0.11)	2 (0.09)	3 (0.13)	
Assets				0.000
Deprived	3648 (81.54)	1912 (83.53)	1736 (79.45)	
Not deprived	826 (18.46)	377 (16.47)	449 (20.55)	
Drinking water				0.000
Deprived	1755 (36.99)	1030 (45.00)	725 (33.18)	
Not deprived	2715 (60.68)	1255 (54.83)	1460 (66.82)	
Electricity				0.000
Deprived	1102 (24.63)	615 (26.87)	487 (22.29)	
Not deprived	3372 (75.37)	1674 (71.95)	1698 (77.71)	

Table 2 (continued)

	Total Sample N (%)	Madang N (%)	East New Britain N (%)	*P*-value
Cooking fuel				
Deprived	3843 (85.90)	1903 (83.14)	1940 (88.79)	
Not deprived	631 (14.10)	386 (16.86)	245 (11.21)	
Housing/floor material				0.001
Deprived	83 (1.86)	27 (1.18)	56 (2.56)	
Not deprived	4387 (98.06)	2258 (98.65)	2129 (97.44)	
Sanitation used				0.000
Deprived	254 (5.67)	200 (8.74)	54 (2.47)	
Not deprived	4220 (94.32)	2089 (91.26)	2131 (97.53)	
Shared toilet facility				0.000
Deprived	1045 (23.36)	618 (27.00)	427 (19.54)	
Not deprived	3401 (76.02)	1658 (72.43)	1743 (79.77)	

Table 1 in the Methods section illustrates the deprivation thresholds

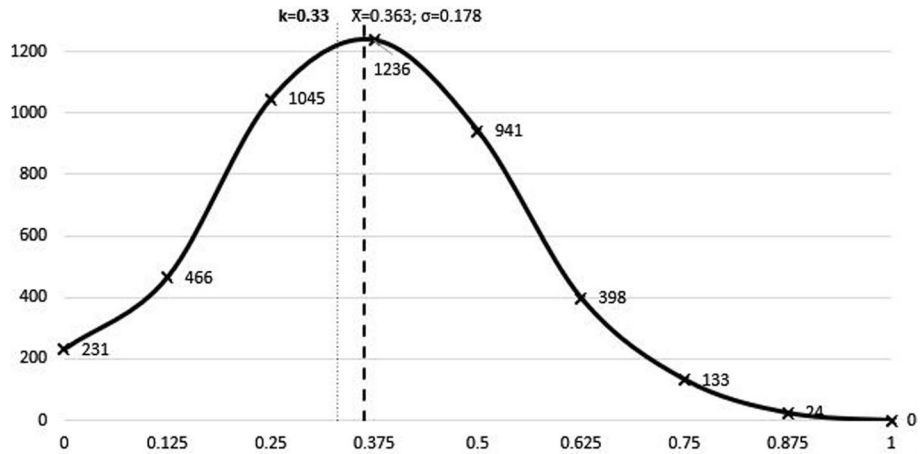

Fig. 2 Distribution of antenatal care attendees by the MPI

Table 3 The number of antenatal clinic visits by multidimensional poverty quartiles

Number of antenatal clinic visits	MPI quartiles			
	Q1 (best off)	Q2	Q3	Q4 (least well off)
Fewer than 4 (1–3 visits)	420	592	168	3
4	369	458	108	10
5–7	821	984	223	10
8	92	102	18	1
More than 8 (9-11 visits)	40	41	14	0

MPI Multidimensional poverty index, *Q* Quartile

the number of visits is demonstrated to summarise utilization. On average, the number of visits for women in our sample was 4.68 (standard deviation 1.85), and the minimum and maximum number of visits was 1 and 11, respectively. This indicates that ANC utilization is low; however, there are some women who attend more antenatal clinics than others.

Following the descriptive statistics, Table 3 explores whether the number of antenatal clinic visits made throughout pregnancy varies with the level of household poverty. Table 3 illustrates the number of antenatal clinic visits disaggregated by MPI quartile; Q1 represents the wealthy proportion of antenatal clinic attendees across the sample, and Q4 the poorest. The table shows that the poorest proportion of antenatal clinic attendees, who arguably have the greatest need to access healthcare, make fewer antenatal clinic visits relative to those that are wealthy, suggesting that service utilization is regressive. The number of deprivations faced by antenatal clinic

Table 4 Univariate OLS regression results: the relationship between MPI and ANC utilization

Variable	Coefficient (SE)	*P* > |t|	95% Confidence Interval
Robust OLS (un-clustered)[a]			
MPI	0.75 (0.158)	0.000	[0.438–1.056]
Robust OLS (clustered)[b]			
MPI	0.75 (0.333)	0.051	[0–1.500]

MPI Multidimensional poverty index, *OLS* Ordinary least squares, *SE* Standard error

[a] Number of observations: 4474; Prob > *F* 0.0000; *R*-squared: 0.0051, RMSE: 1.849

[b] Number of observations: 4472; Prob > *F* 0.0511; *R*-squared: 0.0052, RMSE: 1.8492

attendees in each quartile can be found in Table 7 in Appendix 2.

Regression analysis

Univariate regression

Table 4 presents the results of the univariate OLS. Both regressions illustrate a statistically significant (95% CI) relationship between MPI and ANC utilization i.e. the better off a pregnant woman is, the greater the number of antenatal clinic visits made throughout pregnancy. In the clustered OLS, the size of the coefficient and the size of the 95% confidence interval remains the same, however the standard error increased (from 0.158 to 0.333) and the *p*-value increased to from 0.000 to 0.051. The results of the robustness check using the household asset index echoed those of the MPI (see Table 8 in Appendix 3). The robustness check using

Table 5 Multivariate OLS regression results for the determinants of ANC utilization

Variable	Robust OLS (un-clustered)[a]			Robust OLS (clustered)[b]		
	Coefficient (S.E)	*P* > |t|	95% Confidence Interval	Coefficient (S.E)	*P* > |t|	95% Confidence Interval
MPI	0.59 (0.167)	0.000	[0.266–0.920]	0.60 (0.370)	0.142	[0–1.432]
Age						
16–20	Reference category					
21–30	0.36 (0.076)	0.000	[0.214–0.510]	0.36 (0.085)	0.000	[0.171–0.554]
31–40	0.66 (0.093)	0.000	[0.481–0.846]	0.66 (0.097)	0.000	[0.445–0.885]
41–50	1.13 (0.295)	0.000	[0.551–1.708]	1.13 (0.292)	0.004	[0.470–1.790]
Marital Status						
Single	Reference category					
Married	0.09 (0.137)	0.536	[0–0.355]	0.09 (0.113)	0.470	[0–0.342]
Separated	0.34 (0.284)	0.234	[0–0.893]	0.34 (0.285)	0.267	[0–0.982]
Divorced	1.64 (0.923)	0.075	[0–3.451]	1.64 (1.025)	0.144	[0–3.962]
Widowed	1.32 (0.471)	0.005	[0.392–2.239]	1.30 (0.565)	0.046	[0.025–2.582]
Main use of time						
Homemaker	Reference category					
Subsistence farmer	0.14 (0.123)	0.248	[0–0.383]	0.15 (0.185)	0.452	[0–0.383]
Market vendor	0.28 (0.913)	0.002	[0.104–0.462]	0.28 (0.148)	0.088	[0.104–0.462]
Self-employed	0.31 (0.162)	0.056	[0–0.628]	0.31 (0.170)	0.102	[0–0.628]
Formally employed	0.35 (0.127)	0.006	[0.101–0.597]	0.35 (0.126)	0.022	[0.101–0.597]
Student	0.11 (0.183)	0.541	[0–0.472]	0.11 (0.175)	0.537	[0–0.472]
Unemployed	0.24 (0.182)	0.179	[0–0.602]	0.24 (0.222)	0.300	[0–0.602]
Other[c]	-0.95 (0.565)	0.092	[0–0.156]	-0.95 (0.436)	0.057	[0–0.156]
Nothing stated	0.86 (0.960)	0.368	[0–2.746]	0.87 (1.011)	0.414	[0–2.746]
Time taken to get to health facility						
< 30 min	Reference category					
30–60 min	-0.05 (0.064)	0.414	[0–0.073]	-0.05 (0.074)	0.501	[-0.219–0.115]
> 60 min	-0.22 (0.078)	0.005	[0.370– -0.065]	-0.22 (0.095)	0.049	[0.430– -0.0007]

MPI Multidimensional poverty index, *OLS* Ordinary least squares, *SE* Standard Errors

[a] Number of observations: 4415; Prob > *F* 0.0000; *R*-squared: 0.0283, RMSE: 1.833

[b] Number of observations: 4413; *R*-squared: 0.0282, RMSE: 1.8333

[c] Other uses of time include pastoral duties, and baby sitting

fortnightly household consumption expenditure did not display a statistically significant (95% CI) result (see Table 10 in Appendix 3). This was expected as there was little variation in consumption expenditure, with 53% of the sample spending less than PGK100.00 in a fortnight.

Multivariate regression

Table 5 illustrates the multivariate OLS regression results. The results of the un-clustered OLS illustrated that the MPI; older age; being a widow (reference category single); and being a market vendor or formally employed (reference category being a homemaker) increases the likelihood of antenatal clinic attendance. Lastly, antenatal clinic attendees who travelled for more than an hour (reference category travelling less than 30 min) to get to a health facility were less likely to attend antenatal care. In comparison, when accounting for clustering, older age; being a widow; and being formally employed increases the likelihood of antenatal clinic attendance, while travelling for more than an hour decreases the likelihood of ANC utilization. The number of widows ($n = 3$) in the sample is small, therefore this result must be interpreted with caution. The MPI is no longer a statistically significant determinant of ANC utilization. Similar to the univariate robustness check, the regression results using a household asset index were statistically significant, while those using consumption expenditure were not (see Tables 9 and 11 in Appendix 3). This was expected as just over half the sample indicated spending less than PGK100.00 in a fortnight, and little variation with respect to household expenditure.

Discussion

This study is the first to explore poverty among antenatal clinic attendees, and its association with ANC utilization. The absolute poverty headcount was 61.1%; relative poverty was 29.1%; the average MPI was 0.363; and ANC utilization was found to be regressive. Further, older women, those who were widowed, and formally employed pregnant women were more likely to utilize ANC services; pregnant women travelling over an hour to reach a health facility were less likely to utilize ANC services.

The estimate of absolute poverty in this sample was almost double the most recent estimate for the proportion of the population in PNG living on less than USD2.15 (2017 purchasing power parity prices) per day [3]. The regressive nature of ANC utilization with respect to wealth reported in this study has also been reflected in several similar LMICs [29, 42–44].

The findings of this study echo those set in other LMICs where older pregnant women tend to make more antenatal clinic visits throughout pregnancy [29]. In contrast, previous studies in PNG find no association between age and ANC utilization [45, 46]. Older women utilising ANC more often than younger women can be due to older women are at greater risk of developing complications, or is a direct result of greater agency [40]. In this sample, widows were shown to be significant, but the result must be interpreted with caution given the small number of widows in this sample ($n = 3$). Findings from LMICs, including PNG, have not reported such findings, instead they commonly report that married women tend to access ANC services more often than unmarried women, including widows [15, 29, 46–48]. Women engaging in formal employment access ANC services more often than homemakers. Several studies in LMICs suggest ANC utilization is higher for formally employed women due to financial protection, including insurance, insulting them from potential shocks associated with out-of-pocket expenses on healthcare [48, 49], or have greater exposure and access to information encouraging ANC utilization [29]. In PNG, the main use of time has only been explored as a determinant of ANC utilization in one study [50]. Additionally, an investigation of ANC barriers and facilitators in PNG highlighted that despite understanding the need to access care, financial constraints hindered access [51].

In this study, travelling for over an hour was the only significant deterrent of antenatal clinic attendance. Common barriers in LMICs include transport costs, walking long distances, and the extended time taken away from normal activities [29, 44, 52–54]. In PNG distance plays an important role in accessing ANC services [45, 46, 50, 51, 55]. Commonly in PNG, distance is often a determinant in conjunction with other factors, such as transportation cost; time; motivation; and understanding the need to access care [45, 56, 57].

A key finding of this study was that antenatal clinic attendance was regressive; meaning that pregnant women in the 'least well off' quartile make fewer antenatal clinic visits compared to pregnant women in the 'most well off' quartile. This result illustrates that ANC utilization is not equitable, highlighting that there are gaps in the delivery and access of ANC services. Demand-side interventions have played an important role in addressing gaps in ANC utilization. For a long time, maternal and child health outreach programs supported the provision of ANC services through mobile clinics across PNG. However, without a consistent stream of funding these sorts of

programs cannot be sustained [58]. In addition, a user-fee exemption policy offering free primary health care, including ANC services, has been implemented countrywide since 2013. Systematic reviews indicated that fee-exemption policies may not completely mitigate the financial burdens associated with seeking care [29, 59]. Therefore, fee-exemption policies on their own may not be effective. Lastly, fee-waivers for supervised deliveries at health facilities have been implemented in PNG on an ad hoc basis [60]. Although directed at increasing the number of supervised deliveries at health centres, increased ANC utilization is a positive externality from this intervention. Despite these interventions, ANC utilization has remained far below the global average [27].

The findings of this study prompt several policy recommendations to address ANC utilization in addition to the currently implemented demand-side interventions. Several reviews have suggested various demand-side interventions, including health insurance (or financial risk protection); conditional cash transfer programs; and community-based education to improve ANC utilization [61–64]. Health insurance and conditional cash transfer programs increase utilization by covering the cost of accessing care, which eases the financial burden faced by pregnant women. Easing the financial burden increases the likelihood that a pregnant women will access ANC services [61–64]. Similarly, education programs improve pregnant women's understanding of the danger signs in pregnancy and the importance of ANC services, which stimulates access and increases ANC utilization. However, the financial sustainability of these programs need to be investigated to establish whether they are appropriate for implementation [49, 61, 65–67]. In addition, several systematic reviews suggest the need to address supply-side considerations to improve ANC service delivery to improve ANC utilization [63]. These include, increasing the number of qualified health workers delivering ANC services; and improving the quality of services. In short, the policies implemented should increase demand, complement existing policies, and be sustainable. Further, a combination of supply-side considerations and demand-driven programs are required to improve ANC utilization [52, 58, 68].

No study is without limitations. Firstly, ANC utilization is only measured by the total number of visits and does not include other potential measures such as overall uptake in the population and timing of the first visit. As all trial participants were antenatal clinic attendees, measuring overall uptake, i.e. whether a pregnant women accessed ANC services at all throughout pregnancy was not feasible. Further, participants initiated ANC at similar gestational ages, thus timing of the first visit was not used to measure ANC utilization. Further investigations of ANC utilization could include either or both measures in addition to the number of antenatal clinic visits made. Secondly, given that most of the sample population reside in rural areas, the sample may not be generalizable to the entire country. However, the results do provide a strong basis for understanding the ANC utilization in rural areas given that more than 80% of the population in PNG live in rural areas. Future research could consider looking at whether poverty varies across a larger sample and further explore the association between poverty and ANC utilization. Thirdly, in many LMIC settings common determinants of ANC utilization include the quality of care, whether a health facility is public or privately operated, cultural beliefs and other social factors [39, 69–71]. These variables were not collected for the trial and therefore not available for this analysis, which could result in a confounding variable issue, for example an omitted variable bias. Future studies could include measures of healthcare quality, a mix of public and private health facilities, as well as cultural beliefs and social factors around ANC utilization, to investigate whether poverty (or wealth) determines ANC utilization. Finally, this regression analysis did not include measures of need. Future research could include several need factors including qualitative variables discerning patients' need to access services; understanding complications and/or risks in pregnancy and quantifying them to expand the potential determinants of ANC utilization.

Conclusion

We found that there are high levels of multidimensional poverty in PNG, that ANC is not equitable, and that the utilization of ANC services is regressive. Further, older women and those who are formally employed are more likely to attend ANC care. Long distances to health facilities deterred service utilization. Finally, there is a need to address disparities in ANC utilization, perhaps through implementing demand-side interventions. These interventions include health insurance; conditional cash transfers; or community-driven programs that may encourage women, especially young women, to access ANC services.

Appendix 1

Appendix 1 illustrates the derivation of the headcount, average poverty gap and the adjusted headcount using the equations in the Methods section.

Table 6 The number of antenatal clinic attendees per multidimensional poverty used to calculate the poverty headcount (H), the average poverty gap (A) and the adjusted poverty headcount (M_0)

MPI	Number of deprivations (D)	Antenatal clinic attendees (N)[a,b,c]	Censored score[d]	Censored score× poor people (P)[e]
0	0	231	-	-
0.125	1	466	-	-
0.25	2	1045	-	-
0.375	3	1236	0.375	0.375×1236=463.5
0.5	4	941	0.5	0.5×941=470.5
0.625	5	398	0.625	0.625×398=248.75
0.75	6	133	0.75	0.75×133=99.75
0.875	7	24	0.875	0.875×24=21
1	8	0	1	1×0=0

Abbreviations: ***D*** Deprivations, ***K*** Cross-dimensional poverty threshold, ***MPI*** Multidimensional poverty index, ***N*** Number of antenatal clinic attendees (total sample size), ***P*** Number of poor people

[a] This column indicates the number of antenatal clinic attendees per MPI, the sum of the column is the total number of antenatal clinic attendees (***N*** = 4474)

[b] Shading in this table distinguishes between those that are classified as 'not poor' and 'poor' using the cross-dimensional poverty threshold, K, of 0.33

[c] The unshaded area indicates 'poor people' (P) given K = 0.33. The sum of antenatal clinic attendees in the unshaded area equals the total number of poor people (***P*** = 2732)

[d] An MPI below the K threshold indicates 'not poor', and this portion of the sample is 'censored', and thus not included in the calculations of the average poverty gap and the adjusted poverty headcount

[e] The censored score multiplied by the number of poor people by the number of deprivations faced equals the proportions of deprivations. The sum of the proportion of deprivations is the average poverty gap, A

First, we calculate the headcount (H):

$$H = \frac{P}{N}$$

$$H = \frac{(1236+941+398+133+24+0)}{(231+466+1045+1236+941+398+133+24+0)} = \frac{2732}{4474} \tag{5}$$

$$H = 0.6106$$

Second, we derive the average poverty gap (A):

$$A = \frac{\sum_{n=i}^{d} (proportion\ of\ deprivations)}{P}$$

$$A = \frac{\sum_{n=i}^{d} (censored\ score * P)}{P}$$

$$A = \frac{(0.375*1236)+(0.5*941)+(0.625*398)+(0.75*133)+(0.875*24)+(1*0)}{2732} \tag{6}$$

$$A = \frac{1303.5}{2732}$$

$$A = 0.4771$$

Lastly, we calculate the adjusted headcount (M_0):

$$\begin{aligned} M_0 &= H * A \\ M_0 &= 0.6106 * 0.4771 \\ M_0 &= 0.2913 \end{aligned} \quad (7)$$

Appendix 2

Appendix 2 depicts the number of deprivations faced by antenatal clinic attendees per multidimensional poverty quartile.

Table 7 The number of deprivations faced by antenatal clinic attendees per multidimensional poverty quartile

MPI	Deprivations faced	Q1 (best off)	Q2	Q3	Q4 (worst off)
0	0	231			
.125	1	466			
.25	2	1045			
.375	3		1236		
.5	4		941		
.625	5			398	
.75	6			133	
.875	7				24
1	8				0

ANC Antenatal care, ***MPI*** Multidimensional poverty index, ***Q1*** Quartile 1, ***Q2*** Quartile 2, ***Q3*** Quartile 3, ***Q4*** Quartile 4

Appendix 3

Appendix 3 depicts the robustness check for the OLS regression analysis. The purpose of the robustness check is to verify that the MPI is a robust independent variable. It comprises of two parts using two independent variables, namely a traditional asset index and household consumption expenditure. Each part starts with the univariate regression results showing both un-clustered and clustered results, followed by the multivariate regression results. Tables 8 and 9 illustrate the results of using the traditional asset index while Tables 10 and 11 highlight the results of using household consumption expenditure. The results of both robustness checks are similar to the analysis conducted for this paper. Thus, confirming the robustness of this study's results.

Table 8 Univariate OLS regression result using a traditional asset index

Variable	Coefficient (SE)	*P*> |t|	95% Confidence Interval
Robust OLS (un-clustered)[a]			
Asset Index	0.87 (0.206)	0.000	[0.465–1.274]
Robust OLS (clustered)[b]			
Asset Index	0.75 (0.333)	0.039	[0.056–1.683]

OLS Ordinary least squares, ***SE*** Standard error

[a] Number of observations: 4474; Prob > ***F*** 0.0000; ***R***-squared: 0.0041, RMSE: 1.85

[b] Number of observations: 4472; Prob > ***F*** 0.0387; ***R***-squared: 0.0041, RMSE: 1.8502

Table 9 Multivariate OLS regression results using a traditional asset index

Variable	Robust OLS (un-clustered)[a]			Robust OLS (clustered)[b]		
	Coefficient (S.E)	*P* > |t|	95% Confidence Interval	Coefficient (S.E)	*P* > |t|	95% Confidence Interval
Asset index	0.70 (0.217)	0.001	[0.275–1.125]	0.70 (0.393)	0.109	[0–1.592]
Age						
16–20	Reference category					
21–30	0.38 (0.076)	0.000	[0.229–0.526]	0.38 (0.081)	0.001	[0.195–0.562]
31–40	0.67 (0.093)	0.000	[0.487–0.852]	0.67 (0.098)	0.000	[0.449–0.892]
41–50	1.13 (0.295)	0.000	[0.548–1.703]	1.13 (0.294)	0.004	[0.461–1.789]
Marital Status						
Single	Reference category					
Married	0.09 (0.137)	0.533	[0–0.355]	0.09 (0.114)	0.467	[0–0.343]
Separated	0.36 (0.282)	0.208	[0–0.908]	0.36 (0.281)	0.238	[0–0.991]
Divorced	1.69 (0.918)	0.066	[0–3.491]	1.69 (1.024)	0.133	[0–4.007]
Widowed	1.32 (0.498)	0.008	[0.348–2.300]	1.32 (0.593)	0.052	[0–2.665]
Main use of time						
Home-maker	Reference category					
Subsist-ence farmer	0.13 (0.123)	0.248	[0–0.372]	0.13 (0.183)	0.481	[0–0.549]
Market vendor	0.27 (0.091)	0.003	[0.096–0.453]	0.27 (0.143)	0.086	[0.–0.597]
Self-employed	0.31 (0.162)	0.056	[0–0.629]	0.31 (0.176)	0.111	[0–0.707]
Formally employed	0.35 (0.127)	0.006	[0.101–0.598]	0.35 (0.124)	0.021	[0.067–0.630]
Student	0.12 (0.183)	0.512	[0–0.480]	0.12 (0.177)	0.513	[0–0.520]
Unem-ployed	0.24 (0.182)	0.188	[0–0.595]	0.24 (0.217)	0.299	[0–0.729]
Other[c]	-0.97 (0.562)	0.084	[0–0.132]	-0.97 (0.448)	0.058	[0–0.041]
Nothing stated	0.82 (0.942)	0.383	[0–2.667]	0.82 (1.009)	0.436	[0–3.103]
Time taken to get to health facility						
< 30 min	Reference category					
30–60 min	-0.05 (0.064)	0.400	[0–0.0710]	-0.05 (0.072)	0.475	[0–0.109]
> 60 min	-0.23 (0.078)	0.004	[-0.377–-0.065]	-0.22 (1.03)	0.058	[0–0.009]

OLS Ordinary least squares, ***SE*** Standard Errors

[a] Number of observations: 4415; Prob > ***F*** 0.0000; ***R***-squared: 0.0278, RMSE: 1.8335

[b] Number of observations: 4413; ***R***-squared: 0.0282, RMSE: 1.8333

[c] Other uses of time include pastoral duties, and baby sitting

Table 10 Univariate OLS regression result using household consumption expenditure

Variable	Coefficient (SE)	*P*> |t|	95% Confidence Interval
Robust OLS (un-clustered)[a]			
Consumption	0.0003 (0.0002)	0.094	[0–0.0006]
Robust OLS (clustered)[b]			
Consumption	0.0003 (0.0002)	0.264	[0–0.0007]

OLS Ordinary least squares, ***SE*** Standard error

[a] Number of observations: 4446; Prob > ***F*** 0.0942; ***R***-squared: 0.0007, RMSE: 1.8527

[b] Number of observations: 4444; Prob > ***F*** 0.2645; ***R***-squared: 0.0007, RMSE: 1.8529

Table 11 Multivariate OLS regression results using household consumption expenditure

Variable	Robust OLS (un-clustered)[a]			Robust OLS (clustered)[b]		
	Coefficient (S.E)	*P* > |t|	95% Confidence Interval	Coefficient (S.E)	*P* > |t|	95% Confidence Interval
Consumption	0.00005 (0.0001)	0.749	[0–0.0003]	0.00005 (0.0002)	0.831	[0–0.0005]
Age						
16–20	Reference category					
21–30	0.37 (0.076)	0.000	[0.214–0.510]	0.37 (0.082)	0.001	[0.185–0.558]
31–40	0.66 (0.094)	0.000	[0.481–0.846]	0.67 (0.100)	0.000	[0.438–0.893]
41–50	1.13 (0.296)	0.000	[0.551–1.708]	1.13 (0.293)	0.004	[0.464–1.789]
Marital Status						
Single	Reference category					
Married	0.09 (0.138)	0.526	[0–0.357]	0.09 (0.112)	0.455	[0–0.342]
Separated	0.33 (0.282)	0.247	[0–0.880]	0.33 (0.285)	0.281	[0–0.971]
Divorced	1.68 (0.945)	0.075	[0–3.536]	1.68 (1.061)	0.147	[0–4.084]
Widowed	1.37 (0.471)	0.004	[0.452–2.297]	1.37 (0.564)	0.037	[0.100–2.650]
Main use of time						
Home-maker	Reference category					
Subsistence farmer	0.11 (0.124)	0.394	[0–0.348]	0.11 (0.184)	0.570	[0–0.524]
Market vendor	0.25 (0.092)	0.006	[0.071–0.432]	0.25 (0.134)	0.093	[0–0.554]
Self-employed	0.33 (0.163)	0.041	[0.014–0.653]	0.33 (0.163)	0.083	[0–0.719]
Formally employed	0.40 (0.127)	0.002	[0.148–0.646]	0.40 (0.134)	0.016	[0.093–0.701]
Student	0.17 (0.186)	0.362	[0–0.535]	0.17 (0.156)	0.304	[0–0.522]
Unemployed	0.28 (0.184)	0.133	[0–0.637]	0.28 (0.201)	0.203	[0–0.731]
Other[c]	-0.92 (0.577)	0.110	[0–0.209]	-0.92 (0.447)	0.069	[0–0.088]
Nothing stated	0.71 (0.922)	0.439	[0–2.521]	0.71 (1.006)	0.496	[0–2.990]
Time taken to get to health facility						
< 30 min	Reference category					
30–60 min	-0.07 (0.063)	0.259	[0–0.053]	-0.07 (0.076)	0.373	[0–0.101]
> 60 min	-0.26 (0.077)	0.001	[-0.411–-0.108]	-0.26 (0.111)	0.046	[-0.509–-0.007]

OLS Ordinary least squares, ***SE*** Standard Errors

[a] Number of observations: 4388; Prob > ***F*** 0.0000; ***R***-squared: 0.0250, RMSE: 1.8354

[b] Number of observations: 4386; Prob > ***F*** 0.0000; ***R***-squared: 0.0250, RMSE: 1.8357

[c] Other uses of time include pastoral duties, and baby sitting

Abbreviations

ANC	Antenatal Care
LMIC	Low- and Middle- Income Country
MPI	Multidimensional Poverty Index
OLS	Ordinary least square
PNG	Papua New Guinea
Q	Quartile
RMSE	Root mean squared error
WANTAIM	Women and Newborn Trial for Antenatal Intervention and Management
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12939-024-02241-0.

Supplementary Material 1.

Supplementary Material 2.

Acknowledgements

We thank the women who participated in the WANTAIM Trial and the male partners, families and communities who supported them; the WANTAIM Trial Steering Committee, and Data and Safety Monitoring Committee; and the WANTAIM Study Group of trial investigators (see supplementary file, S1) and project staff. Further, we thank the National Department of Health, and the provincial and church health authorities. Lastly, we acknowledge the PNGIMR for administrative and technical support provided.

Authors' contributions

OPMS, AJV, VW and NB conceptualized the study, study design and methodology. OPMS collated the dataset, conducted the analysis, and drafted the manuscript. WSP, AJV, VW and NB supported data analysis and critically reviewed the manuscript. OPMS, WSP, AJV, VW and NB made key intellectual contributions to the development of the manuscript, including editing, and revisions, and have read and approved the final manuscript.

Funding

WANTAIM is a partnership of academic and governmental institutions in Papua New Guinea, Australia, and Europe. The trial is funded by a Joint Global Health Trials award from the UK Department for International Development, the UK Medical Research Council, and the Wellcome Trust (MR/N006089/1); a Project Grant from the Australian National Health and Medical Research Council (GNT1084429); and a Research for Development award from the Swiss National Science Foundation (IZ07Z0_160909/1). We thank Cepheid (Sunnyvale CA) and GE Healthcare (Australia) for their contributions of equipment and consumables at subsidized cost. OPMS is supported by The University of New South Wales Scientia Higher Degree Candidate Scholarship Scheme. All authors' affiliated institutions contributed via facilities and/or salary contributions. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Availability of data and materials

The data used for this study are included in the manuscript.

Declarations

Ethics approval and consent to participate

This study utilizes data from the WANTAIM trial. Ethical approval for the trial (including this costing) was granted by the PNG Institute of Medical Research (PNGIMR) Institutional Review Board (IRB number 1608); The Medical Research Advisory Committee of PNG (MRAC number 16.24); The University of New South Wales Human Research Ethics Committee (HREC number 16708); and the Research Ethics Committee (REC) of the London School of Hygiene and Tropical Medicine (REC number 12009). Written informed consent was obtained from all trial participants recruited.

Consent for publication

This manuscript contains no personal data.

Competing interests

The authors declare no competing interests.

Author details

[1]The Kirby Institute, University of New South Wales, Sydney, Australia. [2]The Papua New Guinea Institute of Medical Research, Goroka, Papua New Guinea. [3]Department of Global Health and Development, London School of Hygiene and Tropical Medicine, London, UK. [4]Institute for Global Health, University College London, London, UK.

Received: 2 October 2023 Accepted: 31 July 2024
Published online: 02 September 2024

References

1. Castaneda Aguilar RA, et al. September 2022 update to the poverty and inequality platform (PIP). 2022.

2. ESCAP U. Eradicating poverty and promoting prosperity in a changing Asia-Pacific. 2017.
3. The World Bank Group. Papua New Guinea country indicators. 2020. [January 29 2021]; Available from: https://data.worldbank.org/country/papua-new-guinea.
4. Asian Development Bank. Asian development outlook 2022: key indicators for Asia and the Pacific 2021. ADB Manila; 2022.
5. Cookson R, et al. The inverse care law re-examined: a global perspective. Lancet. 2021;397(10276):828–38.
6. Braveman P, Gruskin S. Poverty, equity, human rights and health. Bull World Health Organ. 2003;81:539–45.
7. Sharma J, et al. Poor quality for poor women? Inequities in the quality of antenatal and delivery care in Kenya. PLoS One. 2017;12(1):e0171236.
8. Cookson R, et al. Using cost-effectiveness analysis to address health equity concerns. Value Health. 2017;20(2):206–12.
9. Alkire S, Conconi A, Seth S. Multidimensional poverty index 2014: brief methodological note and results. 2014.
10. Arndt C, Tarp F. Measuring poverty and wellbeing in developing countries. Oxford: Oxford University Press; 2016.
11. Jolliffe DM, et al. Assessing the impact of the 2017 PPPs on the international poverty line and global poverty. 2022.
12. WHO. Using multidimensional poverty and vulnerability indices to inform equitable policies and interventions in health emergencies: research brief. 2021.
13. Alkire S, Foster J. Counting and multidimensional poverty measurement. J Public Econ. 2011;95(7–8):476–87.
14. Guliani H, Sepehri A, Serieux J. Determinants of prenatal care use: evidence from 32 low-income countries across Asia, Sub-Saharan Africa and Latin America. Health Policy Plan. 2013;29(5):589–602.
15. Kamal SMM, et al. Multidimensional socioeconomic deprivations of maternal health care services utilisation: evidence from Bangladesh. Pak J Women's Stud. 2020;27(2):15–33.
16. Noor AM, et al. Wealth, mother's education and physical access as determinants of retail sector net use in rural Kenya. Malar J. 2006;5:5.
17. Ogbo FA, et al. Enablers and barriers to the utilization of antenatal care services in India. Int J Environ Res Public Health. 2019;16(17):3152.
18. Rahman M, et al. Wealth inequality and utilization of reproductive health services in the Republic of Vanuatu: insights from the multiple indicator cluster survey, 2007. Int J Equity Health. 2011;10(1):58–58.
19. Vollmer F, Alkire S. Consolidating and improving the assets indicator in the global Multidimensional Poverty Index. World Dev. 2022;158:105997.
20. UNDP. Multidimensional poverty measures as a policy tool for achieving the sustainable development goals: a review of MPI measurement and uses in Asia and the Pacific. In: B.N.T.U.B.R. Hub, editor. 2019.
21. Filmer D, Scott K. Assessing asset indices. Demography. 2012;49(1):359–92.
22. Alkire S, Kanagaratnam U. Revisions of the global multidimensional poverty index: indicator options and their empirical assessment. Oxf Dev Stud. 2021;49(2):169–83.
23. Dotter C, Klasen S. The multidimensional poverty index: achievements, conceptual and empirical issues. Discussion papers. 2017.
24. WHO. WHO recommendation on antenatal care for a positive pregnancy experience. Luxembourg: WHO Publishing house; 2016.
25. PNG Obstetrics & Gynaecology Society. Manual of standard managements in obstetrics and gynaecology for doctors, HEOs and nurses in Papua New Guinea. 2016.
26. Robbers G, et al. Maternal and newborn health indicators in Papua New Guinea – 2008–2018. Sex Reprod Health Matters. 2019;27(1):52–68.
27. PNG National Department of Health. Health information systems. 2021.
28. Victora CG, et al. Socio-economic and ethnic group inequities in antenatal care quality in the public and private sector in Brazil. Health Policy Plan. 2010;25(4):253–61.
29. Okedo-Alex IN, et al. Determinants of antenatal care utilisation in sub-Saharan Africa: a systematic review. BMJ Open. 2019;9(10):e031890.
30. Tiruaynet K, Muchie KF. Determinants of utilization of antenatal care services in Benishangul Gumuz Region, Western Ethiopia: a study based on demographic and health survey. BMC Pregnancy Childbirth. 2019;19(1):115.
31. Wondemagegn AT, et al. The effect of antenatal care follow-up on neonatal health outcomes: a systematic review and meta-analysis. Public Health Rev. 2018;39:33.
32. Wilunda C, et al. Barriers to utilisation of antenatal care services in South Sudan: a qualitative study in Rumbek North County. Reprod Health. 2017;14(1):65–65.
33. PNG National Department of Health. PNG health plan 2011-2020. 2010.
34. PNG National Department of Health. National Health Service Standards (NHSS) 2021–2030. Port Moresby: GoPNG; 2023.
35. Vallely A, et al. Point-of-care testing and treatment of sexually transmitted infections to improve birth outcomes in high-burden, low-income settings: study protocol for a cluster randomized crossover trial (the WANTAIM Trial, Papua New Guinea) [version 1; peer review: awaiting peer review]. Wellcome Open Res. 2019;4:53.
36. Batura N, et al. Point-of-care testing and treatment of sexually transmitted and genital infections during pregnancy in Papua New Guinea (WANTAIM trial): protocol for an economic evaluation alongside a cluster-randomised trial. BMJ Open. 2021;11(8):e046308.
37. Alkire S, Foster J. Understandings and misunderstandings of multidimensional poverty measurement. J Econ Inequal. 2011;9(2):289–314.
38. Andersen RM. Revisiting the behavioral model and access to medical care: does it matter? J Health Soc Behav. 1995;36(1):1–10.
39. Alibhai KM, et al. Factors impacting antenatal care utilization: a systematic review of 37 fragile and conflict-affected situations. Confl Health. 2022;16(1):33.
40. Banke-Thomas A, et al. The cost of maternal health services in low-income and middle-income countries from a provider's perspective: a systematic review. BMJ Glob Health. 2020;5(6):e002371.
41. Wooldridge JM. Introductory econometrics: a modern approach. 5th ed. Mason: South-Western CENGAGE Learning; 2013.
42. Shibre G, Mekonnen W. Socio-economic inequalities in ANC attendance among mothers who gave birth in the past 12 months in Debre Brehan town and surrounding rural areas, North East Ethiopia: a community-based survey. Reprod Health. 2019;16(1):99.
43. Palmer T, et al. Economic evaluation of a conditional cash transfer to retain women in the continuum of care during pregnancy, birth and the postnatal period in Kenya. PLOS Glob Public Health. 2022;2(3):e0000128.
44. Ayanore MA, Pavlova M, Groot W. Unmet reproductive health needs among women in some West African countries: a systematic review of outcome measures and determinants. Reprod Health. 2016;13(1):5.
45. Andrew EVW, et al. Factors affecting attendance at and timing of formal antenatal care: results from a qualitative study in Madang, Papua New Guinea. PLoS One. 2014;9(5):e93025.
46. Maraga S, et al. Sociodemographic factors associated with maternal health care utilization in Wosera, East Sepik Province, Papua New Guinea. P N G Med J. 2014;54:154–63.
47. Dinsa GD, et al. Equitable distribution of poor quality of care? Equity in quality of reproductive health services in Ethiopia. Health Syst Reform. 2022;8(1):e2062808.
48. Adedokun ST, Yaya S. Correlates of antenatal care utilization among women of reproductive age in sub-Saharan Africa: evidence from multinomial analysis of demographic and health surveys (2010–2018) from 31 countries. Arch Public Health. 2020;78(1):134.
49. Rahman T, Gasbarro D, Alam K. Financial risk protection from out-of-pocket health spending in low- and middle-income countries: a scoping review of the literature. Health Res Policy Syst. 2022;20(1):83.
50. Marshall LB. Influences on the antenatal clinic attendance of central province women in Port Moresby, PNG. Soc Sci Med. 1985;21(3):341–50.
51. Vallely LM, et al. Exploring women's perspectives of access to care during pregnancy and childbirth: a qualitative study from rural Papua New Guinea. Midwifery. 2013;29(10):1222–9.
52. Kananura RM, et al. Persisting demand and supply gap for maternal and newborn care in eastern Uganda: a mixed-method cross-sectional study. Reprod Health. 2017;14(1):136–136.
53. Finlayson K, Downe S. Why do women not use antenatal services in low- and middle-income countries? A meta-synthesis of qualitative studies. PLoS Med. 2013;10(1):e1001373.
54. Steinbrook E, et al. Distance matters: barriers to antenatal care and safe childbirth in a migrant population on the Thailand-Myanmar border from 2007 to 2015, a pregnancy cohort study. BMC Pregnancy Childbirth. 2021;21(1):802.
55. Benjamin AL, Sapak P, Purai JK. User charges and utilisation of obstetric services in the National Capital District, Papua New Guinea. Pac Health Dialog. 2001;8(1):38–43.

56. Davy CP, et al. Seeking treatment for symptomatic malaria in Papua New Guinea. Malar J. 2010;9:268.
57. Sicuri E, et al. The economic cost to households of childhood malaria in Papua New Guinea: a focus on intra-country variation. Health Policy Plan. 2012;27(4):339–47.
58. Byrne A, et al. What works? Strategies to increase reproductive, maternal and child health in difficult to access mountainous locations: a systematic literature review. PLoS One. 2014;9(2):e87683.
59. Simkhada B, et al. Factors affecting the utilization of antenatal care in developing countries: systematic review of the literature. J Adv Nurs. 2008;61(3):244–60.
60. PNG National Department of Health. Ministerial taskforce for maternal health in PNG. 2009.
61. Hurst TE, et al. Demand-side interventions for maternal care: evidence of more use, not better outcomes. BMC Pregnancy Childbirth. 2015;15(1):297.
62. Ensor T, Cooper S. Overcoming barriers to health service access: influencing the demand side. Health Policy Plan. 2004;19(2):69–79.
63. Hirai M, et al. The impact of supply-side and demand-side interventions on use of antenatal and maternal services in western Kenya: a qualitative study. BMC Pregnancy Childbirth. 2020;20(1):453.
64. Murray SF, et al. Effects of demand-side financing on utilisation, experiences and outcomes of maternity care in low- and middle-income countries: a systematic review. BMC Pregnancy Childbirth. 2014;14(1):30.
65. Gopalan SS, et al. Health sector demand-side financial incentives in low- and middle-income countries: a systematic review on demand- and supply-side effects. Soc Sci Med. 2014;100:72–83.
66. Glassman A, et al. Impact of conditional cash transfers on maternal and newborn health. J Health Popul Nutr. 2013;31(4 Suppl 2):S48.
67. Hunter BM, et al. The effects of cash transfers and vouchers on the use and quality of maternity care services: a systematic review. PLoS One. 2017;12(3):e0173068.
68. Santana IR, et al. Need, demand, supply in health care: working definitions, and their implications for defining access. Health Econ Policy Law. 2023;18(1):1–13.
69. Nkangu M, et al. A systematic review of the effect of performance-based financing interventions on out-of-pocket expenses to improve access to, and the utilization of, maternal health services across health sectors in sub-Saharan Africa. J Glob Health. 2023;13:04035.
70. Gopalan S, Mohammed-Roberts R, Zanetti Matarazzo HC. Drivers of utilization, quality of care, and RMNCH-N services in Bangladesh. 2021.
71. Neelsen S, et al. Financial incentives to increase utilization of reproductive, maternal, and child health services in low-and middle-income countries. 2021.

Publisher's Note