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Effect of COVID-19 lockdown on mobile payments for maternal health: Regression discontinuity analysis

Samuel Knauss, Gracia Andriamiadana, Roxane Leitheiser, Zavaniarivo Rampanjato, Till Bärnighausen, Julius Valentin Emmrich

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Samuel Knauss[1] MD; Gracia Andriamiadana[2]; Roxane Leitheiser[1]; Zavaniarivo Rampanjato[3] MD; Till Bärnighausen[4, 5, 6] MD, PhD, MSc; Julius Valentin Emmrich[1] MD, PhD, MPhil

[1]Global Digital Health Lab Charité Center for Global Health Charité - University Medicine Berlin Medical School Berlin DE
[2]Queen Mary University of London London GB
[3]Ministry of Public Health of the Republic of Madagascar Antananarivo MG
[4]Heidelberg Institute of Global Health Medical Faculty and University Hospital University of Heidelberg, Heidelberg Heidelberg DE
[5]Harvard Center for Population and Development Studies Harvard University Cambridge US
[6]Africa Health Research Institute Mtubatuba ZA

Corresponding Author:
Samuel Knauss MD
Global Digital Health Lab
Charité Center for Global Health
Charité - University Medicine Berlin Medical School
Charitéplatz 1
Berlin
DE

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Abstract

Background: The COVID-19 pandemic has resulted in an unprecedented popularity of digital financial services, for contactless payments and government cash transfer programs to mitigate the economic effect of COVID-19. The effect of the pandemic on the use of digital financial services for health in low-and middle-income countries, however, is poorly understood.

Objective: To study the effect of the first COVID-19 lockdown on the use of a Mobile Maternal Health Wallet (MMHW) in Antananarivo, Madagascar, and draw conclusions on the effect of lockdown measures on the use of digital health services.

Methods: We analysed MMHW data from 3,416 women at 25 public-sector primary care facilities and four hospitals from January 1 to August 27, 2020. We collected data on savings, payments, and voucher use initiated at the point-of-care. To estimate effects of the first COVID-19 lockdown in Madagascar, we used regression discontinuity analysis with modified Poisson regression for binary variables to estimate risk ratios.

Results: Over the 819,840 person-days of observation, we recorded 3,719 savings, 1,572 payments, and use of 3,144 electronic vouchers. The first COVID-19 lockdown in Madagascar reduced mobile money savings by 58.5% (P<.0001), payments by 45.8% (P<.001), and voucher use by 49.6% (P<.001). The recovery duration after the lockdown differed by age group: Women aged 30 and older recovered substantially faster than younger women. Results remained robust in sensitivity analyses using ±20 days of the optimal bandwidth.

Conclusions: COVID-19 lockdown strongly reduced the use of mobile money in the health sector, affecting savings, payments, and voucher use. Reduced savings imply that the lockdown diminished women's expectations of future healthcare use, while declines in payment and voucher use indicate decreased actual healthcare utilization. These effects are crucial since many maternal and child healthcare services cannot be delayed for long, as the potential benefits will be lost or diminish if women do not receive the services within a narrow time window. Clinical Trial: This was an ancillary study using data from the 4MOTHERS trial, a randomised hybrid effectiveness implementation trial quantifying the effect of a mobile health wallet intervention on maternal health outcomes in Antananarivo (German Clinical Trials Register, DRKS-ID: DRKS00014928). The study was approved by the institutional review board of the University of Heidelberg on February 3, 2020 (reference number: S-428/2019).

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Effect of COVID-19 lockdown on mobile payments for maternal health: Regression discontinuity analysis

Samuel Knauss[1,2], Gracia Andriamiadana[3], Roxane Leitheiser[1], Zavaniarivo Rampanjato[4], Till Bärnighausen[5,6,7], Julius Valentin Emmrich[1,2]

Affiliations

[1]Charité Global Health and Department of Experimental Neurology and Center for Stroke Research, Charité - University Medicine Berlin Medical School, Berlin, Germany

[2]Berlin Institute of Health, Berlin, Germany

[3]Queen Mary University of London, Mile End Road, E1 4NS London, United Kingdom

[4]Ministry of Public Health of the Republic of Madagascar, Antananarivo, Madagascar

[5]Heidelberg Institute of Global Health, Medical Faculty and University Hospital, University of Heidelberg, Heidelberg, Germany, Heidelberg, Germany

[6]Harvard Center for Population and Development Studies, Harvard University, Cambridge, USA

[7]Africa Health Research Institute (AHRI), Mtubatuba, KwaZulu-Natal, South Africa

Corresponding Author

Dr Samuel Knauss

samuel.knauss@charite.de

Phone: +4917623819512

Global Digital Health Lab, Charité - University Medicine Berlin Medical School, Charitéplatz 1, 10117 Berlin, Germany

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Abstract

Background: The COVID-19 pandemic has resulted in an unprecedented popularity of digital financial services, for contactless payments and government cash transfer programs to mitigate the economic effect of COVID-19. The effect of the pandemic on the use of digital financial services for health in low-and middle-income countries, however, is poorly understood.

Objective: To study the effect of the first COVID-19 lockdown on the use of a Mobile Maternal Health Wallet (MMHW) in Antananarivo, Madagascar, with a particular focus on delineating the age-dependent differential effects, and draw conclusions on the effect of lockdown measures on the use of digital health services.

Methods: We analysed 819,840 person-days of health wallet use data from 3,416 women utilizing healthcare at 25 public-sector primary care facilities and four hospitals in Antananarivo, Madagascar, between January 1 to August 27, 2020. We collected data on savings, payments, and voucher use initiated at the point-of-care. To estimate effects of the first COVID-19 lockdown in Madagascar, we used regression discontinuity analysis around the starting day of the first COIVID-19 lockdown in Madagascar on March 23rd, 2020. We determined the bandwidth using a data-driven method for unbiased bandwidth selection and used modified Poisson regression for binary variables to estimate risk ratios as lockdown effect sizes.

Results: We recorded 3,719 savings, 1,572 payments, and use of 3,144 electronic vouchers. The first COVID-19 lockdown in Madagascar reduced mobile money savings by 58.5% ($P<.0001$), payments by 45.8% ($P<.001$), and voucher use by 49.6% ($P<.001$). Voucher use recovered to the extrapolated pre-lockdown counterfactual after 214 days while savings and payments did not cross the extrapolated pre-lockdown counterfactual. The recovery duration after the lockdown differed by age group: Women aged 30 and older recovered substantially faster, returning to pre-lockdown rates after 34, 226, and 77 days for savings, payments, and voucher use respectively. Younger women below 25 years old did not return to baseline values. Results remained robust in sensitivity analyses using ±20 days of the optimal bandwidth.

Conclusions: COVID-19 lockdown strongly reduced the use of mobile money in the health sector, affecting savings, payments, and voucher use. Savings were most significantly reduced which implies that the lockdown had a particular effect on diminishing women's expectations of future healthcare use. Declines in payment and voucher use indicate decreased actual healthcare utilization caused by the lockdown onset. These effects are crucial since many maternal and child healthcare services cannot be delayed for long, as the potential benefits will be lost or diminish if women do not

receive the services within a narrow time window. To mitigate the adverse impacts of lockdowns on maternal health service use, digital health services could be leveraged to provide access to telemedicine, as well as to enhance user communication with clear information on available healthcare access options, and ensuring adherence to safety protocols.

Trial Registration: This was an ancillary study using data from the 4MOTHERS trial, a randomised hybrid effectiveness implementation trial quantifying the effect of a mobile health wallet intervention on maternal health outcomes in Antananarivo (German Clinical Trials Register, DRKS-ID: DRKS00014928). The study was approved by the institutional review board of the University of Heidelberg on February 3, 2020 (reference number: S-428/2019).

Keywords: Digital Health; Behavioral Surveillance; Digital Health Wallet; Mobile Money; COVID-19; Health Financing; Public Health; Sub-Saharan Africa

Introduction

Globally, more than 6.9 million people have died from COVID-19 and the number of COVID-19-related deaths is still steadily increasing (data as of December 2023).[1] Beyond the direct effect of the disease, the pandemic continues to disrupt essential health services worldwide undermining the achievements of existing public health programs.[2] Health systems and health service delivery are most seriously disrupted by COVID-19 in sub-Saharan Africa (SSA).[3] Maternal health services are among the most severely affected health services in SSA.[4] Redeployment of health staff to provide COVID-19 relief, supply chain interruptions, drug price surges, and pandemic control measures such as lockdowns further hamper access to maternal care.[5]

Within less than a generation, mobile communication, and mobile payments, also known as mobile money, have become ubiquitous in SSA.[6] The COVID-19 pandemic has resulted in an unprecedented popularity of this technology as a safer and more efficient alternative to cash payments particularly for unbanked populations. Several countries in SSA have promoted the use of mobile money during the pandemic through a variety of regulatory and policy-led measures including fee waivers, increased transaction limits, humanitarian cash transfers, and flexible registration of new users.[7] However, the pandemic also had negative effects on use of mobile money. More than half of mobile money users in Kenya and Mozambique reported difficulties in depositing or withdrawing funds from a cash-in/cash-out agent.[8]

Mobile money is being used routinely in the health sector in many countries in SSA improving financial risk protection and access to essential health services.[9] Examples in SSA include remote health insurance enrolment, premium payment, and reimbursement,[10] humanitarian cash transfers and electronic health vouchers,[11] and credits and loans.[9] Overall, mobile money users have a lower risk of catastrophic health expenditure – defined as out-of-pocket expenses exceeding 10% of total income or consumption or exceeding 40% of non-food spending – during emergency care and are less likely to reduce non-medical expenses for education or food than non-users.[12] However, the effect of lockdown measures on mobile payments for health in SSA are not clear.

In Madagascar, a nation of 25 million people financial barriers significantly impede access to maternal healthcare.[13] Fewer than half of expectant mothers adhere to the World Health Organization's recommendation of completing four antenatal care visits, and over half of births occur without skilled attendance. In 2017, the maternal mortality ratio stood at 335 per 100,000 live births, with figures potentially tripling in the poorest regions.[14] Out-of-pocket payments account for nearly a quarter of healthcare spending. Despite efforts towards universal health coverage (UHC) incorporating mobile technologies, specialized mobile money services for maternal health savings or insurance have not been established on a national level. The probability of incurring impoverishing expenses during pregnancy remains substantial.[15,16] Nevertheless, mobile phone subscriptions have soared, from under 3 per 100 people in 2005 to 40 per 100 by 2018, with mobile money accounts surpassing traditional banking figures by 2015.[17] Following human-centered, mixed-methods research in the capital Antananarivo aimed to identify the framework and user experience for a mobile-based service for maternal healthcare payments and savings,[18–20] a Mobile Maternal Health Wallet (MMHW) was subsequently developed and implemented in the capital revealing a strong perceived value of mobile money for maternal health, particularly among women from lower-income backgrounds.[18]

Our study aimed to demonstrate a causal effect of COVID-19 lockdowns on the use of digital health services and explore age-dependent differential effects. In the context of maternal health in Madagascar, we examined three primary uses of the MMHW: savings, payments, and voucher use for maternal care. Reductions in savings suggest lockdowns lowered women's future healthcare expectations, while payment and voucher use declines indicate decreased actual healthcare utilization. This is significant since many maternal and child healthcare services cannot be delayed

without losing or diminishing potential benefits. Our study did not intend to assess the overall impact of the COVID-19 pandemic on healthcare utilization or mobile money usage. Rather, our focus was on examining how lockdowns affected the utilization of digital health services for maternal care, specifically in terms of mobile payments for maternal healthcare services. These findings can guide health policy in developing strategies to mitigate lockdown-related challenges in the future.

Methods

Study setting

We conducted this study in 25 public-sector primary care facilities and four referral hospitals in three administrative districts of Antananarivo, the capital of Madagascar.

Participating primary care facilities are typically staffed by at least one doctor and a couple of midwives or nurses, supported by 15–30 community health workers (CHWs) who promote ANC and educate on health, pregnancy complications, and nutrition. The districts are urban, peri-urban, and rural. All health facilities participating in the study remained open during the lockdown. The study region has 2.2 million inhabitants, 31% of whom live under the national poverty line of 1.90 USD in 2019 (2011 PPP), considerably less than the Malagasy average (71%).[21] In the study region, around 65% of pregnant women complete at least four antenatal care (ANC) visits, 68% deliver in a health facility, and 74% receive skilled birth assistance.[22] While ANC services and delivery assistance, including C-sections, are provided free, patients must cover costs for medications, tests, and materials. A normal delivery at a participating facility costs around 12 USD, and a C-section averages 128 USD—equating to 3% and 32% of the average annual salary in study region, respectively.[23]

Study design

To estimate the effect of lockdown on savings, payments and electronic vouchers use for maternal healthcare, we used a quasi-experimental regression discontinuity design. Regression discontinuity designs are considered the most robust method to estimate causal effects when random assignment is not feasible.[24] They can be implemented when treatment is assigned based on a cut-off value of a continuous running variable. We used count of consecutive days starting on the beginning of the study period on January 1, 2020, as our running variable. The cut-off value for lockdown onset was based on data from the Oxford COVID-19 Government Response Tracker (OxCGRT).[25] We calculated a containment stringency index ranging from 0-23 using all “containment and closure policy” indicators included in the OxCGRT dataset. We obtained data for Madagascar from

the OxCGRT for the study period running from of January 1 to August 27, 2020, as the period covering the first lockdown in Madagascar. **Table 1** summarizes the duration and stringency index during pre-lockdown and lockdown periods in Madagascar. We defined the first day of the lockdown on March 23, 2020 (day 82) as the cut-off value in our regression discontinuity analysis.

Table 1. Lockdown duration and stringency during pre-lockdown and lockdown periods for the first COVID-19 related lockdown in Antananarivo, Madagascar between January 1 to August 27, 2020 according to the Oxford COVID-19 Government Response Tracker.[25]

Period	Dates	Median Stringency Index
Pre-lockdown	01/01/2020-22/03/2020	0
Lockdown	23/03/2020-27/08/2020	19

Mobile Maternal Health Wallet intervention

The mobile health wallet was implemented in the study region as part of the intervention package of the 4MOTHERS trial, we described previously.[26] The MMHW intervention was implemented by a non-governmental organization (NGO) in partnership with the Malagasy Ministry of Health's UHC program. Implementation of the intervention package commenced sequentially at the participating healthcare providers starting in January 2019. In brief, the MMHW allows users, namely, pregnant women, to save and pay for health care services using mobile money and to receive electronic vouchers that can be redeemed at participating health care providers at the point of care. Electronic vouchers were for ANC drugs, emergency referrals, and obstetric ultrasounds at no cost. The MMHW operates on a USSD (Unstructured Supplementary Service Data menu, accessible via GSM (Global System for Mobile Communications) networks provided by the two primary mobile phone operators in Madagascar. Users can receive messages and access the service by dialing a three-digit code followed by the hash sign, without the need for an active internet connection or a smartphone. Users can save to the mobile health wallet using their own mobile money credit or by receiving remittances via mobile money e.g., from relatives and friends. Savings typically require users to convert cash into mobile money with the help of a cash-in/cash-out agent; mobile money is then saved to the mobile health wallet electronically by the user. At the point of service, healthcare facility staff utilized a web-based interface to initiate and authenticate payments or the use of electronic vouchers. This process involved entering necessary treatment details and submitting corroborative documents, like invoices or photographs. Staff of the implementing NGO checked and validated each transaction to ensure remittances from the MMHW were only used for maternal care. Potential users learned about the MMHW intervention through media campaigns, community health workers, and

from health care providers. Registration to the MMHW was performed by employees of the implementing NGO, community health workers and healthcare providers, who received specific training on the sensitization and registration for the MMHW. All pregnant women in the catchment area of a participating healthcare facility were encouraged to register for the service. For registration, users needed to possess an individual subscriber identity module (SIM) card. Users of the MMHW must be able and willing to give verbal consent to the terms and condition of the MMHW intervention including the use of anonymized user data for research.

Participants and sample size

We included anonymized data from all women who used the MMHW at least once to save, pay or redeem an electronic voucher for maternal healthcare at one of the participating healthcare providers during the study period. Health facilities contributing data to the analysis were randomised as part of the main trial reducing the risk of selection bias and ensuring high transferability of results. For each of our three outcomes (savings, payments, electronic voucher use), we observed 3,416 women over 240 days resulting in an observation of 819,840 person-days for each of the outcomes. Because enrolment of participants was performed before the lockdown it can be assumed that participants' characteristics did not systematically change at lockdown. To analyse differential impact of the lockdown on savings, payments, and electronic voucher use, we divided our population into three age groups. Categorisation of age groups were based on evidence of the influence of maternal age on health seeking behaviour in the literature.[27] The age group 'under 25' was chosen to represent younger individuals likely at the beginning of their reproductive years, who may have distinct challenges such as limited financial resources or decision-making autonomy. The '25 to 30' category captures individuals who may be more established in their reproductive life and potentially have different access to resources. The 'above 30' group likely includes women with greater experience and potentially different familial or economic circumstances.

Outcomes

The primary outcomes for the study were i) savings transaction recorded per user per day (binary variable), ii) payments per user per day (binary variable), and iii) electronic voucher use per user per day (binary variable). Savings were defined as a credit transaction to the MMHW. Savings transactions per user were unrestricted. To reflect active use rather than level of use, we binarised counts per user per day by creating a dummy variable and assigning a value of "1" for users for

which any savings transaction was recorded on a given day and a value of “0” if no transaction was recorded. Payments were defined as a debit transaction to the MMHW for a delivery – including surgical delivery and caesarean section – validated by a staff member of the implementing NGO. Since we only included payments for delivery in our analysis, each user had a maximum of one payment during the study period. Electronic voucher use was defined as the recording of a voucher redemption, which was validated by a staff member of the implementing NGO. The mobile health wallet system limited the electronic voucher use to a maximum of one voucher per user per day.

Data sources and data management

Data on savings, payments, electronic voucher use, and demographics were collected over the MMHW online application using a web-based interface available to community health workers and healthcare facility staff. Demographics were collected during registration, while savings, payments, and voucher use were automatically recorded in the MMHW system in real-time upon user or healthcare worker triggers yielding high temporary resolution and completeness of the data. All data were cleaned and validated by staff of the implementing non-governmental organization. Data were securely transmitted and stored on the MMHW database adhering to industry standard for data availability, encryption, and protection of health data. For the purpose of this study, data were extracted from the database and fully anonymized by the non-governmental organization before being transmitted securely to the research team. We extracted anonymized user identifiers and timestamps for each outcome to convert them into daily binary outcomes per user. As we only included data from users with at least one event for saving, payment or voucher use during the study period and all days for which no event was recorded were coded as 0, there were no missing data. All data used for this research were kept in a secure password-protected online repository that were accessible only to the investigators.

Statistical analysis

We used descriptive statistics to summarize demographics and create crude summaries of outcomes before and during lockdown. Our primary analysis tested the null hypothesis that lockdown has no effect on mobile health wallet use. We employed a regression discontinuity analysis as a quasi-experimental approach, treating the start of the COVID-19 lockdown as a natural experiment. Regression discontinuity designs are among the strongest possible designs when random participant assignment is not feasible and increasingly used in public health research. By comparing MMHW usage just before and immediately after the lockdown date, the regression discontinuity analysis allowed us to isolate and measure the causal effect of the lockdown on the use of digital financial

services for maternal health under the assumption that all circumstances are similar in all aspects except for the lockdown itself. We evaluated the relationship between our outcomes and our running variable (consecutive days), allowing for a discontinuity at lockdown onset and different slopes on either side of the threshold. Incidence rate ratios and predicted incidence rates along the running variable were estimated by fitting a Poisson regression model with robust standard errors using sandwich estimation for binary outcomes.[28] The Poisson regression model was deemed appropriate after confirming the absence of overdispersion in the data. The model's goodness-of-fit was further supported by residual deviance values that were consistent with the degrees of freedom.[28] This appropriateness was substantiated by low frequency of events (i.e., payments) relative to the size of the study population and the number of observation periods, which aligns with the assumptions of the Poisson model. The model included a continuous time variable, a binary lockdown variable, and a time-lockdown interaction term. Baseline incidence rate ratios at the commencement of the study period were obtained from the intercept of the model, with the running variable set to zero.

A key choice in the design of regression discontinuity analyses is the bandwidth governing the window of data included in the analysis. While a wider window improves the precision of the estimates, it also increases the risk of bias and for introducing unknown confounders in the model. We relied on the data-driven Imbens-Kalyanaraman optimal bandwidth selector, to avoid conscious and unconscious bias in the bandwidth selection.[29] The running variable (consecutive days) was centered at lockdown. We estimated daily trends during lockdown for each outcome by adding the coefficients associated with time and time-lockdown interaction. To determine whether there are age-specific differences in the recovery in the primary outcomes after the onset of the lockdown, we analysed each age group separately using the same methods as described above and determined whether the predicted incidence rates recovered by calculating the point the extrapolated predicted incidence rate post-lockdown crossed the extrapolated pre-lockdown counterfactual for each outcome measure.

Statistical significance was set at alpha, $P<.05$. No post-hoc analysis were conducted based on our primary results. We conducted a sensitivity analysis for varying bandwidths (±20 days) to check robustness. Results are intention-to-treat effects on an individual user level. All analyses were done on a participant level using R 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria) and RStudio Version 1.4.1106 (RStudio Team, Boston, MA, USA).

Ethical approval

This was an ancillary study using data from the 4MOTHERS trial, a randomised hybrid effectiveness

implementation trial quantifying the effect of a mobile health wallet intervention on maternal health outcomes in Antananarivo (German Clinical Trials Register, DRKS-ID: DRKS00014928). The study was approved by the institutional review board of the University of Heidelberg on February 3, 2020 (reference number: S-428/2019).

Role of the funding source

The funders had no role in the study design, data collection, analysis, interpretation, or writing of the paper.

Results

We analysed the effect of a national lockdown on use of a mobile health wallet for maternal healthcare between January 1, 2020, and August 27, 2020, in Antananarivo, Madagascar using modified Poisson segmented regression models. Data from 3,416 women were included in the study. During the study period we recorded 3,719 savings, 1,572 payments, and use of 3,144 electronic vouchers. The median age of the study population was 26 years (IQR: 9); Figure 1 shows the age distribution. Descriptive statistics of the outcomes for pre-lockdown and lockdown are summarised in supplementary Table S1.

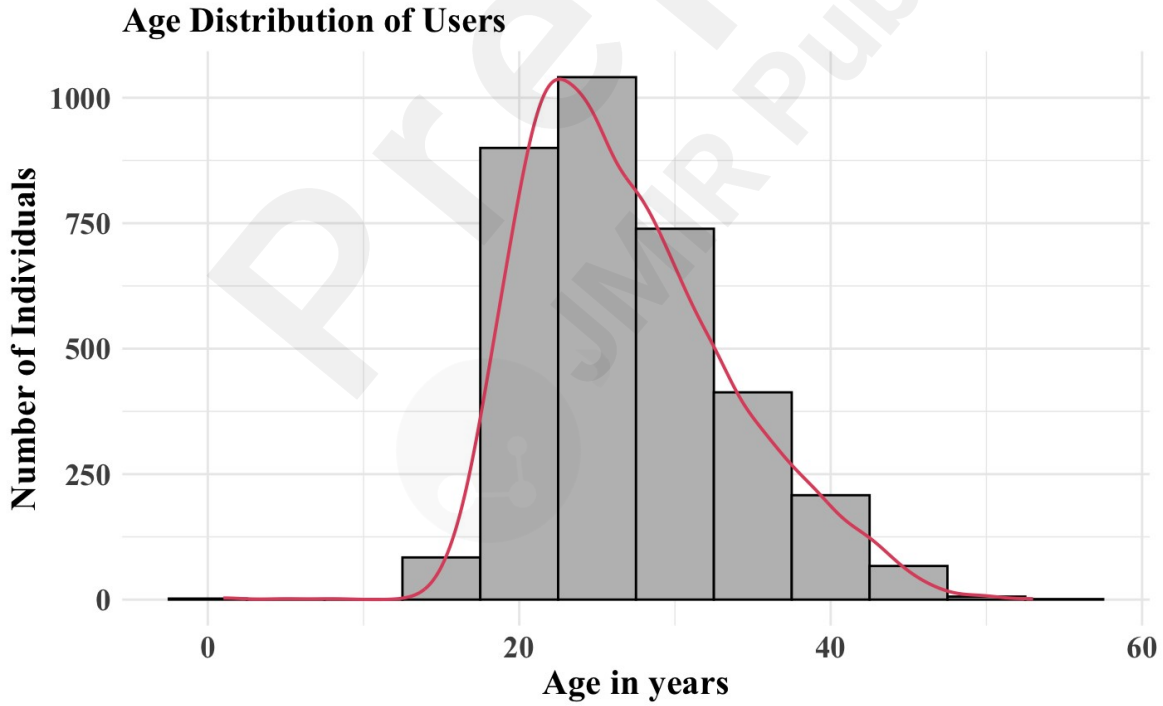

Figure 1. Age distribution of 3,416 women utilizing a Mobile Maternal Health Wallet to save and pay for healthcare in Antananarivo, Madagascar, between January 1 to August 27, 2020, included in a regression discontinuity analysis to determine the effect of COVID-19 lockdown on mobile payments for maternal health. Each histogram bars represent counts for a 5-year age range and the red curve represents the density scaled to fit the count axis.

Table 2. Incidence rate ratios of savings, payments, and electronic voucher use for discontinuity at lockdown and daily trends during pre-lockdown and lockdown for 3,416 women utilizing a Mobile Maternal Health Wallet to save and pay for healthcare in Antananarivo, Madagascar, between January 1 to August 27, 2020 included in a regression discontinuity analysis to determine the effect of COVID-19 lockdown on mobile payments for maternal health. (N = 819,840 events for each use type).

	Baseline on January 1st, 2020	*Incidence rate ratio at lockdown*	*Incidence rate ratio per day (pre-lockdown)*	*Incidence rate ratio per day (lockdown)*
Savings	0.0090 (0.0082-0.0101)	0.4152 (0.3589–0.4802)	1.0124 (1.0098-1.0149)	1.0113 (1.0099-1.0128)
Payments	0.0026 (0.0021-0.0032)	0.5412 (0.3929-0.7456)	1.0111 (1.0040-1.0183)	1.0054 (0.9979-1.0130)
Electronic Vouchers	0.0051 (0.0045-0.0057)	0.5047 (0.4178- 0.6095)	1.0034 (1.0005-1.0064)	1.0067 (1.0032–1.0102)

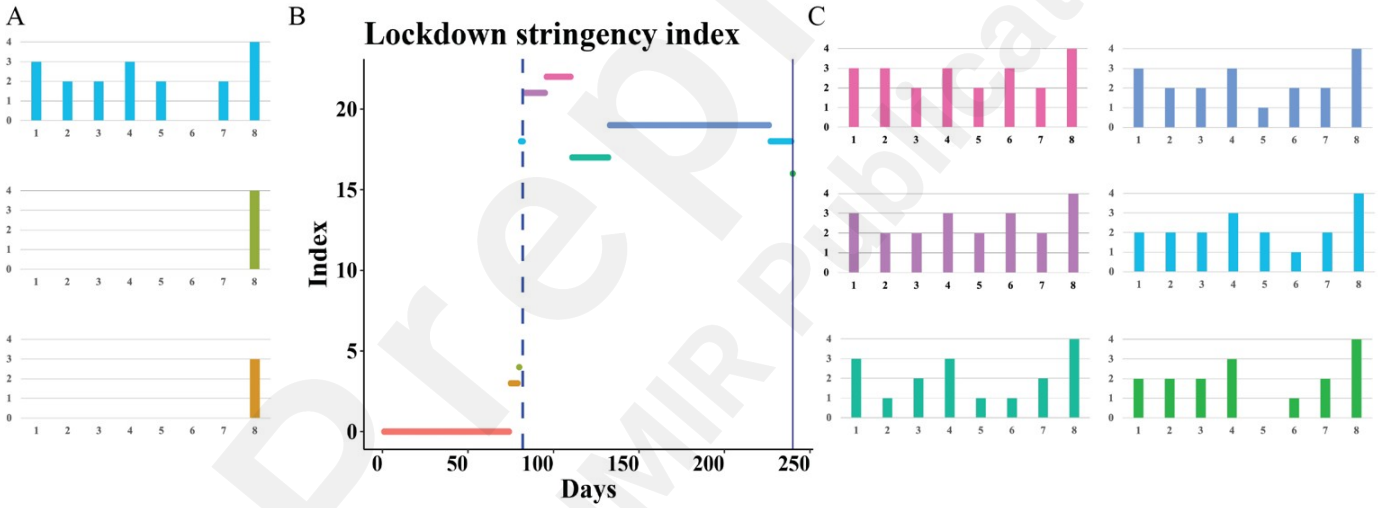

Figure 2. Overview of lockdown stringency index for Madagascar according to containment and closure policy indicators from the Oxford COVID-19 Government Response Tracker.[25] Panel **(B)** displays the overall Lockdown Stringency Index, a composite measure based on several policy indicators, during the study period. The blue dashed vertical line represents the initiation of lockdown, while the solid blue line signifies its conclusion. Color-coded horizontal lines in Panel B correspond to the specific periods for which eight containment and closure policies are detailed in the respective bar charts in (A) before and (C) during lockdown. . Containment and closure policies are listed on the x-axis of each sub-panel and rated on a scale from 0 (least severe restriction) to 4 (most severe restriction) according to the Oxford COVID-19 Government Response Tracker on the y-axis. The eight policies are 1) school closing, 2) workplace closing, 3) cancel public events, 4) restrictions on gatherings, 5) close public transport, 6) stay at home requirements, 7) restrictions on internal movement, and 8) international travel controls.

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Savings for pregnancy-related healthcare were reduced during lockdown

For the optimal bandwidth of 110 days, we found a significant 58.5% decrease of savings at lockdown (Incidence rate ratio [IRR] 0.4152, 95% CI 0.3589–0.4803, *P*<.0001, **Table 2**). This means, that the likelihood of savings for pregnancy-related healthcare was only 41.5% of the rate before the lockdown, signifying a substantial reduction in women's ability or willingness to set aside funds for expected maternal health services. This finding remained stable in our sensitivity analysis, when varying the bandwidth between 90 and 130 days (**Figure 3**). During pre-lockdown, daily savings increased by 1.2% (IRR 1.0124, 95% CI 1.0098-1.0149) per day. This trend remained stable during lockdown (1.1% per day (IRR 1.0113, 95% CI 1.0099-1.0128, P=.491) and did not cross the extrapolated pre-lockdown counterfactual. This indicates that after a pronounced drop at lockdown, the number of participants saving for healthcare did not recover rapidly.

Payments for pregnancy-related healthcare were reduced during lockdown

Using the optimal bandwidth of 55 days, showed a drop of payments by 45.8% at lockdown (IRR 0.5412, 95% CI 0.3929-0.7456, *P*<.001). This means, that the likelihood of a women paying for a pregnancy related treatment was at only 54.1% of pre-lockdown values, indicating a significant reduction in the utilization of the MMHW to pay for pregnancy-related healthcare at participating health facilities. Sensitivity analysis confirmed a robust effect ranging from 34.8% to 56.3% reduction for bandwidths between 35-75 days (**Figure 3**). During pre-lockdown, daily payments increased by 0.54% (IRR 1.0054, 95% CI 0.9979-1.0130) per day. This trend reduced to 0.54% (IRR 1.0054, 95% CI 0.9979-1.0130, *P*=.28) during lockdown and did not cross the extrapolated pre-lockdown counterfactual.

Electronic voucher use for pregnancy-related healthcare decreased

At lockdown, electronic voucher use dropped by 49.6% (IRR 0.5047, 95% CI 0.4178- 0.6095, *P*<.0001) using the optimal bandwidth of 70 days. This means that the likelihood of a women using a voucher for pregnancy-related healthcare was at only 50.4% of the values before lockdown, implying a substantial decrease in the use of antenatal care at participating facilities. Sensitivity analysis for bandwidths ranging from 50-90 days revealed robust results. Voucher use increased by 0.3% per day (IRR 1.0034, 95% CI 1.0005-1.0064) during pre-lockdown and increased to 0.67% per day during lockdown (IRR 1.0067, 95% CI 1.0032–1.0102, *P*=.16), recovering to the extrapolated pre-lockdown counterfactual after 214 days.

Recovery of the use of mobile health wallet is age-dependent

After an initial drop at lockdown the predicted incidence rates recovered but only crossed the extrapolated pre-lockdown counterfactual for the electronic voucher use. Analysing the rate of recovery separately for three age groups of women <25 years of age, women between the age of 25 and 30 years and women 30 years and above, revealed differences in the time for the predicted incident rate after lockdown to reach the counterfactual predicted incident rate extrapolated from the pre-lockdown incident rate (**Figure 3D)**. For women <25 years of age, predicted incident rates after lockdown did not reach the counterfactual predicted incident rates for any of the measured outcomes, indicating a lasting effect of lockdown. For women between 25 and 30 years of age, predicted incidence rates recovered and crossed the counterfactual predicted incident rate at 268, 84, and 77 days after lockdown for savings, payments, and electronic vouchers respectively. This crossing of lockdown incident rates and the counterfactual incident rates already occurred at day 38 and day 77 for savings and electronic vouchers respectively in the group of women of 30 years of age and above, indicating a faster return to pre-lockdown incident rates. In the same age group, incident rates for payments only recovered after 226 days after lockdown.

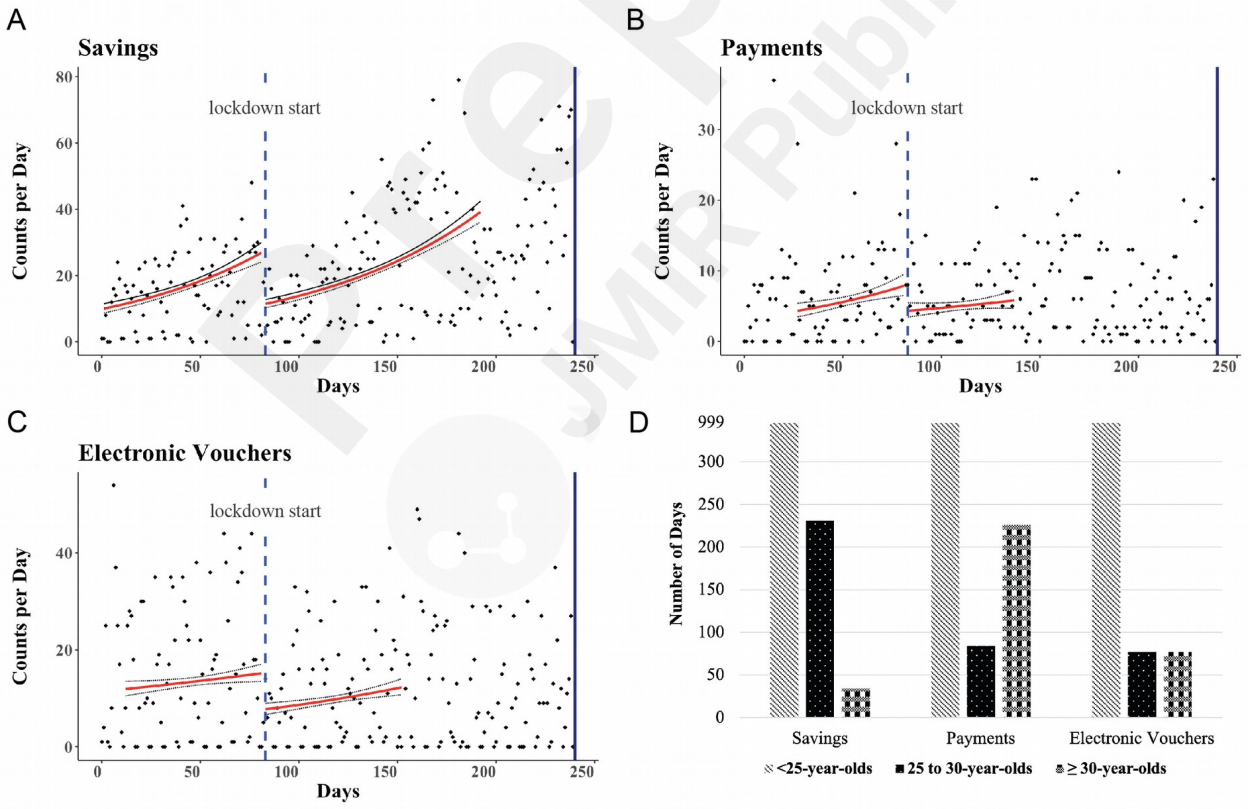

Figure 3. Regression discontinuity analysis of the effect of lockdown on savings, payments and electronic voucher use for maternal healthcare. (**A-C**) Total events of 3,416 women utilizing the Mobile Maternal Health Wallet to save and pay for maternal care at 25 public-sector health primary

care facilities and four referral hospitals in Antananarivo, Madagascar between January 1, 2020, and August 27, 2020 depicted as count of events per day (blue dots). Solid red line and black fine-dotted lines depict the predicted incidence rate and confidence intervals respectively before and after lockdown using a modified Poisson regression model and the optimal bandwidth determined by a data-dependent algorithm describe by Imbens and Kalyanaraman.[29] The origin on the x-axis corresponds to January 1, 2020. **D)** Time-to-reach-baseline for different age groups. Time relative to the lockdown for the predicted incidence rate after the lockdown to reach the extrapolated counterfactual predicted incidence rate. Time to reach the extrapolated counterfactual was shortest in the age group of above 30-year-olds for savings and electronic vouchers and shortest in the age group of 25 to 30-year-olds for payments. In the age group of below 25-year-olds, the predicted incidence rate after lockdown did not return to the counterfactual predicted incidence rate for savings, payments and electronic voucher use and was coded as 999 days.

Discussion

Principal Results

We aimed to quantify the effect of COVID-19 lockdown on use of key components of a mobile health wallet, namely savings, payments, and electronic voucher use for maternal healthcare at 25 public-sector primary-care health facilities and 4 reference hospitals in Antananarivo, Madagascar. Using a quasi-experimental regression discontinuity design analysing 819,840 events for each use type, we found that mobile money-based savings and payments and electronic voucher use for pregnancy-related health services decreased by 58.5%, 45.8%, and 49.6% at lockdown, respectively. Our findings suggest that lockdown had a strong negative effect on the use of a mobile health wallet. Savings quickly rebounded already during lockdown, whereas payments and voucher use were slower to recover. Further analysing this revealed age dependent differences of the speed of recovery. For the youngest age-group of below 25-year-olds the lockdown had a lasting effect and none of the outcome measures returned to the pre-lockdown predicted incident rates indicating age-dependent differences in access to healthcare related resources and healthcare access.

To our knowledge, this is the first study quantifying the effect of COVID-19 lockdown on use of mobile money and electronic vouchers to access essential health services. The quasi-experimental regression discontinuity design of our study enabled causal inference on the effect of lockdown in a real-world setting without the strong assumptions made in most observational studies. To date, there are only few published data from SSA on the effect of lockdown on utilization of maternal healthcare services and maternal outcomes. A cross-sectional study including all public health facilities in Rwanda found that maternal health service utilization indicators for antenatal care, deliveries, postnatal care, and vaccinations significantly decreased during the first national COVID-19 lockdown in March and April 2020 compared to historical controls.[30] In contrast, an interrupted time series analysis using data from 11 public-sector primary care facilities in South Africa found no

change in the number of daily outpatient clinic visits for perinatal care and family planning before and after lockdown.[31] A study using data from an ongoing nationwide birth outcomes surveillance study in Botswana found no difference in the number of facility-based deliveries during lockdown but a slight reduction in the risk of adverse pregnancy outcomes during lockdown compared to pre-lockdown.[32] Conversely, a recent meta-analysis found a substantial effect of COVID-19 on family planning, antenatal care, institutional deliveries, and postnatal care in Ethiopia.[33]

Why did savings for maternal healthcare reduce during lockdowns? The reduction in savings suggest that the lockdown diminished women's expectation of using maternal and child healthcare in the future. An analysis of labour market data from South Africa during the first wave of the pandemic and a longitudinal cohort study among informal settlers in Nairobi suggest that these observations might have been caused by reduced availability of financial resources due to lockdown measures.[34,35] In South Africa, about one of every three employed people lost their job during the first wave of the pandemic with women working in the informal sector being among the most severely affected.[35] Likewise, in Kenya, women were disproportionally affected by lockdown measures resulting in increased food insecurity and lower utilization rates of maternal and child healthcare services because of financial constraints.[34] Previously, we found the majority of pregnant women in the study area being unemployed or working in the informal sector,[36] making them especially vulnerable to the economic effects of lockdowns. In addition, savings behaviour might have been affected by difficulties women faced converting cash into electronic currency. Survey data from Kenya, Mozambique, and Nigeria suggest that mobile money users faced difficulties depositing or withdrawing funds from a cash-in/cash-out agents because agents were short on cash, closed or because of infection concerns.[7]

The decline in payments and voucher use indicates a decrease in the actual utilization of maternal and child healthcare during the lockdown. An important finding from our study was that electronic voucher use, which did not require users to rely on their own financial resources to access maternal healthcare, also reduced during lockdown. Other studies have shown that user fee removal is associated with increased utilization of maternal healthcare services including antenatal care visits and facility-based normal and complicated deliveries (including caesarean sections).[37,38] A review on demand-side financial incentive programs found increased utilization of antenatal care and facility-based delivery by vouchers aiming to reduce or waive costs of care at the point of use.[11] In our study we showed an effect of lockdown on electronic voucher use for maternal healthcare

services. This is an important finding because governments and implementers rely on distributing direct cash transfers or vouchers for maternal healthcare services during the pandemic to ensure equitable access to care.[39] It is likely that factors contributing to the overall disruption of maternal healthcare services including availability of health workers, drug supply shortage, and pandemic control measures such as interrupted public transport may also affect the uptake of voucher programs. A recent rapid review on accessibility and utilization of antenatal care services in SSA found movement restrictions and limited transport access as well as anxiety about contracting COVID-19 at the health facilities as the main reason for reduced utilization of antenatal care services and facility-based deliveries during the COVID-19 pandemic.[40] These findings highlight the potential of digital tools, such as the MMHW, which facilitate direct communication with users, to address barriers to accessing maternal healthcare during lockdowns. The MMHW for instance allows for direct communication with users without the need for an active internet connection using USSD and SMS (Short Message Service) protocols. In contrast to mass message campaigns, utilizing the information available through the MMHW database on the users, their visits to healthcare facilities and received treatments could allow for more targeted and effective communication with users. By conveying individualized information about available transport options and emphasizing the necessity of maternal healthcare, these tools can help assuage concerns related to infection risks and safety measures. Ensuring that women using the MMHW are aware of public transport availability to healthcare facilities and providing details on schedules is crucial. Lockdowns can impose time restrictions on daily activities, like grocery shopping, complicating access to antenatal and maternal care when health centre opening hours coincide with restricted activity times. It is essential for women to understand that they can continue to access necessary pregnancy and maternal healthcare through the MMHW during lockdowns. Communication should focus on the importance of utilizing maternal care and outlining how it can be safely accessed by adhering to social distancing guidelines and using personal protective equipment. Lastly, it is vital to ensure that women find compliance with additional procedural restrictions, such as testing and vaccination, both manageable and feasible. This can be achieved through general public engagement campaigns and the MMHW, which can send notifications, reminders, and calls to users.

Age is one of the most important determinants for accessing healthcare.[41,42] This has been attributed to higher financial barriers to care for younger adults, less decision making power within a family and lower quality of care when they can access it.[41] This effect is particularly pronounced for access to maternal care including skilled assisted delivery, as young maternal age itself has been associated with lower socio-economic status, lower agency within the family and resulting poorer

health outcomes for both, mother and offspring.[42] In line with these findings, we found age dependent differences in the effect of lockdowns on healthcare savings, payments, and electronic voucher use. Our findings imply that the lockdown had a stronger negative effect on expected and actual maternal care use of mothers below the age of 25, likely reflecting their comparatively lower economic standing and decision-making capacity. More research is needed to better understand the underlying mechanisms of these effects. Nonetheless, our findings highlight the importance to prioritize support for this vulnerable demographic in efforts to mitigate the detrimental effects of lockdowns on maternal healthcare access.

Limitations

Limitations include that pandemic control measures in Madagascar were not consistently implemented or enforced, which limits the discriminating power of our analysis and might introduce unknown confounders we could not control for. However, the stepwise implementation and partly short duration of pandemic control measures reflect the reality in many countries in SSA. To allow for a robust definition of lockdown, we chose to determine the timing and stringency based on data from the Oxford COVID-19 Government Response Tracker, which provides the most accurate data on lockdown measures for Madagascar. Second, we did not measure and include in our analysis effects of the pandemic on the societal attitude towards healthcare and the perception of mobile money in general. However, these general, lockdown independent, effects would likely be more gradual over a longer period and be controlled for by using a regression discontinuity analysis to infer causality. Third, participant enrolment for the main trial was ongoing during the study period, thus use of the mobile health wallet increased over time. To reduce confounding, we chose to report daily incidence rates per patient instead of total counts for all outcomes. Fourth, use of the mobile health wallet may not be a substitute for use of mobile money for health. However, because the mobile health wallet uses the mobile money infrastructure of mobile network operators, savings and payment processes for users closely resembled standard mobile money processes. Fifth, we only included data from women who used the MMHW at least once during the study period. No direct conclusions can be drawn on the change in health seeking of savings behaviour of women, who did not use the MMHW. However, previous studies on the user profiles of active MMHW users, highlighted that users come from all socio-demographic strata.[18]

Conclusions

In conclusion, lockdowns significantly reduced mobile money-based savings, payments, and

electronic voucher use for maternal healthcare. These effects on expected and actual maternal care use are crucial since many services cannot be delayed for long, with potential benefits being lost or diminished. Our results highlight the challenges in using mobile money and electronic vouchers for maternal healthcare services during lockdown in a resource-restricted setting. Further research is needed to identify what specific aspects of handling mobile money savings and payments and electronic voucher use caused patients to refrain from its use. These findings are important for designing strategies to ensure equitable financial access to healthcare services during this and future pandemics.

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The study was conceptualized by SK, GA, TB, and JVE. Methodology development was carried out by SK, GA, and JVE. Data curation was handled by SK, GA, RL, ZR, and JVE. Full access to raw data was granted to SK, GA, RL, and JVE. All data in the study was fully accessed and verified by SK, GA, and JVE. The manuscript's original draft was written by SK and GA. Investigation, formal analysis, validation, and visualization were performed by SK, GA, TB, and JVE. Reviewing and editing of the report were done by SK, GA, RL, ZR, TB, and JVE. Funding, computational, and data analytics resources were managed by SK, TB, and JVE. The final decision to submit the manuscript for publication was made by SK and JVE and approved by all co-authors.

Data Availability

The data sets generated and analyzed during this study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author on reasonable request. The data that support the findings of this study are available with the stipulation that they will be used solely for scholarly and non-commercial purposes, in compliance with the appropriate ethical regulations. Requests for access to these data should be addressed to the corresponding author, subject to approval by the Institutional Review Board and adherence to the confidentiality agreements.

Conflicts of Interest

SK and JVE received funding from German Research Foundation (DFG), German Ministry of Education and Research, and ElseKröner-Fresenius- Stiftung. SK and JVE reports personal fees from Biogen outside the submitted work. TB reports research grants from the European Union (Horizon 2020 and EIT Health), German Research Foundation (DFG), US National Institutes of Health, German Ministry of Education and Research, Alexander von Humboldt Foundation, Else Kröner-Fresenius- Stiftung, Wellcome Trust, Bill & Melinda Gates Foundation, KfW, UNAIDS, and WHO. TB reports personal fees from KfW outside the submitted work. TB has served on Data Safety

Monitoring Board or Advisory Board for NIH-funded study “Healthy Options” (PIs: Smith Fawzi, Kaaya), Chair, Data Safety and Monitoring Board (DSMB), German National Committee on the “Future of Public Health Research and Education”, Chair of the scientific advisory board to the EDCTP Evaluation, Member of the UNAIDS Evaluation Expert Advisory Committee, National Institutes of Health Study Section Member on Population and Public Health Approaches to HIV/AIDS (PPAH), US National Academies of Sciences, Engineering, and Medicine’s Committee for the “Evaluation of Human Resources for Health in the Republic of Rwanda under the President’s Emergency Plan for AIDS Relief (PEPFAR)”, University of Pennsylvania (UPenn) Population Aging Research Center (PARC) External Advisory Board Member. TB has co-chairs the Global Health Hub Germany (which was initiated by the German Ministry of Health). All other authors declare no competing interests.

Abbreviations

ANC: antenatal care
CHWs: community health workers
MMHW: Mobile Maternal Health Wallet
SSA: Sub-Saharan Africa
UHC: universal health coverage
PPP: purchasing power parity

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Supplementary Files

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Figures

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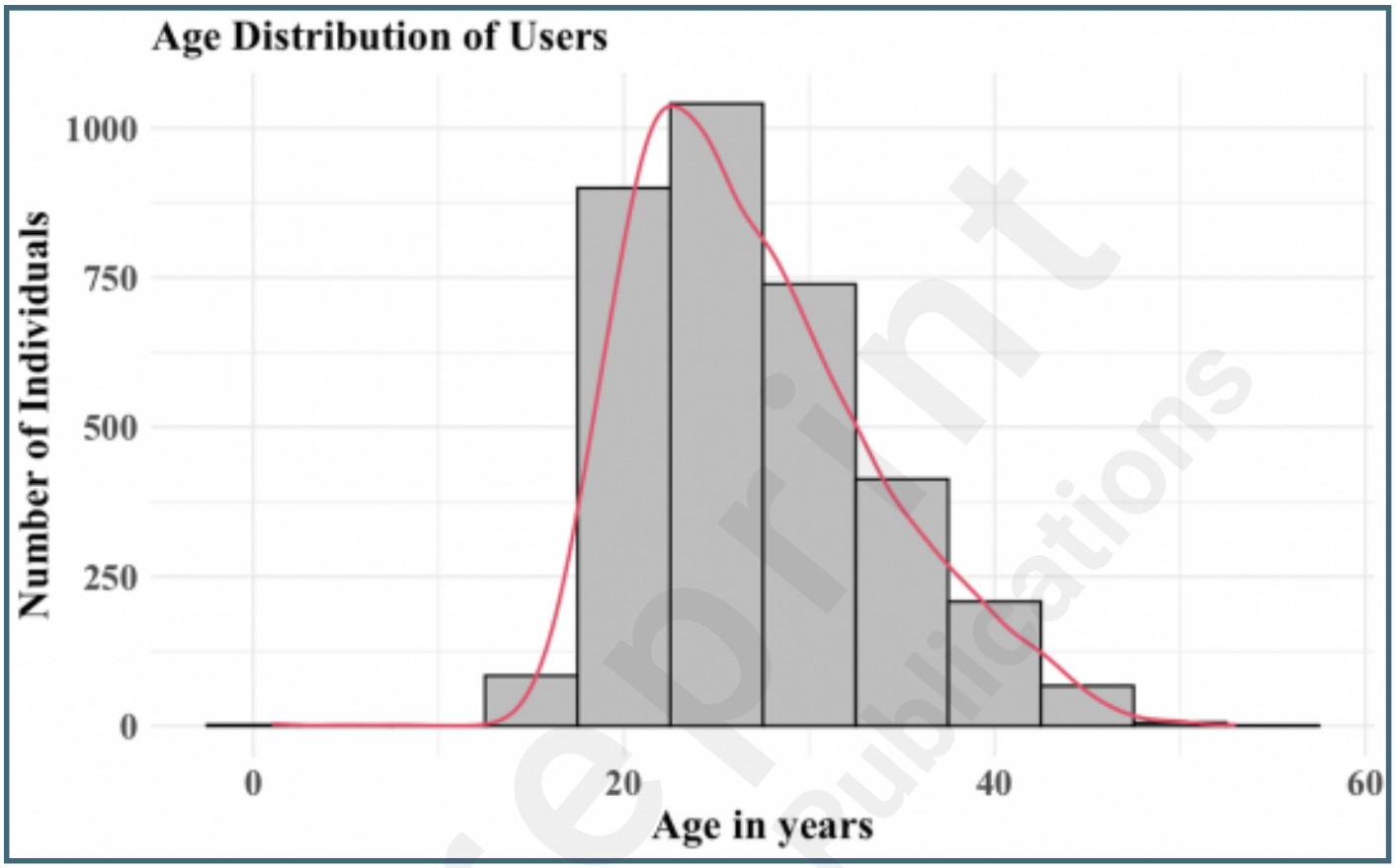
Age distribution of 3,416 women utilizing a Mobile Maternal Health Wallet to save and pay for healthcare in Antananarivo, Madagascar, between January 1 to August 27, 2020 included in a regression discontinuity analysis to determine the effect of COVID-19 lockdown on mobile payments for maternal health. Each histogram bars represent counts for a 5-year age range and the red curve represents the density scaled to fit the count axis.



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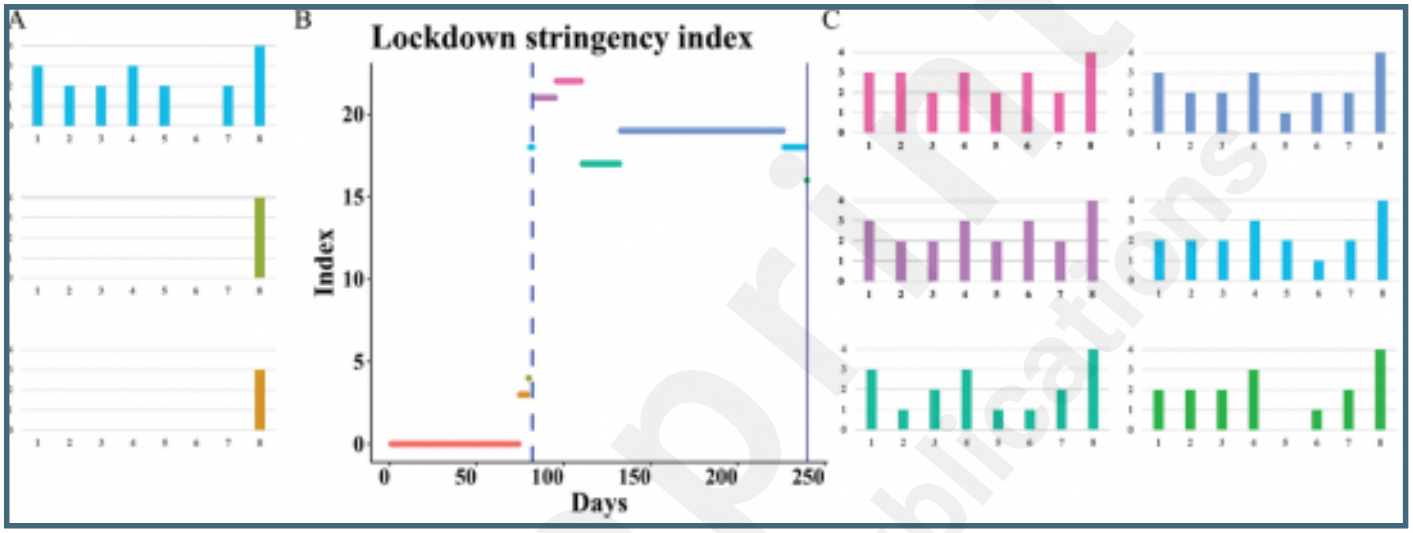
Overview of lockdown stringency index for Madagascar according to containment and closure policy indicators from the Oxford COVID-19 Government Response Tracker.[25] Panel (B) displays the overall Lockdown Stringency Index, a composite measure based on several policy indicators, during the study period. The blue dashed vertical line represents the initiation of lockdown, while the solid blue line signifies its conclusion. Color-coded horizontal lines in Panel B correspond to the specific periods for which eight containment and closure policies are detailed in the respective bar charts in (A) before and (C) during lockdown. . Containment and closure policies are listed on the x-axis of each sub-panel and rated on a scale from 0 (least severe restriction) to 4 (most severe restriction) according to the Oxford COVID-19 Government Response Tracker on the y-axis. The eight policies are 1) school closing, 2) workplace closing, 3) cancel public events, 4) restrictions on gatherings, 5) close public transport, 6) stay at home requirements, 7) restrictions on internal movement, and 8) international travel controls.



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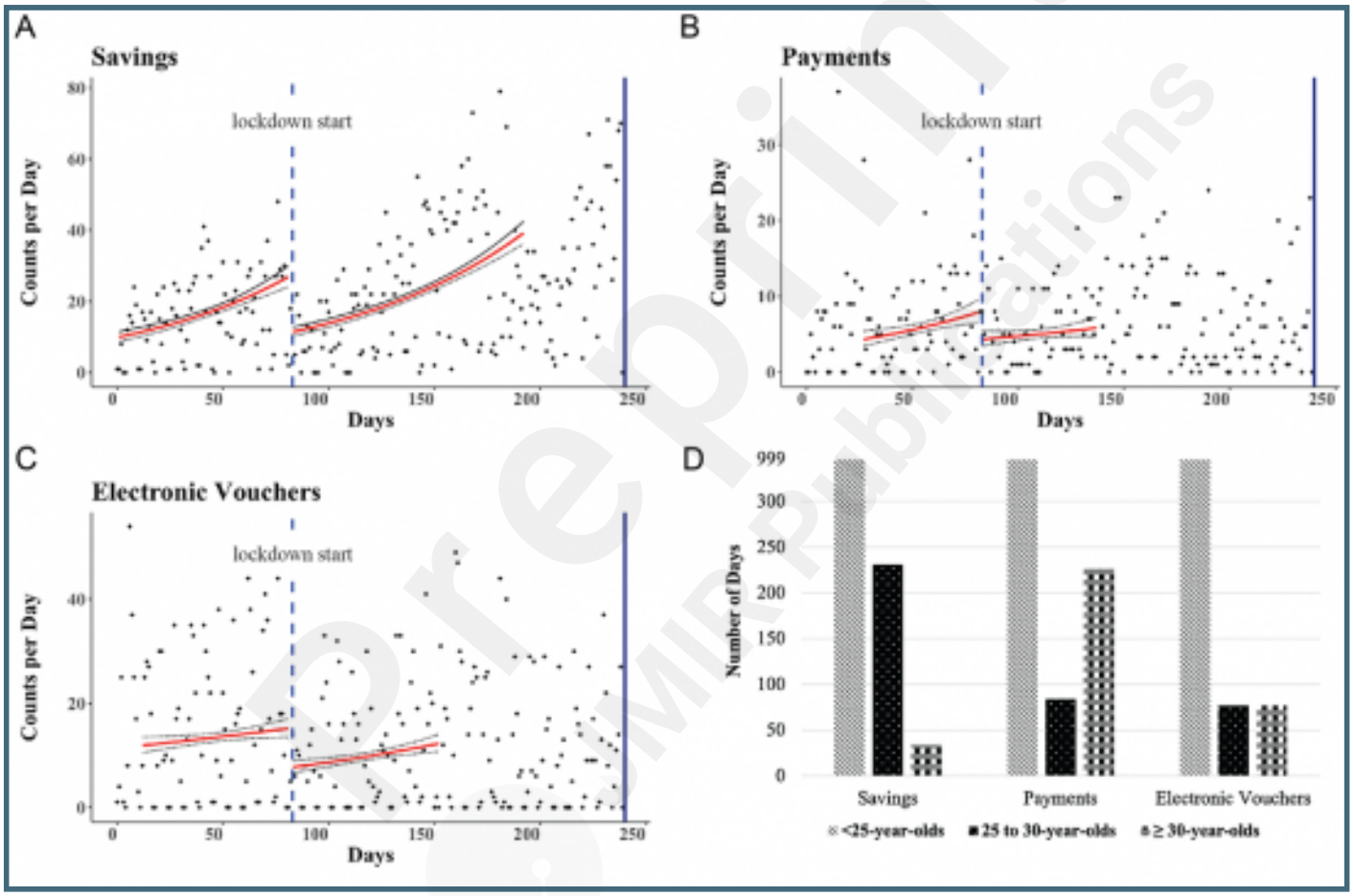
Regression discontinuity analysis of the effect of lockdown on savings, payments and electronic voucher use for maternal healthcare. (A-C) Total events of 3,416 women utilizing the Mobile Maternal Health Wallet to save and pay for maternal care at 25 public-sector health primary care facilities and four referral hospitals in Antananarivo, Madagascar between January 1, 2020, and August 27, 2020 depicted as count of events per day (blue dots). Solid red line and black fine-dotted lines depict the predicted incidence rate and confidence intervals respectively before and after lockdown using a modified Poisson regression model and the optimal bandwidth determined by a data-dependent algorithm describe by Imbens and Kalyanaraman.[28] The origin on the x-axis corresponds to January 1, 2020. D) Time-to-reach-baseline for different age groups. Time relative to the lockdown for the predicted incidence rate after the lockdown to reach the extrapolated counterfactual predicted incidence rate. Time to reach the extrapolated counterfactual was shortest in the age group of above 30-year-olds for savings and electronic vouchers and shortest in the age group of 25 to 30-year-olds for payments. In the age group of below 25-year-olds, the predicted incidence rate after lockdown did not return to the counterfactual predicted incidence rate for savings, payments and electronic voucher use and was coded as 999 days.



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Multimedia Appendixes

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Supplementary material including descriptive statistics (Supplementary Table 1) and sensitivity analysis for different bandwidths centered at the optimal bandwidth (Supplementary Figure 1).
URL: http://asset.jmir.pub/assets/d902cc3229bb38889f31c451989e44e1.docx

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