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Improving Completeness and Quality of Antenatal Care Documentation Using a DHIS2 Tracker-Based Electronic Tool in Rural Tanzania: A Pilot Implementation Study

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Abstract

Introduction: Accurate gestational age (GA) documentation is essential for quality antenatal care (ANC), yet paper-based systems in low-resource settings are often affected by incomplete, illegible, and inconsistent records. In Tanzania, these challenges limit continuity of care, maternal vaccination scheduling, and health system decision-making. Digital health innovations, including DHIS2 Tracker-based tools, offer potential to improve data quality and strengthen routine ANC documentation.

Methods: A retrospective–prospective assessment study was conducted in five health facilities in Kilimanjaro Region, Tanzania. Retrospective ANC records (2019–2022; N = 81,843) were extracted from paper registers to assess GA documentation and trends over time. Additionally, a DHIS2 Tracker-based electronic tool (E-tool) was implemented prospectively among 200 pregnant women. Data quality indicators included completeness of GA recording, visit-date documentation, legibility, and missing data. Descriptive statistics and percentage-point differences were used to compare paper-based and electronic records.

Results: Retrospective analysis showed increasing missing GA records in urban facilities, rising from 15.3% in 2019 to 41.7% in 2022, while rural facilities showed lower and declining gaps. Paper-based GA completeness was 82.8%. Following E-tool implementation, GA completeness improved to 96.0%, visit-date documentation increased from 68.0% to 100%, and record legibility improved from 74.0% to 100%, with overall improvements ranging from + 13.2 to + 32.0 percentage points.

Conclusion: The DHIS2 Tracker-based E-tool significantly improved completeness, accuracy, and readability of ANC documentation compared with paper-based systems. Scaling up digital ANC tools could strengthen maternal health information systems and improve continuity of care in resource-limited settings

Background

Accurate estimation and documentation of gestational age (GA) are fundamental components of quality antenatal care (ANC), guiding the timing of maternal vaccinations, fetal growth monitoring, screening for congenital anomalies, identification of preterm birth risk, and planning of obstetric interventions (World Health Organization [WHO], 2023). Reliable GA information supports appropriate clinical decision-making throughout pregnancy and contributes to improved maternal and neonatal outcomes. Conversely, inaccurate or incomplete GA records may lead to delayed interventions, misclassification of pregnancy risk, reduced continuity of care, and adverse maternal and newborn outcomes (Lee et al., 2022; Haider et al., 2021).

In many low- and middle-income countries (LMICs), including Tanzania, gestational age estimation commonly relies on the last normal menstrual period (LNMP) and, where available, obstetric ultrasound. However, LNMP-based estimation is often affected by recall bias, irregular menstrual cycles, delayed ANC initiation, and inconsistent clinical verification (Rumisha et al., 2020; Åhman et al., 2018). Although obstetric ultrasound is considered the preferred method for early pregnancy dating, access to ultrasound equipment and trained personnel remains limited in many resource-constrained settings (WHO, 2018; Viner et al., 2022). Consequently, maternal health services frequently depend on paper-based ANC records that are susceptible to incomplete documentation, transcription errors, illegible handwriting, fragmented follow-up, and weak linkage between ANC and delivery records (German et al., 2023; Shabani et al., 2023).

Delayed initiation of ANC further compromises accurate gestational age assessment and pregnancy monitoring. Evidence from sub-Saharan Africa indicates that many women attend their first ANC visit after the first trimester, limiting opportunities for early gestational dating and timely preventive interventions (Odusina et al., 2021; Mare et al., 2024). Although WHO recommends early and repeated ANC contacts to improve maternal and neonatal outcomes, maintaining complete longitudinal documentation across multiple visits remains challenging, particularly in high-volume facilities with substantial documentation burdens (Tunçalp et al., 2017; WHO, 2016; Rumisha et al., 2020).

Digital health interventions have increasingly been recognized as effective approaches for strengthening routine health information systems and improving maternal healthcare documentation. The WHO Global Strategy on Digital Health 2020–2025 emphasizes the role of digital technologies in enhancing data quality, service integration, continuity of care, and evidence-based decision-making (WHO, 2021). In Tanzania, the District Health Information Software 2 (DHIS2) platform has been adopted as part of the national digital health strategy, although its implementation has largely focused on aggregate reporting rather than individual-level longitudinal maternal records (Doctor et al., 2019; Ministry of Health Tanzania, 2019). Emerging evidence suggests that electronic maternal health tools can improve data completeness, legibility, longitudinal tracking, and continuity of care through structured data entry, automated validation, and real-time documentation (Masoi et al., 2023; Mbunge & Sibiya, 2024). DHIS2-based tracking systems may further support individual-level follow-up throughout pregnancy while reducing documentation errors associated with paper-based systems (Doctor et al., 2019; German et al., 2023). However, evidence comparing the quality of gestational age documentation between routine paper-based ANC systems and DHIS2-enabled electronic tools in Tanzania remains limited.

Therefore, this study aimed to compare the completeness and quality of gestational age documentation between routine paper-based ANC registers and a DHIS2-enabled electronic tool (E-tool) implemented in selected health facilities in the Kilimanjaro Region, Tanzania. Specifically, the study assessed the completeness of gestational age recording, gestational age distribution at ANC attendance, completeness of visit-date documentation, record legibility, and selected documentation quality indicators. The study was conducted within the framework of the broader multi-country project, *Antenatal Care Attendance across Gestational Age Windows: A Protocol for a Multi-country, Longitudinal Retrospective Data Extraction Study*, which aimed to evaluate ANC attendance patterns and gestational age documentation across multiple low- and middle-income countries. (Ford et al., 2025)

Methods

Study Design and Setting

This study employed a retrospective–prospective design to assess the quality of routine antenatal care (ANC) documentation in paper-based registers and a DHIS2-enabled electronic tool (E-tool). The study was conducted in five selected health facilities in the Kilimanjaro Region, Tanzania. The retrospective phase involved abstraction of historical records from paper-based registers, while the prospective phase involved real-time data entry using the electronic system during routine ANC services.

Development of the E. tool System

The electronic tool (E-tool) was developed using the District Health Information Software 2 (DHIS2) Tracker platform. Tanzania uses DHIS2 as its national Health Management Information System (HMIS) for aggregated

reporting from health facilities to district, regional, and national levels to support planning, monitoring, and decision-making.

In the national DHIS2 system, facilities submit aggregated monthly reports compiled by designated health workers. In contrast, this study used a locally customized DHIS2 Tracker instance managed by the Kilimanjaro Clinical Research Institute (KCRI). This instance operates independently from the national DHIS2 platform and was specifically configured to capture individual-level maternal health records.

The system was designed using data elements derived from national HMIS registers (MTUHA books), including MTUHA Book No. 6 (Antenatal Care) and MTUHA Book No. 12 (Labor and Delivery). The E-tool was installed on tablet devices and used by nurses and midwives during routine ANC consultations.

The system incorporated structured electronic forms, mandatory data-entry fields, automated date capture, appointment tracking, and validation rules to reduce missing data and improve documentation quality. A unique patient identifier enabled linkage of records across ANC visits and between antenatal care and delivery records, supporting longitudinal tracking of pregnancy outcomes and continuity of care.

Because electronic systems are not yet approved as a full replacement for paper-based HMIS registers in Tanzania, healthcare workers were required to maintain both paper-based and electronic records concurrently during service delivery. The customized DHIS2 instance was not integrated with the national DHIS2 platform at the time of implementation; however, it was designed with the potential for future interoperability

Approach of the study

Retrospective Phase -Paper-Based Registers

Historical ANC records from 2019–2022 were extracted from routine national Health Management Information System (HMIS) paper registers, including MTUHA Form No. 6 (Antenatal Care Register) and MTUHA Form No. 12 (Labor and Delivery Register).

Data were abstracted using a standardised REDCap template to ensure consistency and completeness of extraction. The variables assessed included gestational age (GA) at ANC visit, visit dates, maternal outcome documentation, and record legibility. A structured abstraction process was used to minimize transcription errors during data collection (Ford et al., 2025).

Prospective Phase -Electronic E-tool Data Collection

In the prospective phase, a DHIS2-enabled electronic ANC tool was used to capture data during routine ANC service delivery. A total of 200 pregnant women were enrolled prospectively and followed during routine ANC visits.

The E-tool incorporated a unique patient identifier that enabled linkage of records across repeated ANC visits and between antenatal and delivery services. This functionality supported longitudinal tracking of individual women throughout pregnancy and facilitated assessment of continuity of care, which was difficult to achieve using routine paper-based registers.

The prospective phase assessed documentation quality using four predefined indicators: completeness of gestational age recording, completeness of visit-date documentation, record legibility, and missing data. These indicators were compared with paper-based ANC records, and percentage-point differences were calculated to evaluate improvements following implementation of the DHIS2 Tracker-based electronic tool

The DHIS2 Tracker electronic tool was configured with mandatory data-entry fields and built-in validation rules requiring completion of essential ANC variables before a record could be saved or submitted. These system-level validation checks minimized missing data and promoted standardized and complete documentation of ANC information.

Percentage-point improvements were calculated to quantify differences in documentation quality between paper-based registers and the electronic system. This was computed by subtracting the proportion observed in paper registers from the corresponding proportion observed in the DHIS2 Tracker dataset.

Legibility was assessed during record review by determining whether handwritten or electronic entries were clearly readable and interpretable without ambiguity. Records with unclear handwriting or illegible entries were classified as not legible in paper registers, while all electronic entries were considered legible due to standardized digital formatting.

Documentation Quality Assessment and Measurement of Outcomes

Documentation quality was assessed using four predefined indicators to evaluate the completeness and quality of antenatal care (ANC) records before and after implementation of the DHIS2 Tracker electronic tool. The assessed indicators included: (i) completeness of gestational age recording, defined as the proportion of ANC records with gestational age documented; (ii) completeness of visit-date recording, defined as the proportion of records with a fully documented ANC visit date; (iii) legibility/readability, defined as the proportion of records in which all recorded information could be clearly read and interpreted without ambiguity during review; and (iv) reduction in missing data, defined as the decrease in incomplete documentation following implementation of the electronic documentation system.

Documentation quality was assessed through structured record reviews using standardized assessment criteria. Retrospective reviews of paper-based ANC registers were conducted to determine the completeness and readability of routinely documented variables. During the pilot implementation phase, electronic ANC records generated through the DHIS2 Tracker were assessed using the same predefined indicators to ensure comparability between paper-based and electronic documentation systems. This approach enabled assessment of changes in documentation quality associated with the transition from paper-based to electronic ANC record management.

Completeness of gestational age documentation in paper-based registers was assessed using all available retrospective ANC records from 2019 to 2022 (N = 81,843). However, indicators requiring detailed individual record assessment, including visit-date completeness and legibility/readability, were evaluated using a subset of records from the DHIS2 Tracker pilot implementation (n = 200). These records represented consecutive ANC records entered into the electronic system during the pilot phase and were selected to facilitate direct assessment of documentation quality between the paper-based and electronic systems.

Statistical Analysis

All analyses of the retrospective data were conducted using routinely collected antenatal care (ANC) records extracted from a facility-based database covering the period 2019–2022, with a total of 81,843 records included in the final analysis. Prior to analysis, data were exported, cleaned, and checked for completeness, duplication, and internal inconsistencies. Records with implausible values or missing key identifiers were identified and handled in accordance with predefined data-cleaning rules to ensure analytical validity.

Descriptive statistics were used to summarize ANC attendance, gestational age (GA) distribution, and documentation quality indicators across years and facility types. Categorical variables were presented as frequencies and percentages, with denominators clearly specified for each indicator to reflect the number of eligible records within each analysis domain (e.g., total ANC attendance records, GA-recorded sub-samples, and completeness assessments).

Documentation quality was assessed using four key domains: completeness of documentation, overall documentation quality (including internal consistency of recorded fields), legibility/readability of handwritten entries (where applicable), and proportion of missing data across key ANC variables. Completeness of documentation was defined as the proportion of records with all required ANC fields fully completed, while missing data were quantified as the proportion of records with absent or incomplete entries for specific variables of interest. Documentation quality therefore incorporated both completeness and internal consistency checks across recorded ANC variables.

To assess changes over time, trends in key indicators were analyzed across the four-year study period (2019–2022) using year-to-year comparisons. Differences in proportions between years and/or facility types were expressed as percentage-point changes, calculated as the arithmetic difference between two proportions (e.g., the proportion in 2022 minus the proportion in 2019), rather than as relative percentage change. This approach was used to provide a clearer interpretation of absolute changes in ANC documentation quality and service indicators over time.

Where appropriate, stratified analyses were conducted by facility type and year to explore variation in documentation quality and GA recording patterns across different settings. All analyses were performed using standard statistical software, and findings were presented in tables to support interpretation of trends in ANC attendance, gestational age distribution, and documentation quality over the study period.

The prospective pilot phase assessed documentation quality among 200 pregnant women using four predefined indicators: gestational age recording, completeness of ANC visit-date documentation, record legibility/readability, and missing data. These indicators were evaluated using electronic records generated by the DHIS2 Tracker and compared with paper-based ANC records, using the same assessment criteria, to determine improvements in documentation quality following implementation of the electronic system.

Results from the retrospective record review are presented in **Table 1**, summarising ANC attendance patterns, gestational age documentation, and related indicators from 2019–2022. Findings from the prospective pilot evaluation are presented in **Table 2**, showing changes in documentation quality indicators following implementation of the DHIS2 Tracker electronic tool.

Ethical Considerations

Ethical approval was obtained from the KCMC Research Committee (Ref: 2643) and the National Institute for Medical Research (Ref: NIMR/HQ/R.Sa/Vol.IX/4480). Written informed consent was obtained for the prospective pilot.

Results

Retrospective results

The retrospective phase findings present an analysis of antenatal care attendance, delivery rates, gestational age (GA) distribution, and completeness of pregnancy outcome records across rural and urban health facilities from 2019 to 2022. The data were assessed to examine trends in maternal service utilization and the quality of routinely collected records, with particular attention to ANC attendance within gestational age windows relevant to maternal health interventions and vaccine eligibility, as well as missing GA information.

Table 1
Retrospective dataset (N = 81,843) describing routine ANC documentation trends

Year	Facility	Attendance n (%)†	GA Recorded (Denominator) n	20–23 weeks n (%)‡	24–28 weeks n (%)‡	29–32 weeks n (%)‡	33–36 weeks n (%)‡	≥ 37 weeks n (%)‡	Missing GA n (%)§
2019	Rural	2,990 (3.7)	1,609	398 (24.7)	608 (37.8)	314 (19.5)	207 (12.9)	82 (5.1)	309 (2.2)
2020	Rural	3,231 (3.9)	1,984	551 (27.8)	743 (37.4)	372 (18.8)	227 (11.4)	91 (4.6)	369 (2.6)
2021	Rural	12,784 (15.6)	1,589	420 (26.4)	549 (34.6)	320 (20.1)	214 (13.5)	86 (5.4)	559 (4.0)
2022	Rural	17,322 (21.2)	1,968	556 (28.3)	588 (29.9)	378 (19.2)	272 (13.8)	174 (8.8)	74 (0.5)
2019	Urban	3,803 (4.6)	5,977	1,626 (27.2)	1,863 (31.1)	1,032 (17.3)	813 (13.6)	643 (10.8)	2,162 (15.3)
2020	Urban	3,224 (3.9)	7,039	1,637 (23.3)	2,125 (30.2)	1,356 (19.3)	1,042 (14.8)	879 (12.5)	1,699 (12.1)
2021	Urban	13,696 (16.7)	8,022	1,974 (24.6)	2,605 (32.5)	1,438 (17.9)	1,133 (14.1)	872 (10.9)	3,040 (21.6)
2022	Urban	24,793 (30.3)	11,330	2,546 (22.5)	3,400 (30.0)	2,114 (18.7)	1,614 (14.2)	1,656 (14.6)	5,881 (41.7)

Footnotes

† Percentages for attendance were calculated using the total ANC records included in the study (N = 81,843).

‡ Percentages for gestational age categories were calculated using the number of records with documented gestational age (GA Recorded denominator) within each facility-year.

§ Percentages for missing gestational age were calculated using the total number of ANC records included in the retrospective review (N = 14,093 missing GA records across all years).

Interpretation

Table 1 shows substantial variation in antenatal care (ANC) attendance, gestational age (GA) distribution, and completeness of GA documentation across rural and urban facilities from 2019 to 2022. Overall, ANC attendance increased markedly over time, particularly in urban facilities, which accounted for the largest proportion of records in 2022 (30.3%), compared with rural facilities (21.2%).

Among records with documented gestational age, the majority of women attended ANC between **24–28 weeks of gestation** across all years and facility types, representing approximately 30–38% of recorded visits. Attendance within the **20–23-week window**, which is important for timely maternal vaccination and other preventive interventions, ranged from 22.5% to 28.3%, with slightly higher proportions observed in rural facilities during later years. Attendance at later gestational ages (≥ 37 weeks) remained relatively low but increased over time, particularly in urban facilities (10.8% in 2019 to 14.6% in 2022).

The completeness of gestational age documentation differed considerably by facility type. Urban facilities accounted for the majority of missing GA records, rising from 2,162 cases (15.3% of all missing records) in 2019 to 5,881 cases (41.7%) in 2022. In contrast, rural facilities had substantially fewer missing GA records, with the proportion declining sharply to 0.5% in 2022. These findings suggest improved documentation practices in rural facilities over time, while the growing volume of ANC attendance in urban facilities may have contributed to persistent challenges in maintaining complete gestational age records. Overall, the results highlight the need to strengthen gestational age documentation, particularly in high-volume urban settings, to support accurate monitoring of maternal health interventions and vaccine eligibility.

Prospective Results

The prospective phase evaluated the effectiveness of the DHIS2 Tracker-based electronic tool in improving the completeness and quality of antenatal care (ANC) documentation during pilot implementation. A total of 200 pregnant women were enrolled, and their ANC records were captured using the customized DHIS2 Tracker platform. The findings below **Table 2**, demonstrate the contribution of the electronic system to more complete, standardized, and reliable ANC documentation

Table 2: Prospective pilot assessment (n = 200) evaluating documentation quality improvements after the introduction of the DHIS2 Tracker E-tool.

Documentation Indicator	Paper Registers n/N (%)	E-tool n/N (%)	Improvement (Percentage Points)
Complete gestational age recording	67,750/81,843 (82.8)	192/200 (96.0)†	+13.2
Complete visit-date recording	136/200 (68.0)*	200/200 (100.0)‡	+32.0
Legible records	148/200 (74.0)*	200/200 (100.0)‡	+26.0

Abbreviations: ANC, antenatal care.

Footnotes:

† Gestational age completeness for the E-tool was assessed among the 200 records reviewed during the pilot implementation.

‡ Complete visit-date recording and legibility were observed in all E-tool records reviewed during the pilot implementation.

Paper-register visit-date completeness and legibility were assessed through retrospective documentation audits of sampled records.

Complete gestational age recording in paper registers was calculated from 81,843 retrospective ANC records, of which 14,093 records had missing gestational age information.

Improvement in percentage points was calculated as the difference between E-tool and paper-register values.

The E-tool incorporated mandatory data-entry fields and validation checks that prevented submission of incomplete records.

Interpretation of E-tool Results

The implementation of the DHIS2 Tracker-based E-tool demonstrated marked improvements in antenatal care documentation completeness and quality indicators. Gestational age recording reached 96.0% among the E-tool records reviewed during the pilot implementation, indicating a high level of completeness and a substantial reduction in missing clinical information compared to routine paper-based registers.

A complete documentation of visit dates was achieved (100%), reflecting the effectiveness of the system's mandatory data-entry fields and validation checks, which ensured that all required fields were completed before record submission. This design feature eliminated missing visit-date entries and strengthened the reliability of routine ANC monitoring data.

Similarly, record legibility improved to 100%, indicating that all electronic entries were clearly readable and free from interpretation challenges commonly associated with handwritten paper registers. This improvement enhances the usability of data for clinical decision-making, supervision, and reporting.

Overall, the findings suggest that the E-tool substantially enhances the completeness and quality of antenatal care documentation by reducing missing data, enforcing standardized data entry, and eliminating readability constraints inherent in paper-based systems. These improvements support stronger routine data use for maternal health service monitoring and continuity of care.

Note:- 100% among records reviewed during the pilot implementation

Discussion

The findings showed that data Quality dimensions improved by the DHIS2-Enabled Electronic Tool which demonstrates substantial improvements across four critical dimensions of health information quality including the completeness of documentation, documentation quality, legibility/readability, and reduction of missing data. These dimensions are widely recognized indicators of routine health information system performance and are essential for ensuring accurate clinical decision-making, continuity of care, and effective health system monitoring (Nutley & Reynolds, 2013; WHO, 2019).

Completeness of documentation improved considerably following implementation of the DHIS2-enabled electronic tool. Complete gestational age recording increased from 82.8% in paper-based registers to 96.0% in the electronic system, while visit-date documentation reached 100%. These findings suggest that electronic data capture substantially reduces omissions that commonly occur in routine paper records. The use of mandatory fields, real-time validation prompts, and standardized electronic forms ensures that essential clinical information cannot easily be skipped during patient encounters. Similar improvements in documentation completeness have been reported in DHIS2 implementations and other digital health interventions in low- and middle-income countries, where electronic systems have strengthened routine health information systems and improved data availability for decision-making (Braa et al., 2012; WHO, 2019; Labrique et al., 2018).

Beyond completeness, the electronic system improved the overall quality of ANC documentation. Documentation quality encompasses accuracy, consistency, timeliness, and reliability of recorded information. The E-tool facilitated standardized data entry, automated calculations, longitudinal tracking, and structured clinical workflows, thereby minimizing inconsistencies commonly observed in paper records. Similar findings have been reported in Tanzania and other low-resource settings where digital systems reduced transcription errors and improved the reliability of routine health information data (Rumisha et al., 2020; German et al., 2023). Improved documentation quality is particularly important for gestational age monitoring because accurate pregnancy dating influences maternal vaccination schedules, risk assessment, and obstetric decision-making.

The improvement in record legibility from 74.0% in paper-based registers to 100% in the E-tool highlights another important advantage of digital documentation. Handwritten records are often affected by poor handwriting, incomplete entries, and interpretive difficulties, which may compromise patient safety and continuity of care. Electronic records eliminate handwriting-related errors by producing standardized and clearly readable information. Fraser et al. (2005) reported that improved readability is one of the major benefits of electronic medical records, particularly in resource-constrained settings where documentation quality may be compromised by high workloads. Enhanced readability also facilitates data retrieval, clinical review, supervision, and secondary use of data for program monitoring and health planning.

A major finding of this study was the reduction of missing information following the implementation of the E-tool. Missing gestational age data represented a substantial challenge within routine paper records, particularly in urban facilities where missing values increased considerably over time. Electronic systems reduce missing data through compulsory data fields, automated validation rules, and immediate identification of incomplete records during data entry. The WHO recommendations on digital health interventions emphasize that electronic systems can improve data quality by minimizing missing information and strengthening accountability within health information systems (WHO, 2019). Reducing missing data is particularly important in maternal health because incomplete records may compromise gestational age estimation, eligibility assessment for maternal vaccines, monitoring of pregnancy progression, and linkage between ANC and delivery outcomes.

The substantial improvement in data completeness observed following E-tool implementation can largely be attributed to the capabilities of the DHIS2 Tracker platform. Unlike paper-based systems, DHIS2 Tracker captures individual-level longitudinal records and incorporates structured electronic forms, mandatory fields, validation rules, appointment scheduling, and automated follow-up mechanisms. These features reduce opportunities for missing data, transcription errors, and inconsistencies while supporting real-time data entry and patient tracking across multiple visits. The platform was specifically designed to facilitate case-based monitoring and longitudinal follow-up, enabling healthcare providers to capture more complete and timely information at the point of care. Consequently, the improvements in gestational age recording, visit-date documentation, record legibility, and overall documentation quality observed in this study are consistent with the documented benefits of DHIS2 Tracker implementations in strengthening data quality and reducing information loss in routine health services (DHIS2, 2023; WHO, 2019; Braa et al., 2012).

An important distinction should be made between Tanzania's national DHIS2 system and the customized DHIS2 Tracker used in this study. The national DHIS2 platform primarily serves as a Health Management Information System, collecting and reporting aggregated facility-level indicators for monitoring and planning. In contrast, the customized DHIS2 Tracker instance was designed to capture patient-level maternal health information and support longitudinal tracking of individual women throughout pregnancy and delivery. While the national DHIS2 focuses on aggregate reporting, Tracker applications enable continuous individual-level monitoring, automated validation checks, appointment tracking, and follow-up management. This distinction explains why the E-tool was able to address documentation gaps, improve documentation quality, reduce missing data, and strengthen continuity of care in ways that aggregate reporting systems alone cannot achieve.

Despite the documented improvements in data quality, healthcare workers were still required to maintain both paper registers and electronic records simultaneously. This parallel reporting approach creates a substantial documentation burden that can reduce efficiency and contribute to staff workload, particularly in busy antenatal clinics with limited human resources. Double documentation requires healthcare workers to record the same information multiple times, increasing the risk of inconsistencies between systems and reducing the time available for direct patient care. Similar challenges have been documented in digital health implementations across sub-Saharan Africa, where parallel reporting systems have limited the efficiency gains of electronic technologies (Labrique et al., 2018; WHO, 2021).

Although the customized DHIS2 Tracker demonstrated clear improvements in ANC documentation quality, its lack of integration with the national DHIS2 platform represents an important limitation and policy challenge. Non-integrated systems can create data silos, limit information sharing across programs, and reduce opportunities for comprehensive analysis at district and national levels. The WHO Global Strategy on Digital Health emphasizes interoperability as a key requirement for sustainable digital health investments (WHO, 2021). Future digital health investments should therefore prioritize interoperability standards that allow individual-level maternal health systems to contribute directly to national reporting requirements. Such integration could eliminate duplicate reporting processes, improve documentation completeness, reduce missing data, and strengthen evidence-based maternal health planning.

Study Limitation

A limitation of this study is that it assessed completeness, documentation quality, legibility, and the reduction of missing data rather than validating clinical accuracy against an external gold standard. In addition, the prospective E-tool implementation phase may have been influenced by the Hawthorne effect, whereby healthcare workers improved documentation due to awareness of being observed and the novelty of the system. The relatively small prospective sample size (n = 200) compared with the large retrospective dataset (N = 81,843) may limit direct comparability between paper-based and electronic systems. Furthermore, the E-tool was implemented in a limited number of facilities, primarily in an urban setting, which may affect generalizability to rural and lower-resource contexts. The concurrent use of paper and electronic registers may have introduced duplication bias and additional workload, potentially affecting consistency of documentation. Finally, the study did not assess cost-effectiveness, feasibility, or long-term sustainability of the DHIS2 Tracker system. Future studies should address these gaps through larger multi-site evaluations, randomized implementation designs, and economic analyses

Recommendations

Future research should examine the long-term sustainability, user acceptability, cost-effectiveness, interoperability with national DHIS2 systems, and the impact of digital maternal health systems on maternal and newborn health outcomes. Qualitative assessments involving both healthcare providers and pregnant women are also needed to provide deeper insights into system usability, acceptability, and contextual factors influencing implementation.

From a policy and implementation perspective, the findings support scaling up the E-tool across both rural and urban health facilities to evaluate its effectiveness at a broader national level. Investment in ultrasound training for nurses and midwives is recommended to complement digital gestational age recording and improve the accuracy of pregnancy dating. In addition, strengthening digital infrastructure, technical support, and supportive supervision, particularly in rural settings, is essential to ensure the consistent and sustainable use of the E-tool.

Declarations

Conception and Author’s Contribution

BM contributed to the collaboration and supervision of the project. AM was involved in the project's conception and design, as well as in working with MM to adapt and develop the protocol from the main study. AM, MM, AL, GN, MO, GL, and PZ participated in data collection and analysis. All authors were involved in reviewing and approving the final manuscript.Top of Form

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