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Digital Connectivity as a Structural Factor Associated with Adequate Antenatal Care Utilization in Indonesia: A Multilevel Analysis of Linked SDKI–Podes Data

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ABSTRACT

Maternal mortality in Indonesia remains high, particularly in rural areas with limited access to quality antenatal care (ANC). Digital health approaches, including telemedicine, require adequate digital infrastructure to support implementation. This study examined whether community-level digital connectivity was associated with adequate ANC utilization in Indonesia and assessed its relevance as an indicator of telemedicine readiness. Methods: A cross-sectional study linked individual-level data from the 2017 Indonesia Demographic and Health Survey (SDKI) with village-level communication signal data from the 2018 Village Potential Survey (Podes), involving 14,621 women across 1,912 clusters. Adequate ANC was defined as completion of at least four visits (K4). Multilevel logistic regression was used to estimate associations while adjusting for sociodemographic and access-related factors. Results: Overall K4 coverage was 77.1%. Women living in areas with strong 4G/LTE signal had higher odds of completing adequate ANC (aOR=1.38; 95% CI: 1.14–1.67), and internet use was positively associated with ANC utilization (aOR=1.27; 95% CI: 1.06–1.52). Conclusions: Community-level digital connectivity was associated with adequate ANC utilization and may support telemedicine readiness. However, telemedicine was not directly measured, and the temporal mismatch between SDKI 2017 and Podes 2018 limits causal interpretation.

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INTRODUCTION

Maternal mortality in Indonesia remains a pressing public health challenge, with the 2017 Indonesia Demographic and Health Survey (Survei Demografi dan Kesehatan Indonesia, SDKI) estimating 177 per 100,000 live births, far above the Sustainable Development Goal target of fewer than 70 by 2030 (Badan Pusat Statistik et al., 2018; World Health Organization, 2019). The burden is heaviest in rural and remote areas, where geographic isolation, poverty, and limited health infrastructure limit women's access to care. Antenatal care (ANC), particularly adequate ANC defined as completion of at least four antenatal visits (K4), is a cornerstone of safe motherhood, yet regional disparities remain substantial: women in Eastern Indonesia are consistently less likely to achieve K4 than those in Java and Bali (Titaley et al., 2021).

The rapid expansion of digital health technologies has created opportunities to strengthen maternal healthcare access through communication, health information exchange, and remote support mechanisms (Manyazewal et al., 2021). During the COVID-19 pandemic, Indonesia's Ministry of Health formally permitted telemedicine services for maternal and child health, accelerating broader digital health transformation efforts (Kemenkes RI, 2020). However, telemedicine implementation depends not only on service availability but also on the presence of enabling digital conditions. In this context, telemedicine readiness refers to the extent to which individuals and communities possess the necessary supporting conditions including internet connectivity, communication infrastructure, and digital accessibility to enable future telemedicine implementation. This concept differs from telemedicine utilization, which refers to the actual use of telemedicine services.

Because this study did not directly measure telemedicine use, it does not evaluate telemedicine utilization or effectiveness. Instead, this study focuses on digital readiness indicators, including internet connectivity, mobile phone ownership, internet use, and village-level internet signal availability, as structural factors that may support telemedicine implementation and influence maternal healthcare access. Therefore, digital connectivity is interpreted as an indicator of telemedicine readiness and enabling infrastructure rather than as evidence of telemedicine use.

Indonesia's digital landscape remains characterized by substantial urban–rural disparities: although internet penetration in urban areas exceeds 77%, many rural villages still lack reliable 4G/LTE signals and affordable internet access (APJII, 2024). Evidence from Zanzibar demonstrated that mobile phone–based maternal health interventions were more effective in settings with adequate network availability (Lund et al., 2022). Likewise, the WHO Global Strategy on Digital Health emphasizes that resilient digital infrastructure is a prerequisite for sustainable digital health implementation and that equitable health gains depend on reducing inequalities in digital access and connectivity (World Health Organization, 2022; Kickbusch et al., 2021).

To design equitable telemedicine strategies, it is important to understand not only whether women have access to digital devices but also whether community-level infrastructure enables meaningful connectivity. The WHO has highlighted that scaling digital health requires addressing structural constraints, including internet coverage and digital accessibility (Labrique et al., 2022).

Studies in Ethiopia, Kenya, and India reported that digital access and connectivity-related interventions were associated with improved maternal healthcare utilization under supportive infrastructure conditions (Azene et al., 2022; Mohan et al., 2021; Prasad et al., 2021). In Indonesia, however, few studies have integrated individual health data with contextual indicators of digital infrastructure. Previous analyses using SDKI identified wealth, maternal education, and parity as important determinants of ANC utilization (Titaley et al., 2021; Laksono et al., 2023), but did not incorporate measures of digital readiness or community-level connectivity. Other studies found that socioeconomic characteristics influenced access to online maternal health information, while the role of supporting digital infrastructure remained underexplored (Manyazewal et al., 2021).

To address this gap, the present study links SDKI 2017 with the Village Potential Survey (Potensi Desa, Podes) 2018 to capture both individual digital engagement and village-level internet signal availability. Given the one-year difference between datasets, village connectivity should be interpreted as contextual information rather than contemporaneous exposure. Using multilevel modeling, this study evaluates whether community-level digital connectivity is independently associated with adequate ANC utilization and discusses its implications as a structural indicator of telemedicine readiness in maternal health services.

METHODS

This study employed a cross-sectional design utilizing secondary data from two nationally representative surveys. Individual-level data were obtained from the 2017 Indonesia Demographic and Health Survey (Survei Demografi dan Kesehatan Indonesia, SDKI), which applied a stratified two-stage cluster sampling design and interviewed 49,627 women aged 15–49 years. The women's questionnaire collected information on antenatal care for the most recent live birth within the five years preceding the survey. Community-level data on digital infrastructure were obtained from the 2018 Village Potential Survey (Potensi Desa, Podes), which collects administrative information on village characteristics, including communication infrastructure and the availability and quality of communication signals across all villages in Indonesia.

The use of SDKI 2017 and Podes 2018 reflects the integration of individual-level health behavior data with contextual village-level infrastructure characteristics. Although the two datasets were collected in different years, this linkage was considered methodologically acceptable because village internet infrastructure and communication signal availability are structural contextual characteristics that generally change gradually over short periods rather than fluctuating rapidly at the individual level. Therefore, Podes 2018 was used to approximate the digital environment surrounding communities represented in SDKI 2017 and interpreted as contextual infrastructure rather than contemporaneous exposure. This approach has been used in multilevel population health research where contextual administrative data are linked to survey-based individual data to capture environmental determinants of health behavior. Accordingly, findings should be interpreted as reflecting associations between ANC utilization and the broader digital environment rather than direct temporal effects of internet infrastructure.

The SDKI 2017 dataset includes a cluster variable identifying the primary sampling unit, corresponding to a census block (blok sensus). Each Podes village comprises several census blocks. Data linkage was performed using a restricted master sample frame concordance file maintained by Statistics Indonesia (Badan Pusat Statistik, BPS), which maps census block codes to village identifiers. Access to the concordance file was obtained through institutional collaboration under a data use agreement and remains subject to institutional approval and data-sharing regulations. Using this bridge file, each SDKI cluster was assigned the corresponding Podes village code.

Because the Demographic and Health Survey (DHS) cluster represents the smallest identifiable sampling unit after anonymization, all multilevel models were specified with random intercepts at the cluster level, while village-level connectivity variables were assigned through the linkage process. Clusters with ambiguous matching were excluded (n=12). Linkage validity was assessed by cross-tabulating province and district identifiers before and after merging, with concordance exceeding 99%. The final analytical dataset comprised 14,621 women nested within 1,912 clusters.

The dependent variable was adequate antenatal care, defined as completion of at least four antenatal care visits (K4) during the most recent pregnancy (1 = ≥4 visits; 0 = <4 visits). K4 was the official Indonesian maternal health performance indicator during the survey period and is consistently collected in SDKI, ensuring comparability with prior studies [24]. At the individual level, digital engagement variables included mobile phone ownership (yes/no) and internet use during the previous month (yes/no). At the contextual level, the main predictor was village internet signal strength obtained from Podes. The original Podes variable categorizes signal quality on an ordinal scale reflecting communication access conditions reported by village officials. For the primary analysis, categories were grouped into "strong 4G/LTE signal" (coded 1) and "moderate, weak, 3G, or no signal" (coded 0), based on the assumption that stable digital health services require higher-quality connectivity.

To assess robustness, sensitivity analysis was conducted using the original signal categories. The Podes indicator reflects perceived signal availability and does not directly measure internet speed, bandwidth, latency, affordability, or actual telemedicine utilization; therefore, it should be interpreted as a proxy indicator of digital readiness and supporting infrastructure for telemedicine implementation.

Control variables were selected based on Andersen's behavioral model and previous ANC literature and included maternal age (<20, 20–34, ≥35 years), education (no schooling, primary, secondary, higher), parity (1, 2–3, ≥4), household wealth index (poorest to richest quintiles), residence (urban/rural), region (Java–Bali, Sumatra, Kalimantan, Sulawesi, Eastern Indonesia), pregnancy wantedness, perceived distance barriers, financial barriers, permission barriers, and health insurance coverage (National Health Insurance/Badan Penyelenggara Jaminan Sosial Kesehatan, JKN/BPJS, or other). Missing data were minimal (Supplementary Table S1); therefore, complete-case analysis was applied.

All analyses incorporated SDKI sampling design characteristics. Individual sampling weights were normalized before estimation according to DHS recommendations and incorporated into multilevel modeling. Stratification variables from the original survey design were retained, while clustering was explicitly accounted for through random intercept specification at the cluster level. Multicollinearity was evaluated using variance inflation factors (VIF), with all values below 2.5. Interaction between internet use and village signal was tested and excluded because it was not statistically significant (p=0.44). Given the hierarchical structure of women nested within census-block clusters, multilevel mixed-effects logistic regression models were fitted. The intraclass correlation coefficient (ICC) was calculated as $\sigma^2u/(\sigma^2u+\pi^2/3)$.

Four sequential models were estimated: Model 1 (empty model); Model 2 included digital variables only; Model 3 added individual-level covariates; and Model 4 (full model) additionally included village internet signal. Variance components and model fit statistics (AIC and likelihood ratio test) were reported. Adjusted odds ratios (aORs) with 95% confidence intervals and p-values from Model 4 are presented. Sensitivity analyses using the original signal categories are reported in Supplementary Table S3. All analyses were conducted using Stata version 17.0.

The SDKI 2017 received ethical approval from the Institutional Review Board of the University of Indonesia and ICF International. Permission to use DHS data was obtained from the DHS Program. This secondary analysis of fully anonymized data did not require additional ethical approval.

RESULTS

1. Sample Characteristics

Table 1 presents the sociodemographic, digital, and access-related characteristics of the 14,621 women included in the analysis. The majority of respondents were aged 20–34 years (66.8%), and 42.3% had completed primary education only. Nearly half belonged to the poorest or poorer household wealth quintiles (47.5%), and 58.0% resided in rural areas. Regarding access barriers, 23.0% reported distance to health facilities as a major problem and 37.0% reported financial constraints. Health insurance coverage reached 60.8%.

Digital access remained uneven. Although 64.2% of women owned a mobile phone, only 34.8% reported internet use in the previous month. At the contextual level, 53.6% of respondents lived in clusters whose parent village was classified as having strong 4G/LTE internet signal according to the Village Potential Survey (Potensi Desa, Podes). Overall, 77.1% of women achieved adequate antenatal care (K4), defined as completion of at least four antenatal care visits. Descriptively, K4 coverage was higher among women living in villages with strong internet signal (82.3%) than among those in villages with moderate, weak, 3G, or no signal (71.5%; p<0.001). Likewise, internet users had substantially higher K4 coverage than non-users (85.6% vs. 72.8%).

Figure 1 illustrates the adjusted predicted probability of adequate ANC according to village internet signal category, while Figure 2 presents adjusted predicted probability according to individual internet use.

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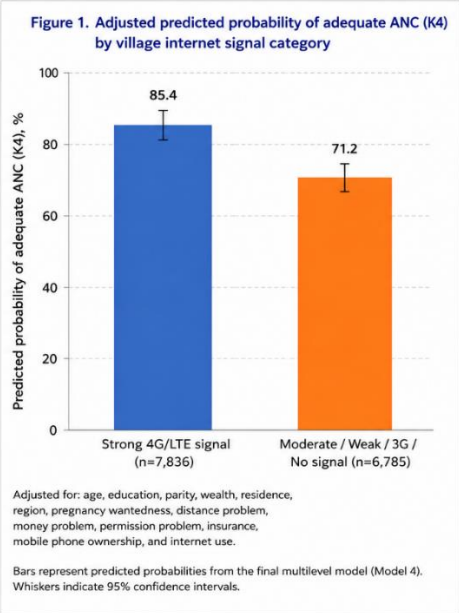

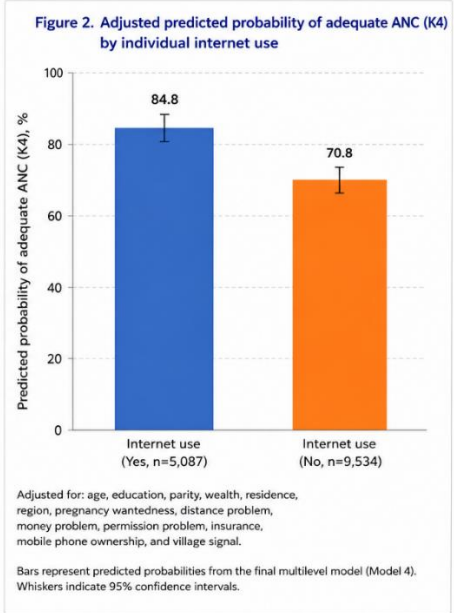

2. Multilevel Regression Analysis

Table 2 summarizes the multilevel mixed-effects logistic regression results. The empty model (Model 1) showed cluster-level variance of 0.561 and an intraclass correlation coefficient (ICC) of 14.6%, indicating meaningful variation in ANC utilization across clusters and supporting multilevel modeling. Model fit improved progressively across sequential models. In the fully adjusted model (Model 4), cluster variance declined to 0.483 and ICC decreased to 12.8%, accompanied by improvement in Akaike Information Criterion (AIC=14,181.2 compared with 14,227.9 in Model 3), suggesting that inclusion of contextual connectivity variables improved model performance.

Women living in villages with strong 4G/LTE signal had significantly higher odds of completing adequate ANC compared with women living in villages with moderate, weak, 3G, or no signal (aOR=1.38; 95% CI: 1.14–1.67; p=.001). Individual internet use remained independently associated with higher ANC utilization (aOR=1.27; 95% CI: 1.06–1.52; p=.010), whereas mobile phone ownership became marginally non-significant after adjustment (aOR=1.11; p=.074).

To complement odds ratio interpretation, adjusted predicted probabilities were estimated from Model 4. Figure 1 shows that women residing in villages with strong internet signals had an adjusted predicted probability of adequate ANC of 85.4%, compared with 71.2% among women living in villages with weaker connectivity. Figure 2 demonstrates a similar pattern at the individual level: internet users had an adjusted predicted probability of 84.8%, whereas non-users had a probability of 70.8%. These findings indicate that digital connectivity was associated not only with relative increases in odds but also with meaningful absolute differences in expected ANC utilization.

Consistent socioeconomic gradients were observed. Higher household wealth and educational attainment were strongly associated with greater ANC utilization. Conversely, rural residence (aOR=0.79; 95% CI: 0.69–0.90), parity ≥4 (aOR=0.53), perceived distance barriers (aOR=0.69), absence of health insurance (aOR=0.78), and residence in Eastern Indonesia (aOR=0.63)

remained negatively associated with adequate ANC. Full model estimates are presented in Supplementary Table S2.

3. Sensitivity Analysis

Sensitivity analysis treating village internet signal as a three-category variable yielded consistent findings. Strong signal remained significantly associated with adequate ANC (aOR=1.37; 95% CI: 1.13–1.66), whereas moderate signal was not statistically significant (aOR=1.10; 95% CI: 0.92–1.32). These results support the robustness of the primary dichotomized village connectivity specification.

Table 1. Sociodemographic, digital, and access-related characteristics (n=14,621), SDKI 2017

Variable	n	%
Age <20 years	1,023	7.0
20–34 years	9,764	66.8
≥35 years	3,834	26.2
Education: No schooling	1,174	8.0
Primary	6,183	42.3
Secondary	5,894	40.3
Higher	1,370	9.4
Wealth: Poorest	3,748	25.6
Poorer	3,198	21.9
Middle	2,862	19.6
Richer	2,511	17.2
Richest	2,302	15.7
Urban residence	6,140	42.0
Rural residence	8,481	58.0
Parity 1	4,894	33.5
Variable	**n**	**%**
2–3	7,097	48.5
≥4	2,630	18.0
Distance big problem	3,362	23.0
Money big problem	5,414	37.0
JKN/BPJS insurance	8,895	60.8
Mobile phone ownership	9,387	64.2
Internet use (past month)	5,087	34.8
Village strong 4G/LTE	7,836	53.6
Adequate ANC (K4)	11,273	77.1

Weighted percentages. Supplementary Table S1 details missing data.

Table 2. Multilevel logistic regression models with variance components, SDKI 2017 – Podes 2018

Variable	Model 2 OR (95% CI)	Model 3 aOR (95% CI)	Model 4 aOR (95% CI)	p (Model 4)
Mobile phone	1.48 (1.33–1.66)	1.13 (0.99–1.28)	1.11 (0.98–1.26)	.074
Internet use	1.91 (1.68–2.17)	1.30 (1.09–1.55)	1.27 (1.06–1.52)	.010
Village 4G/LTE	-	-	1.38 (1.14–1.67)	.001
Richest vs. poorest	-	2.84 (2.19–3.68)	2.79 (2.15–3.62)	<.001
Higher vs. no education	-	1.90 (1.42–2.54)	1.87 (1.40–2.50)	<.001
Rural residence (ref: urban)	-	0.81 (0.71–0.92)	0.79 (0.69–0.90)	<.001
Parity ≥4 vs. 1	-	0.54 (0.46–0.64)	0.53 (0.45–0.63)	<.001
Distance problem	-	0.71 (0.63–0.80)	0.69 (0.61–0.78)	<.001
No insurance	-	0.80 (0.71–0.90)	0.78 (0.69–0.88)	<.001
Eastern vs. Java-Bali	-	0.64 (0.51–0.81)	0.63 (0.50–0.80)	<.001
Cluster variance	0.520	0.496	0.483	
ICC	13.7%	13.1%	12.8%	
AIC	14,285.3	14,227.9	14,181.2	

Model 1 empty: ICC 14.6% (variance 0.561). Models also adjusted for age, pregnancy wantedness, permission, money barrier. See Supplementary Table S2.

DISCUSSION

This study provides evidence that community-level digital connectivity is independently associated with adequate antenatal care utilization in Indonesia, after accounting for individual characteristics, access barriers, and urban-rural residence. Women living in clusters with strong 4G/LTE signal at the village level had 38% higher odds of completing K4 ANC, underscoring internet infrastructure as a structural factor that may serve as a key enabler for telemedicine deployment. This finding is consistent with the emerging concept of digital determinants of health, wherein access to digital resources becomes increasingly consequential for health equity alongside traditional social determinants (Labrique et al., 2022; Feroz et al., 2021).

Digital connectivity may influence ANC utilization through several pathways relevant to telemedicine. Reliable internet access can facilitate exposure to maternal health information, increase awareness of recommended ANC schedules, improve communication between pregnant women and health providers, and reduce informational barriers to care-seeking all fundamental components of telemedicine services. Connectivity may also strengthen community health systems by supporting digital reporting, appointment reminders, and communication among health workers. The non-significant interaction between individual internet use and village signal (p=0.44) further suggests that community-level connectivity benefits both users and non-users through improved ser-

vice delivery environment and information diffusion within social networks rather than solely amplifying the advantage of individual internet users. These mechanisms could collectively contribute to higher ANC utilization even in settings where direct use of telemedicine remains limited. This aligns with the ecological model, where community infrastructure shapes health behavior irrespective of individual characteristics (WHO, 2016).

The inclusion of urban-rural residence in the model is important: rural women had 21% lower odds of K4 even after controlling for wealth, education, and distance. The persistent effect of village signal beyond residence suggests that connectivity is not merely an urban-rural marker. However, we acknowledge that village internet signal may also partially reflect broader community development such as road quality or health facility readiness that we could not fully measure. The comprehensive adjustment for wealth, education, distance, insurance, and region mitigates, but does not eliminate, this concern. The modest reduction in ICC (from 14.6% to 12.8%) indicates that digital infrastructure explains only a small part of contextual variation; substantial unexplained cluster-level heterogeneity remains, likely due to other structural factors.

Our results resonate with evidence from Ethiopia and Kenya, where community internet access and digital interventions improved maternal care use independently of household wealth (Azene et al., 2022; Mohan et al., 2021). The attenuation of mobile phone ownership to borderline significance reinforces that meaningful connectivity actual internet use within an enabling community environment is what matters for health behavior (Banke-Thomas et al., 2023; Rahman et al., 2022). A systematic review further confirms that mHealth interventions can improve ANC utilization in low-resource settings, but their effectiveness hinges on addressing underlying infrastructure constraints (Lee et al., 2022).

Several limitations merit attention. The cross-sectional design precludes causal inference, and residual confounding cannot be ruled out despite extensive covariate adjustment. The temporal mismatch between ANC reports (2012–2017) and internet signal measurement (2018) may introduce exposure misclassification, although the 2018 measure likely provides a conservative, upper-bound estimate. The Podes signal indicator serves only as a proxy for actual internet quality and does not capture bandwidth, latency, or affordability critical factors for telemedicine. The bridge-file linkage relies on restricted BPS data, limiting immediate reproducibility. Recall bias in ANC reporting is also possible given the five-year recall window. Moreover, village-level effects were assigned to clusters because a three-level hierarchical model could not be estimated, which may somewhat underestimate village-level contextual effects. As this study measured digital readiness rather than actual telemedicine utilization, findings should not be interpreted as direct evidence of telemedicine effectiveness but rather as foundational evidence for its potential deployment. Finally, the K4 indicator, while nationally standard during the survey period, is less rigorous than the WHO eight-contact model (Bronfenbrenner, 1979); future studies should examine whether connectivity supports this more intensive ANC schedule.

In the Indonesian context, these findings suggest that digital infrastructure may be an important component of maternal health strategies, particularly for telemedicine optimization. Prioritizing reliable 4G coverage for all *puskesmas* and *pustu*, subsidizing data packages for health use, and training *kader* as digital navigators could help translate connectivity gains into improved maternal care, though further evaluation is warranted. The World Bank's report on Indonesia's digital economy underscores that bridging the digital divide is essential for inclusive development (World Health Organization, 2021), and our findings extend this imperative to the health sector, particularly for telemedicine-enabled maternal health services.

CONCLUSIONS

Community-level digital connectivity was independently associated with adequate antenatal care utilization in Indonesia after accounting for socioeconomic, access, and regional factors. These findings suggest that digital infrastructure may serve as an important structural condition and indicator of telemedicine readiness rather than actual telemedicine utilization. Expanding equitable internet access, improving digital literacy, and reducing affordability barriers may help create a more supportive environment for maternal healthcare delivery. This study contributes to the evidence on digital determinants of maternal health in Indonesia by integrating individual health data with contextual digital infrastructure indicators. Future studies should use longitudinal designs and directly measure telemedicine utilization to evaluate whether improved digital readiness leads to better antenatal care outcomes in line with the WHO eight-contact recommendation.

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