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Child Electronic Growth Monitoring System: An innovative and sustainable approach for establishing the Kaduna Infant Development (KID) Study in Nigeria

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Abstract

Background: Developing countries bear the burden of childhood stunting but lack resources for cohort studies to develop preventive strategies. To enable future prospective studies, we designed and tested the Child Electronic Growth Monitoring System (CEGROMS) using a readily available electronic data capture platform, the Research Electronic Data Capture (REDCap).

Objectives: To demonstrate the feasibility of using CEGROMS for data collection for a pilot study for the Kaduna Infant Development (KID) Birth Cohort Study in Nigeria.

Methods: CEGROMS consists of the data capture form for growth monitoring, a central cloud server, electronic tablets, and desktop computer. We implemented the pilot study in 2017-2019 at the Barau Dikko Teaching Hospital, Kaduna, Nigeria. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for completeness of baseline data (relative to individuals with incomplete data) and completion of follow-up at different time points (relative to individuals with no follow-up visit) by the participant characteristics. Complete data were defined as date of birth, sex, and birthweight recorded at recruitment.

Results: Among 3152 infant records in CEGROMS, 2789 (88.5%) had complete data. Of these, 1905 (68.3%) had at least one follow-up visit. The main determinants of data completeness were health facility delivery (OR 19.17, 95% CI 13.65, 26.92) and tertiary education (OR 3.54, 95% CI 2.69, 4.67). Follow-up was greater for women with tertiary education (OR 1.33, 95% CI 1.06, 1.51 for at least one visit). Maternal education is associated with completeness and follow-up (following adjustments for parity and employment).

Conclusions: The CEGROMS electronic data collection system enables complete and consistent data collection. The data will enable design of strategies to improve follow-up in the future implementation of the birth cohort study.

KEYWORDS
birth cohort, childhood stunting, growth registry

1 | INTRODUCTION

Childhood stunting often begins *in utero* and predominantly occurs in the first 1000 days of life, resulting in severe physical and neurocognitive damage, as well as increased risk of mortality.[1] Globally, the developing countries, including sub-Saharan Africa (SSA), disproportionally bear the burden of childhood stunting and its sequelae.[2-5] Childhood stunting is a risk factor for adverse health outcomes in adults such as obesity, signifying the need for growth monitoring of children to identify stunting early in life.[6] Contemporary evidence indicates a rising trend of childhood overweight and obesity in developing countries.[2,7] These nations are still contending with childhood stunting and micronutrient deficiencies when almost all of them now have the double burden of undernutrition and overnutrition as a result of epidemiologic, nutritional, and economic transitions.[7-9]

Longitudinal studies are pertinent for insight on the timing of interventions in early life to prevent stunting and halt the impending chronic disease epidemic and its economic consequences in developing countries.[8-13] A review of existing birth cohort studies shows that the majority of them are in high-income countries, and only a few are from SSA.[14] Among these few in SSA, not all assessed childhood growth for more than a year and were mostly conducted in only five African countries.[15-20] Urban residence has been identified as a risk factor for intrauterine and postnatal malnutrition in Africa, the continent with the highest urbanisation rate in the world.[21,22] A number of the existing longitudinal data collection systems on the continent are located in rural areas with relatively homogenous populations, which are unsuitable for addressing the complex interaction of sociodemographic and economic factors with growth faltering and urbanisation.[23,24]

In Nigeria, a rapidly urbanising and the most populous country in Africa with a population of 200 million, stunting occurs in 36.9% of children.[25] Nigeria is among the five countries contributing 45% of the global burden of preterm births and where most of the small-for-gestational-age infants are born in the world.[26,27] Most of the child growth data in the country are from cross-sectional and household surveys.[22,28] Unfortunately, the lack of resources required for establishing and sustaining longitudinal data collection is the major challenge in resource-constrained settings like Nigeria.[9] The District Health Information System (DHIS), a software system for managing health facility data and monitoring priority health indicators, could not be exploited for follow-up of individual persons for several reasons.[29,30] Therefore, we designed and piloted the Child Electronic Growth Monitoring System (CEGROMS) using a readily available electronic data capture platform, the Research Electronic Data Capture (REDCap).[31] The primary objective of the pilot study was to demonstrate the feasibility of using CEGROMS for complete and consistent data collection for a longitudinal study, the Kaduna Infant Development (KID) Birth Cohort Study. The secondary objective was to evaluate the determinants of sustainable participant follow-up. A third objective was to demonstrate how CEGROMS could be used for a sub-study to explore relevant exposures and outcomes.

Synopsis

Study question

Is there an electronic data collection system that can be used sustainably for longitudinal growth monitoring in a resource-constrained setting?

What is known about this topic

- Childhood stunting often begins in utero and predominantly occurs in the first 1000 days of life, resulting in severe physical and neurocognitive damage, as well as increased risk of mortality.
- The burden of childhood stunting is disproportionately high in developing countries, but the development of preventive strategies is hampered by lack of resources.
- Paper-based growth monitoring registers could not be exploited for follow-up of individual persons for several reasons.

What this study adds

- It was feasible to use Child Electronic Growth Monitoring System (CEGROMS) to enrol mother-child pairs for longitudinal study and surveillance.
- Data completeness and participation in successive follow-up visits were associated with place of delivery and factors correlated with maternal education.
- Participants could be re-contacted and recruited later for additional data collection using CEGROMS.

2 | METHODS

2.1 | Child Electronic Growth Monitoring System (CEGROMS)

The Child Electronic Growth Monitoring System (CEGROMS) consists of the data capture form for growth monitoring, a server, electronic tablets, and desktop computer (Figure S1).[31,32] We adopted and adapted the growth monitoring register (Figure S2) used in

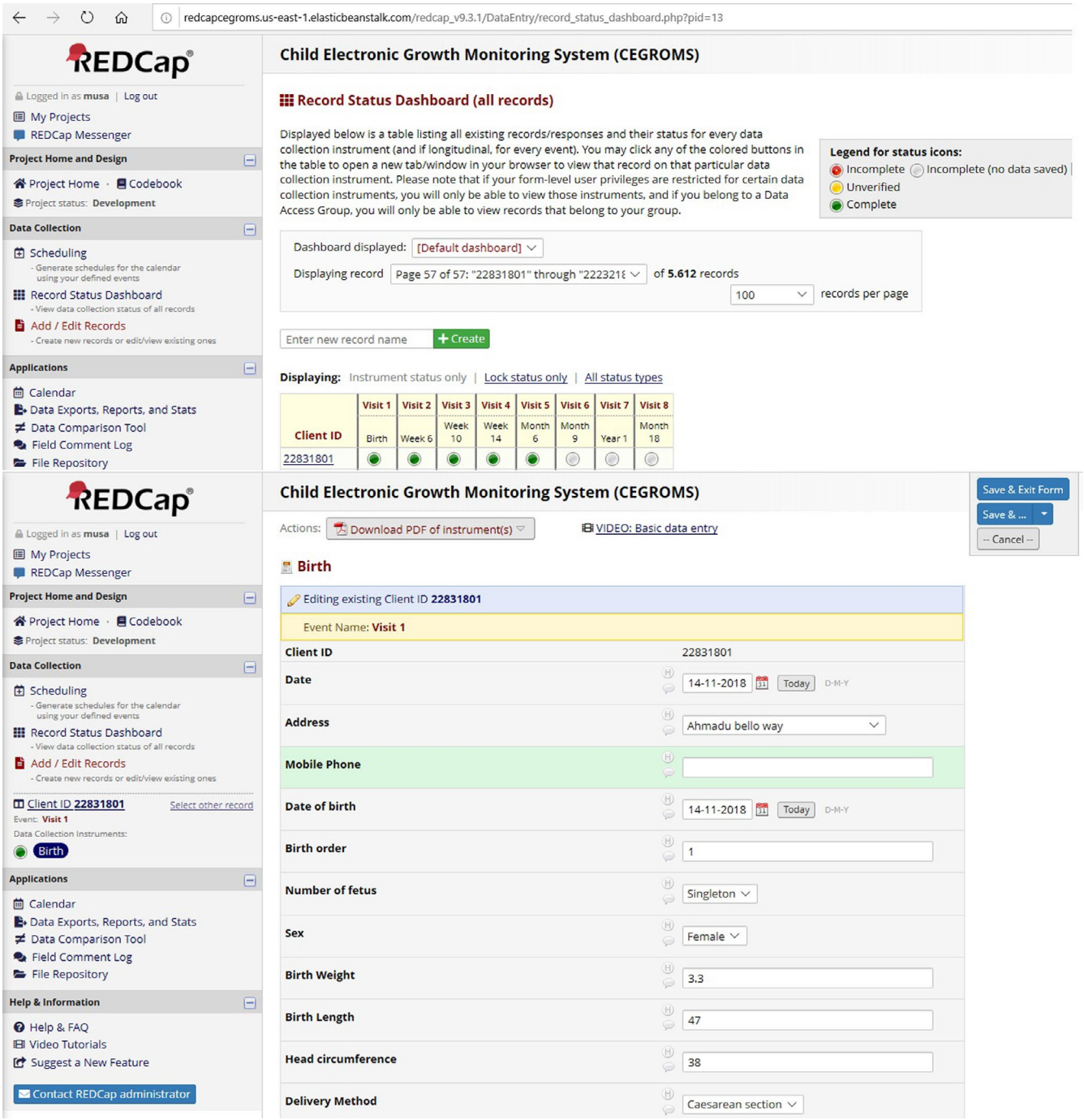

FIGURE 1 CEGROMS data capture form [Colour figure can be viewed at wileyonlinelibrary.com]

the Nigerian public health system for the Child Electronic Growth Monitoring System data capture form (Figure 1). The CEGROMS data capture form was accessed securely over the Internet via a web browser interface or a mobile application installed on an android device (offline). The CEGROMS data form captured information of mother-child pairs for baseline and successive follow-up visits. During the first visit, a unique identification number was assigned to each participant pair. We used the branching logic capabilities of the REDCap software to implement relational database requirements linking maternal and infant information (Table S1). The linked data collected during all the visits using the data capture form constituted a record for each participant (mother-child/children for multiple births) pair. The pilot study data clerk was trained on operating REDCap on an android device to record data into the CEGROMS data capture form and upload it to the cloud database onsite in the clinic. The data manager was responsible for database management and maintaining CEGROMS information technology infrastructure.

We implemented the pilot study at the Child Welfare Clinic of Barau Dikko Teaching Hospital, Kaduna, Kaduna State (Northwestern

Nigeria) from 1 January 2017 to 26 April 2019. Kaduna is an expanding urban metropolis occupying an area of 260 km^2 and is the fourth most populous city in Nigeria with 1.6 million people.[33,34] The teaching hospital was selected because of its central location, extensive geographical coverage, and diversity of the population using this referral health facility. International scientific advisers supported the pilot study that was implemented by the project steering committee of investigators. The operations involved an administrative officer, data manager, scientific supervisors, public health physicians and nurses, nutritionists, and data clerk. The scientific supervisors, public health physicians, nutritionists, and nurses are the staff of the Teaching Hospital. The investigators are employees of the Kaduna State University (Nigeria) who designed the study protocol, supervised data collection, management, and analysis. Epidemiological Resources and Investigation Consultancy (ERIC) Limited and Perinatal Epidemiological Research Unit (Kaduna, Nigeria) provided infrastructure, administrative support, human resource, and logistics for data collection and management.

2.2 | Participant recruitment and follow-up procedure

We recruited mother-child pairs when children were brought for the first immunisation at the study site around the time of birth. All the follow-up growth monitoring visits coincided with routine scheduled immunisations at 6, 10, 14, 24, and 36 weeks. The routine follow-up visit at 24 weeks is for vitamin A supplementation and growth monitoring. Our recruitment of participants considered the inclusion of all mother-infant pairs attending immunisation and growth monitoring at the study site. The goal was to achieve integration of those that gave birth at home since in this area only 32.4% of women deliver in a health facility, but 78.3% of all infants receive the first (BCG) vaccination around the time of birth.[35] The flow chart for recruitment of mother-child pairs from CEGROMS for the pilot Kaduna Infant Development (KID) birth cohort study is in Figure 2. The study was conducted within the context of developmental surveillance, which is a longitudinal, continuous, cumulative process of observing the child's development and identifying potential risk and protective factors for developmental delay.[36] We conducted a sub-study after 22 months of pilot study (October-November 2018) using an additional data capture form on the CEGROMS platform (Figure S3) to explore the determinants of infant feeding practices.

2.3 | Exposure variable measurements

Sociodemographic, obstetric, and infant birth characteristics were recorded in CEGROMS during enrolment (Table S1). Household addresses of participants were assigned to the area postal code and geocoded using a central landmark. We used this central landmark to estimate the distance between participant home and the hospital in kilometres.

2.4 | Outcome variable measurements

Anthropometric measurements were done at baseline and subsequent follow-up visits. The head circumference, length, and birthweight were measured at birth by trained nurses/midwives for infants delivered in the health facility or during BCG immunisation

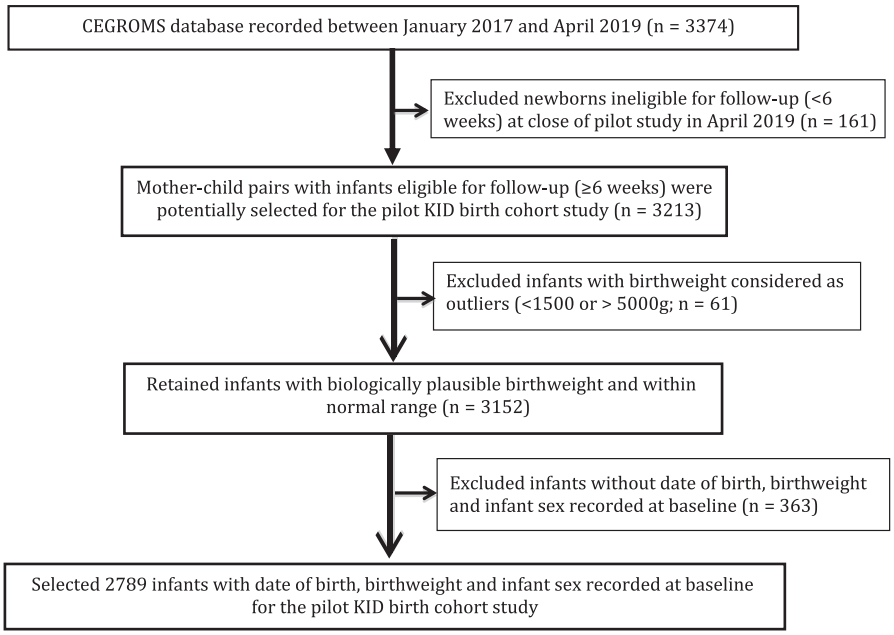

FIGURE 2 The KID Birth Cohort Study participants' selection pathway

for those born at home. Nutritionists performed the anthropometric measurements during all the infant visits in the Child Welfare Clinic. We adopted methods used to perform accurate, precise, and standardised anthropometric measurements for the INTERGROWTH-21st study.[37] This protocol was used to train all the nutritionists that performed our anthropometric measurements. During clinic sessions, the data clerk entered the collected information into the CEGROMS data capture form in real-time. Data were usually first recorded into the paper-based register that is permanently kept under lock in the clinic.

2.5 | Data management

In January 2017, we installed REDCap under the terms of the user agreement with Vanderbilt University, USA.[31] Our data manager handled all the aspects of REDCap installation, server maintenance, security, online access for data collection, data upload, and backup support throughout the pilot study. The REDCap database server software was hosted on a local server at Perinatal Epidemiological Research Unit (Kaduna, Nigeria) exclusively for CEGROMS. In the initial months of the implementation, we encountered recurrent power outage from the municipal electricity source that impeded uninterrupted access to the server. Subsequently, we procured solar panels and batteries that served as a backup electricity source for the server. We currently maintain CEGROMS on a mirror server using the cloud-based server that supports REDCap through Amazon's AWS Cloud Formation service for a fee.

We adopted and used the protocol for file storage and backup previously described.[38] The data manager backed up the databases daily and kept several copies on site. Once a week, a copy is encrypted and stored off-site. At the closure of the pilot data collection, we downloaded the accumulated database directly from CEGROMS. We removed participants' personal identification information from the database that was handled and protected with strict confidentiality. Data were cleaned and deposited into a secure database stored within the project's domain and cloud backup. Requests from study researchers for analysis of cohort data require a detailed analysis plan and approval by the steering committee. All data transferred to researchers for analysis are anonymised so that researchers cannot link data back to any specific individual.

2.6 | Statistical analysis

In this pilot study, we considered the feasibility of adapting and integrating CEGROMS into routine child growth monitoring, and the practicality of using it for longitudinal data collection. Hence, we measured the feasibility of collecting complete data and consistent participant follow-up by assessing data completeness and follow-up rates. Data completeness was defined as the proportion of stored data at baseline from CEGROMS meeting our completeness criteria against the denominator of the total number of participants. We considered data as complete if the Unique ID was included, as well as the date of birth, infant sex, and birthweight. These variables are essential for the longitudinal data linkage and analysis. We classified everyone by a binary variable for 1 = complete or 0 = not complete. We calculated the data completeness rate overall and according to participant characteristics. We tested the association of sociodemographic characteristics with data completeness estimated as odds ratio and 95% confidence interval (CI) using logistic regression. We adjusted for parity, maternal education, and employment status to identify independent determinants of the follow-up visit. We considered that confounding was present if the difference between the unadjusted and the confounder adjusted odds ratio was different by 10% or more.

Only infants who have at least one follow-up visit and attained the minimum age for a follow-up visit were included in the follow-up analysis; for example, the follow-up rate for 24 weeks involved only infants who were 24 weeks or older at the close of the pilot study. The comparison group were participants lost to follow-up defined as infants who did not have weight recorded in any follow-up visit. We calculated the follow-up completion with infants who had weight recorded at different time points as the numerator and total eligible participants for the follow-up visit at the specified time point as the denominator.[39] Participants who had infant weight recorded for all five follow-up visits were categorised as having full follow-up. An overall follow-up completion was estimated for at least one follow-up visit, 24 weeks (a visit for growth monitoring and vitamin A supplementation), and full follow-up. We evaluated the association of participant characteristics and follow-up for these three follow-up time points relative to participants with no follow-up. We adjusted for parity, maternal education, and employment status to identify independent determinants of the follow-up visit. We considered that confounding was present if the unadjusted and adjusted odds ratios were different by at least 10%.

We assessed the external validity of the anthropometric measurements for the pilot KID Birth Cohort Study by comparing with standards of other Nigerian studies and INTERGROWTH-21 (Table S2).[40-43] The sub-study participants included individuals listed in CEGROMS at 22 months of the pilot study (October 2018) and have a phone number. Risk difference (RD) was used to assess the association of baseline maternal characteristics and participation in the sub-study. The non-participants were individuals for whom we had baseline data and phone numbers but had no contact with the persons. We calculated the overall sub-study participation rate and in relation to maternal characteristics (eg maternal education categorised as tertiary or less than tertiary education). We then calculated the RD (95% CI) by subtracting the sub-study participation rate in mothers with less than tertiary education from the rate in the group with tertiary education.[44] An adjusted RD was estimated, controlling for maternal education, employment status, and parity. The adjusted variables were mutually controlled in their adjusted models. The

characteristics of sub-study participants are outlined by place of delivery in Table S3.

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS), version 23.0 (IBM Corp., New York, USA).

2.7 | Ethics approval

We obtained the Institutional Review Board approval for CEGROMS, Kaduna Infant Development Birth Cohort Study, and sub-study from the Health Research Ethics Committee of the Ministry of Health and Human Services, Kaduna State, Nigeria (MOH/ADM/744/VOL/584). The study complied with the Helsinki Declaration and relevant national legislation. Additional informed consent was obtained from mothers who were interviewed by telephone for the sub-study.

3 | RESULTS

3.1 | Characteristics of the KID Birth Cohort Study

Among 3152 infant records in CEGROMS, 2789 (88.5%) had complete data. Of these, 1905 (68.3%) had at least one follow-up visit (Table 1). We found that 42.2% of participants lived < 5km from the clinic. The mothers were 29 years on the average, 45% received tertiary education, only 36% were employed, 32% were primiparous, 97.7% delivered in a health facility, and 20% gave birth via caesarean section. Half of the children were males, 1.2% were multiple births, the mean birthweight was 3049 g (SD 542), and 97% of the infants commenced breast feeding within 24 hours after delivery. At baseline, 90.4% of the participants had a phone number available in CEGROMS.

TABLE 1 Characteristics of the pilot KID Birth Cohort Study participants at baseline

Variable	Number	%
Recruitment year		
2017	1427	51.2
2018	1215	43.6
2019	147	5.3
Follow-up rate		
At least one follow-up visit	1905	68.3
No follow-up visit	884	31.7
Participation in each follow-up visit		
Six weeks (n = 1905[a])	1744	91.5
Ten weeks (n = 1905[a])	1470	77.2
Fourteen weeks (n = 1902[a])	1090	57.8
Twenty-four weeks (n = 1843[a])	585	31.7
Thirty-six weeks (n = 1703[a])	380	22.3
Distance from home to the clinic		
<5 km	1157	42.2
5-9 km	681	24.8
≥10 km	906	33.0
Availability of phone number in CEGROMS	2520	90.4
Maternal characteristics		
Mean age at birth of index child (SD)	2638	29.1 (5.9)
Mothers aged ≥ 35 y	560	20.1
Tertiary educated	1247	44.6
Employed	953	35.6
Parity, Primiparae	880	32.0
Place of delivery, health facility	2716	97.7
Type of delivery, caesarean section	555	20.0
Infant characteristics		
Multiple births	34	1.2
Sex, male	1425	51.1
Mean birthweight (SD), g		3049 (542)
Low birthweight (<2500 g)—all births	286	10.3
Low birthweight—term births only	215	8.2
Macrosomia (>4000 g)	131	4.8
Initiated breast feeding within 24 h	2620	96.6

[a]Number of infants that have attained the minimum age is eligible for this follow-up visit analysis.

3.2 | Factors associated with data completeness at baseline

The major factors that predict data completeness (Table 2) included facility delivery, primiparity, tertiary education, and maternal employment.

3.3 | Participant follow-up rates and associated factors

The participant follow-up rate for at least one follow-up visit was 68.3% (1905 of 2789). Among the eligible participants, 44.0% participated in the 24-week follow-up visit, and 25.4% completed all five follow-up visits (Table 3). There was a reduction in the participation rate in the successive follow-up visits (Table 1): 6 weeks (91.5%), ten weeks (77.2%), 14 weeks (57.8%), 24 weeks (31.7%), and 36 weeks (22.3%). Mothers whose home were located <5 km from the hospital had greater odds than those located ≥5 km of coming for the 24-week follow-up visit (OR 1.26, 95% CI 1.01, 1.57) but not full follow-up (OR 1.06 95% CI 0.79, 1.44). Compared with mothers with less education, the tertiary educated had higher odds of participating in at least one follow-up visit, 24-week follow-up, and full follow-up visits. Maternal education was associated with follow-up after adjusting for parity and employment.

TABLE 2 Data completeness by participant characteristic at baseline: rate and odds ratio (n = 3152)

Variable	Complete data	Incomplete data	Odds ratio (95% confidence interval)	
			Unadjusted	Adjusted
Overall completeness rate	2789 (88.5)	363 (11.5)		
Distance from home to clinic				
<5 km	1157 (86.3)	183 (13.7)	0.68 (0.55, 0.86)	0.77 (0.61, 0.97)
≥5 km	1587 (90.2)	172 (9.8)	1.00 (Reference)	1.00 (Reference)
Place of delivery				
Health facility	2716 (91.6)	250 (8.4)	19.17 (13.65, 26.92)	17.71 (12.46, 25.17)
Home	65 (36.7)	112 (63.3)	1.00 (Reference)	1.00 (Reference)
Type of delivery				
Caesarean	555 (89.5)	65 (10.5)	1.07 (0.79, 1.44)	0.84 (0.62, 1.14)
Vaginal	2220 (88.3)	295 (11.7)	1.00 (Reference)	1.00 (Reference)
Maternal age				
≥35 years	560 (89.7)	64 (10.3)	1.18 (0.88, 1.57)	1.18 (0.88, 1.59)
<35 years	2110 (88.0)	288 (12.0)	1.00 (Reference)	1.00 (Reference)
Parity				
Primiparae	880 (91.6)	81 (8.4)	1.59 (1.22, 2.07)	1.48 (1.13, 1.93)
Multiparae	1872 (87.3)	273 (12.7)	1.00 (Reference)	1.00 (Reference)
Maternal education				
Tertiary	1247 (94.7)	70 (5.3)	3.54 (2.69, 4.67)	3.08 (2.32, 4.09)
Less than tertiary	1429 (83.7)	278 (16.3)	1.00 (Reference)	1.00 (Reference)
Maternal employment				
Employed	953 (92.9)	73 (7.1)	2.08 (1.58, 2.73)	1.62 (1.22, 2.14)
Unemployed	1726 (86.3)	274 (13.7)	1.00 (Reference)	1.00 (Reference)

Note: Odds ratios were adjusted for parity, maternal education, and employment status.

3.4 | Participation in sub-study by baseline maternal characteristics

The overall participation rate in the sub-study by baseline KID pilot study participants was 43.1%, and it varied according to maternal characteristics (Table 4). The sub-study participation rate among mothers who delivered at home was 20.7% (95% CI 12.2, 29.2) more than those than delivered in the health facility. The participation rate of tertiary-educated mothers was 4% (95% CI 0.1, 8.2) higher than those with less than tertiary education.

4 | COMMENT

4.1 | Principal findings

In this study, we designed and piloted the Child Electronic Growth Monitoring System (CEGROMS). It was feasible to use this tool to enrol mother-child pairs and record the required data. This tool enabled us to follow-up these pairs for the pilot of the Kaduna Infant Development (KID) Birth Cohort Study over nine months. We found that the data completeness rate was high at baseline, but that we had a relative paucity of women delivering at home, compared with their high prevalence in the population as a whole.[35] Not surprisingly, follow-up declined over successive follow-up visits. We were able to examine the factors associated with data completeness and follow-up. The primary factor influencing data completeness appears to be the place of delivery. Participation in successive follow-up visits was significantly associated with place of delivery and factors correlated with maternal education. We demonstrated that the KID study participants could be later re-contacted and recruited for additional data collection (sub-study) on infant feeding practices using CEGROMS. Overall, the sub-study participants have similar maternal characteristics as the non-participants.

4.2 | Strengths of the study

Our study had many strengths. We conducted the pilot study in a referral hospital with extensive geographic coverage and ease of participant recruitment. This enabled us to study how the distance between home and hospital affects follow-up. Mothers who

TABLE 3 Participant follow-up by maternal characteristics: rate and odds ratio

Variable	At least one follow-up[a]			24-wk follow-up[a]			Full follow-up[a,c]		
	n (%)	Unadjusted OR (95% CI)	aOR (95% CI)[b]	n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[b]	n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[b]
Overall	1905 (68.3)			585 (44.0)			235 (25.4)		
Distance to clinic									
<5 km	815 (70.4)	1.15 (0.97 1.36)	1.19 (1.00, 1.41)	266 (47.9)	1.26 (1.01, 1.57)	1.28 (1.02, 1.61)	97 (26.5)	1.06 (0.79, 1.44)	1.06 (0.77, 1.44)
≥5 km	1067 (67.2)	1.00 (Reference)	1.00 (Reference)	318 (42.2)	1.00 (Reference)	1.00 (Reference)	138 (25.3)	1.00 (Reference)	1.00 (Reference)
Place of delivery									
Health facility	1858 (68.4)	1.19 (0.69, 2.04)	1.18 (0.69, 2.02)	575 (45.5)	2.05 (0.94, 4.46)	1.89 (0.85, 4.17)	235 (26.1)	Not estimable	Not estimable
Home	42 (64.6)	1.00 (Reference)	1.00 (Reference)	9 (28.1)	1.00 (Reference)	1.00 (Reference)	0 (0.0)	1.00 (Reference)	1.00 (Reference)
Maternal age (y)									
≥35	382 (68.2)	0.97 (0.79, 1.19)	0.97 (0.79, 1.19)	132 (47.0)	1.09 (0.84, 1.43)	1.13 (0.86, 1.49)	55 (28.5)	1.16 (0.81, 1.66)	1.16 (0.80, 1.68)
<35	1461 (69.2)	1.00 (Reference)	1.00 (Reference)	437 (44.7)	1.00 (Reference)	1.00 (Reference)	173 (25.5)	1.00 (Reference)	1.00 (Reference)
Parity									
Primiparae	625 (71.0)	1.14 (0.96, 1.37)	1.13 (0.95, 1.36)	212 (51.0)	1.46 (1.15, 1.84)	1.39 (1.09, 1.78)	75 (28.7)	1.24 (0.89, 1.71)	1.20 (0.86, 1.67)
Multiparae	1263 (67.5)	1.00 (Reference)	1.00 (Reference)	372 (41.6)	1.00 (Reference)	1.00 (Reference)	160 (24.6)	1.00 (Reference)	1.00 (Reference)
Maternal education									
Tertiary	901 (72.3)	1.33 (1.11, 1.55)	1.24 (1.05, 1.48)	290 (50.8)	1.45 (1.16, 1.82)	1.37 (1.08, 1.73)	113 (30.1)	1.37 (1.00, 1.85)	1.27 (0.92, 1.74)
Less than tertiary	952 (66.6)	1.00 (Reference)	1.00 (Reference)	287 (41.5)	1.00 (Reference)	1.00 (Reference)	119 (23.9)	1.00 (Reference)	1.00 (Reference)
Maternal employment									
Employed	688 (72.2)	1.26 (1.06, 1.51)	1.20 (1.00, 1.44)	208 (48.8)	1.20 (0.95, 1.52)	1.16 (0.90, 1.48)	147 (25.3)	1.22 (0.89, 1.67)	1.19 (0.86, 1.66)
Unemployed	1168 (67.7)	1.00 (Reference)	1.00 (Reference)	371 (44.3)	1.00 (Reference)	1.00 (Reference)	147 (25.3)	1.00 (Reference)	1.00 (Reference)

[a]The comparison group were participants recruited at baseline but did not participate in any follow-up.

[b]Adjusted for parity, maternal education, and employment status. The adjusted factors were mutually controlled in their adjusted models.

[c]Participants who had infant weight recorded for all five follow-up visits were defined as having full follow-up.

TABLE 4 Participation in sub-study by maternal characteristics among 2414 participants in the baseline survey: rate and risk difference

Variable	Baseline (n)	Sub-study participants (n)	Non-participants (n)	Participation rate (%)	Risk difference[a] (95% confidence interval)	
					Unadjusted	Adjusted[b]
Overall participation rate	2414	1040	1374	43.1		
Distance from home to clinic						
<5 km	1044	445	599	42.6	−0.5 (−4.5, 3.5)	0.3 (−3.8, 4.4)
≥5 km	1339	577	762	43.1	0.0 (Reference)	0.0 (Reference)
Place of delivery						
Home	145	88	57	60.7	18.7 (10.4, 27.0)	20.7 (12.2, 29.2)
Health facility	2264	950	1314	42.0	0.0 (Reference)	0.0 (Reference)
Type of delivery						
Caesarean	469	201	268	42.9	−0.3 (−5.3, 4.7)	0.4 (−4.9, 5.5)
Vaginal delivery	1936	835	1101	43.1	0.0 (Reference)	0.0 (Reference)
Maternal age (years)						
≥35	492	211	281	42.9	−0.2 (−4.8, 5.1)	−1.0 (−6.1, 4.1)
<35	1844	788	1056	42.7	0.0 (Reference)	0.0 (Reference)
Maternal education						
Tertiary	1047	474	573	45.3	4.1 (0.1, 8.1)	4.1 (0.1, 8.2)
Less than tertiary	1295	533	762	41.2	0.0 (Reference)	0.0 (Reference)
Maternal employment						
Employed	821	365	456	44.5	2.2 (−2.0, 6.4)	1.1 (−3.20, 5.50)
Unemployed	1523	644	879	42.3	0.0 (Reference)	0.0 (Reference)
Parity						
Primiparae	738	314	424	42.5	−0.8 (−5.0, 3.2)	0.2 (−1.3, 1.7)
Multiparae	1646	712	934	43.3	0.0 (Reference)	0.0 (Reference)
Initiation of breast feeding						
>24 h of delivery	90	38	52	42.2	−0.9 (−11.4, 9.5)	0.9 (−11.0, 11.0)
≤24 h of delivery	2316	999	1317	43.1	0.0 (Reference)	0.0 (Reference)

[a]Risk difference expressed as per cent.

[b]Adjusted for parity, maternal education, and employment status. The adjusted factors were mutually controlled in their adjusted models.

initially attended the hospital (site of the pilot study) for delivery and first immunisation might opt for subsequent vaccinations in available clinics nearer to home. Evidence from our results also suggests that mothers who delivered by caesarean section or at home might be unavailable during the first visit to provide their data. The clinic where we did the pilot study conducts routine immunisation and tracks the weight of infants. Hence, missing information could be corrected during follow-up. We did not actively employ any strategy like reminders or incentives for follow-up but depended on maternal self-selection according to the identified factors. Even though the participant follow-up rates were low, CEGROMS enabled us to easily see the reasons for loss to follow-up, which will be useful for planning the future birth cohort study with improved participation rates.

Generally, we plan to devise strategies to improve both the initial response rate for enrolment into the study and the follow-up rate by using publicity, flexible data collection approaches, and providing incentives that will lessen burden of participation.[45] The specific strategies would include obtaining multiple contact phone numbers from participants at baseline or subsequent visits to be used for phone interviews, making reminders for a follow-up visit in the form of telephone calls, and SMS in a preferred language, as well as incentives to support transport for follow-up visits. REDCap has a feature for sending a short message (SMS) to participants that we could use for participant reminders in the future implementation of the KID Birth Cohort Study.

4.3 | Limitations of the data

The main limitations of the pilot study were low enrolment and follow-up rates and the low proportion of home births. Nonetheless, we have learned about the mitigating factors and how we could improve the future implementation of the KID study. A significant

challenge in recruiting a representative sample of participants for perinatal research in Nigeria is the difficulty of enrolling women giving birth at home. Even with recruitment at the immunisation clinic, we were able to recruit only a small proportion of this category of mothers. Despite the baseline underrepresentation of mothers giving birth at home, the distribution of newborn anthropometric measurements was consistent with other Nigerian studies and INTERGROWTH-21.[40-43] In the sub-study, we observed that the women giving birth at home were less educated and displayed lower utilisation of maternal health services including antenatal care, attendance by health professional during delivery and postnatal family planning. Interestingly, their children were breast fed exclusively for a comparable duration, and the prevalence of self-reported diarrhoea during infancy was not significantly different from those born in the health facility. Although we were unable to reach all the participants during the sub-study, our sub-study sample size was high, and the maternal characteristics of the enrolled participants were mostly comparable to the non-participants. An important lesson is that in future utilisation of CEGROMS for sub-studies, we will include a variable categorising participant whom we attempted to contact but could not reach them.

4.4 | Interpretation

Our tool has shown how epidemiological and health informatics collaboration can provide a solution to conducting a longitudinal study in a resource-constrained setting. We have an interest in studying the prenatal and postnatal factors influencing birthweight and early childhood growth and development, but we lacked an electronic medical record system and did not have funding to establish an expensive system. We took advantage of REDCap to create CEGROMS, which addressed the problem of data quality issues associated with paper-based data collection. The system has enabled rapidly generated individual-level follow-up records to pilot the Kaduna Infant Development (KID) Birth Cohort Study during the critical 1000 days of life.[26] CEGROMS is flexible and enabled changes in the data entry template based on experience in the field. It also enabled us to re-contact a subset of women for a sub-study involving additional data collection. In the future implementation of the KID Birth Cohort Study, we plan more extensive data collection on prenatal and early childhood exposures, which would include household, maternal, and paternal variables.

The system we have developed and piloted can be used for research and surveillance of individual-level risk factors to guide public health response. The longitudinal monitoring of childhood growth and development will enable us to investigate the prenatal and postnatal trajectories of both weight and length/height.[46] The electronic growth surveillance system would aid the identification of sensitive periods during early childhood growth and development for the screening and mitigation of stunting and obesity.[47-49] CEGROMS could also be efficiently and effectively scaled-up at sub-national and national levels for growth surveillance.

5 | CONCLUSIONS

CEGROMS is an electronic data collection system that is feasible for complete and consistent data collection. Publicity and incentives could be used to address the factors that we found to predict follow-up during future implementation of the KID Birth Cohort Study.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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REFERENCES

1. de Onis M, Branca F. Childhood stunting: a global perspective. *Matern Child Nutr*. 2016;12(Suppl 1):12-26.
2. United Nations Children's Fund, World Health Organization,TheWorld Bank. *Levels and Trends in Child Malnutrition: Key Findings of the 2019 Edition of the Joint Child Malnutrition Estimates*. Geneva: World Health Organization; 2019.
3. Lartey A. Maternal and child nutrition in Sub-Saharan Africa: challenges and interventions. *Proc Nutr Soc*. 2008;67(1):105-108.
4. Ricci C, Carboo J, Asare H, Smuts CM, Dolman R, Lombard M. Nutritional status as a central determinant of child mortality in sub-Saharan Africa: a quantitative conceptual framework. *Matern Child Nutr*. 2019;15(2):e12722.
5. Campisi SC, Cherian AM, Bhutta ZA. World perspective on the epidemiology of stunting between 1990 and 2015. *Horm Res Paediatr*. 2017;88(1):70-78.
6. Keino S, Plasqui G, Ettyang G, van den Borne B. Determinants of stunting and overweight among young children and adolescents in sub-Saharan Africa. *Food Nutr Bull*. 2014;35(2):167-178.
7. Abdullah A. The double burden of undernutrition and overnutrition in developing countries: an update. *Curr Obes Rep*. 2015;4(3):337-349.
8. Kelishadi R. Childhood overweight, obesity, and the metabolic syndrome in developing countries. *Epidemiol Rev*. 2007;29:62-76.

9. Lawlor DA, Andersen AM, Batty GD. Birth cohort studies: past, present and future. *Int J Epidemiol*. 2009;38(4):897-902.
10. Halim N, Spielman K, Larson B. The economic consequences of selected maternal and early childhood nutrition interventions in low- and middle-income countries: a review of the literature, 2000–2013. *BMC Womens Health*. 2015;15:33.
11. Angood C, Khara T, Dolan C, Berkley JA. Research priorities on the relationship between wasting and stunting. *PLoS ONE*. 2016;11(5):e0153221.
12. Bogin B. *Human Growth And Development*. Amsterdam: Elsevier/Academic Press; 2012.
13. Golding J, Jones R, Bruné M-N, Pronczuk J. Why carry out a longitudinal birth survey? *Paediatr Perinat Epidemiol*. 2009;23(s1):1-14.
14. Araujo WR, Santos IS, Barros FC, Matijasevich A. Birth cohort studies and the early origins of adult health and disease. *NeoReviews*. 2018;19(6):e313-e321.
15. Monyeki MA, Awotidebe A, Strydom GL, de Ridder JH, Mamabolo RL, Kemper HC. The challenges of underweight and overweight in South African children: are we winning or losing the battle? A systematic review. *Int J Environ Res Public Health*. 2015;12(2):1156-1173.
16. Murray-Kolb LE, Rasmussen ZA, Scharf RJ, et al. The MAL-ED cohort study: methods and lessons learned when assessing early child development and caregiving mediators in infants and young children in 8 low- and middle-income countries. *Clin Infect Dis*. 2014;59(Suppl 4):S261-S272.
17. Garzon M, Papoila AL, Alves M, Pereira-da-Silva L. Comparison of growth curve estimates of infants in Sao Tome Island, Africa, with the WHO growth standards: a birth cohort study. *Int J Environ Res Public Health*. 2019;16:E1693.
18. Mwangome M, Ngari M, Bwahere P, et al. Anthropometry at birth and at age of routine vaccination to predict mortality in the first year of life: a birth cohort study in BukinaFaso. *PLoS ONE*. 2019;14(3):e0213523.
19. Richter L, Norris S, Pettifor J, Yach D, Cameron N. Cohort Profile: Mandela's children: the 1990 birth to twenty study in South Africa. *Int J Epidemiol*. 2007;36(3):504-511.
20. Donald KA, Hoogenhout M, du Plooy CP, et al. Drakenstein Child Health Study (DCHS): investigating determinants of early child development and cognition. *BMJ Paediatr Open*. 2018;2(1):e000282.
21. Martin-Prevel Y, Maire B, Delpeuch F. Nutrition, urbanization and poverty in subsaharan Africa. *Med Trop*. 2000;60(2):179-191.
22. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho AMN, Stunting MD. Wasting and underweight in Sub-Saharan Africa: a systematic review. *Int J Environ Res Public Health*. 2017;14(8):863.
23. Coates MM, Kamanda M, Kintu A, et al. A comparison of all-cause and cause-specific mortality by household socioeconomic status across seven INDEPTH network health and demographic surveillance systems in sub-Saharan Africa. *Global health action*. 2019;12(1):1608013.
24. Alabi O, Doctor HV, Jumare A, et al. Health & demographic surveillance system profile: the Nahuche Health and Demographic Surveillance System, Northern Nigeria (Nahuche HDSS). *Int J Epidemiol*. 2014;43(6):1770-1780.
25. Akombi BJ, Agho KE, Merom D, Renzaho AM, Hall JJ. Child malnutrition in sub-Saharan Africa: a meta-analysis of demographic and health surveys (2006–2016). *PLoS ONE*. 2017;12(5):e0177338.
26. Lee ACC, Katz J, Blencowe H, et al. National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. *Lancet Glob Health*. 2013;1(1):e26-36.
27. Chawanpaiboon S, Vogel JP, Moller A-B, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37-e46.
28. Ogwumike FO, Ozughalu UM. Empirical evidence of child poverty and deprivation in Nigeria. *Child Abuse Negl*. 2018;77:13-22.
29. Meribole EC, Makinde OA, Oyemakinde A, et al. The Nigerian health information system policy review of 2014: the need, content, expectations and progress. *Health Info Libr J*. 2018;35(4):285-297.
30. Bhattacharya AA, Umar N, Audu A, et al. Quality of routine facility data for monitoring priority maternal and newborn indicators in DHIS2: a case study from Gombe State, Nigeria. *PLoS ONE*. 2019;14(1):e0211265.
31. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381.
32. Anand V, Spalding SJ. Leveraging electronic tablets and a readily available data capture platform to assess chronic pain in children: the PROBE system. *MedInfo*. 2015;216:554-558.
33. Oluwole OA. Pattern of residential mobility in Kaduna metropolis, Nigeria. *Pak Geograph Rev*. 2014;69(1):46-61.
34. World Population Review. *Population of cities in Nigeria*. 2019. Last accessed 11th April 2019. Available from: http://worldpopulationreview.com/countries/nigeria-population/cities/
35. National Population Commission (NPC) [Nigeria] and ICF. *Nigeria Demographic and Health Survey 2013*. Abuja, Nigeria and Calverton, Maryland: National Population Commission and ICF Macro; 2014.
36. Drotar D, Stancin T, Dworkin P. *Pediatric Developmental Screening: Understanding and Selecting Screening Instruments*. New York: Commonwealth Fund; 2008.
37. Cheikh Ismail L, Knight HE, Bhutta Z, Chumlea WC. Anthropometric protocols for the construction of new international fetal and newborn growth standards: the INTERGROWTH-21st Project. *BJOG*. 2013;120(Suppl 2):42-47.
38. Klipin M, Mare I, Hazelhurst S, Kramer B. The process of installing REDCap, a web based database supporting biomedical research: the first year. *Appl Clin Inform*. 2014;5(4):916-929.
39. Bauman A, Phongsavan P, Cowle A, et al. Maximising follow-up participation rates in a large scale 45 and up study in Australia. *Emerg Themes Epidemiol*. 2016;13:6.
40. Pam VC, Yilgwan CS, Shwe DD, et al. Head circumference of babies at birth in Nigeria. *J Trop Pediatr*. 2019;65(6):626-633.
41. Ayoola OO, Gemmell I, Omotade OO, Adeyanju OA, Cruickshank JK, Clayton PE. Maternal malaria, birth size and blood pressure in Nigerian newborns: insights into the developmental origins of hypertension from the Ibadan growth cohort. *PLoS ONE*. 2011;6(9):e24548.
42. Onubogu CU, Egbuonu I, Ugochukwu EF, Nwabueze AS, Ugochukwu O. The influence of maternal anthropometric characteristics on the birth size of term singleton South-East Nigerian newborn infants. *Niger J Clin Pract*. 2017;20(7):852-859.
43. Villar J, Cheikh Ismail L, Staines Urias E, et al. The satisfactory growth and development at 2 years of age of the INTERGROWTH-21(st) Fetal Growth Standards cohort support its appropriateness for constructing international standards. *Am J Obstet Gynecol*. 2018;218(2S):S841-S854.e2.
44. Armitage P, Berry G, Matthews JNS. *Statistical Methods in Medical Research*. New Jersey: John Wiley & Sons; 2008.
45. Teague S, Youssef GJ, Macdonald JA, et al. Retention strategies in longitudinal cohort studies: a systematic review and meta-analysis. *BMC Med Res Methodol*. 2018;18(1):151.
46. Svefors P, Sysoev O, Ekstrom E-C, et al. Relative importance of prenatal and postnatal determinants of stunting: data mining approaches to the MINIMat cohort, Bangladesh. *BMJ Open*. 2019;9(8):e025154.
47. Prendergast AJ, Humphrey JH. The stunting syndrome in developing countries. *Paediatr Int Child Health*. 2014;34(4):250-265.
48. Hossain M, Choudhury N, Adib Binte Abdullah K, et al. Evidence-based approaches to childhood stunting in low and middle income countries: a systematic review. *Arch Dis Child*. 2017;102(10):903-909.

49. Monasta L, Batty GD, Cattaneo A, et al. Early-life determinants of overweight and obesity: a review of systematic reviews. *Obes Rev*. 2010;11(10):695-708.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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