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Using an app for COVID-19 contact tracing costs less per person traced than manual tracing: microcosting analysis of a randomised trial in Cameroon

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ABSTRACT

Introduction SARS-CoV-2 contact tracing in Cameroon has been done manually using paper forms and phone calls. However, there were reports of inaccurate contact details, resulting in delays in identifying and testing contacts. A recently introduced digital contact-tracing module using the Mamal Pro app automatically sends SMS messages to notify all reported contacts and the district unit. We assessed the total costs, cost per contact reached, tested and found SARS-CoV-2-positive for both manual (standard of care, SOC) and app-based (intervention, ITV) contact-tracing approaches.

Methods A cluster randomised trial comparing the SOC and ITV was implemented across eight health districts in Cameroon between October 2022 and March 2023. The cost per contact reached, tested and found SARS-CoV-2-positive was calculated by dividing the total cost of each approach by the number of contacts reached, tested and found SARS-CoV-2-positive, respectively. We also estimated the minimum number of SARS-CoV-2-positive contacts that need to be found and the maximum total cost of ITV in order to equal the SOC's cost per SARS-CoV-2-positive contact.

Results In the SOC, of 849 contacts identified, 463, 123 and 5 were reached, tested and found SARS-CoV-2-positive, respectively. In the ITV, of the 854 contacts identified, 801, 182 and 4 were reached, tested and found SARS-CoV-2-positive, respectively. In the SOC, the cost per contact reached was US$70, per contact tested was US$262 and per SARS-CoV-2-positive contact was US$6437. In the ITV, the cost per contact reached was US$48, per contact tested was US$210 and per SARS-CoV-2-positive contact was US$9573. The minimum number of SARS-CoV-2-positive contacts the ITV needs to find and the maximum total cost of the ITV to equal the SOC's cost per SARS-CoV-2-positive were 6 and US$25 748, respectively.

Conclusion Using the Mamal Pro digital contact tracing app module increased the number of clients' contacts reached and tested for SARS-CoV-2 and reduced the cost per contact reached and tested.

Trial registration number NCT05684887.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Very little data exist on the costs and cost efficiency of the different COVID-19 contact tracing approaches in sub-Saharan Africa.

WHAT THIS STUDY ADDS

⇒ We assessed the total costs and the cost per contact reached, tested and found SARS-CoV2-positive of manual and app-based contact-tracing approaches.
⇒ We found that COVID-19 contact tracing using an app enhances the number of contacts reached and tested, and costs less per contact.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The results shared can be used for budgeting, identification of priority areas for vaccination and expansion of the model on the continent.
⇒ The cost data provided here can be used for contact tracing for other respiratory diseases such as tuberculosis.

INTRODUCTION

In Cameroon, at the end of 2022, there were 124 392 confirmed cases of COVID-19 with 1965 deaths.[1] Isolation of index cases and contact tracing are essential for interrupting chains of transmission of SARS-CoV-2 and reducing mortality associated with COVID-19.[2]

In developed countries, COVID-19 contact tracing is done using mobile apps that aid the execution of various tasks such as tracing, data gathering, data visualisation, artificial intelligence-based diagnosis and data transformation.[3] These apps use a variety of clinical, geographical, demographic, radiological, serological and laboratory data to identify and trace COVID-19 cases or exposed individuals.[3] In addition to mobile apps, machine learning has also been used to identify COVID-19 cases, an example is the deep convolutional neural network-based computer-aided detection system that was implemented in Iran to identify COVID-19 cases using multiple lung scans.[4] Others, used X-ray equipped with artificial intelligence to screen scans to identify COVID-19 cases.[5]

However, in sub-Saharan Africa, there are multiple challenges and barriers for the effective implementation of these contact tracing approaches such as: lack of equipment and technology, incomplete identification of contacts, inefficiencies in paper-based reporting systems, complex data management requirements, overwhelming workload of contact tracing and case detection for healthcare workers (HCWs), delays in identification and testing of contacts.[6] In many settings in sub-Saharan Africa, contact tracing has proven to be too resource-intensive to implement at scale, particularly in communities with high transmission rates. There is an urgent need in the continent for more efficient contact tracing.

As part of the COVID-19 response, the Cameroon's Ministry of Health (MOH) deployed in October 2021 an online digital application (app), the Mamal Pro app (www.mamalpro.com), as the main data capture platform for SARS-CoV-2 testing in Cameroon. The app is used for managing various activities related to SARS-CoV-2 testing including scheduling appointments, documenting testing conducted, notification and reporting of results, scheduling and documentation of SARS-CoV-2 vaccination. It is hosted on a secure server, and designated HCWs are required to receive credentials issued by MOH in order to access the platform.

A secondary module that supports the tracing of contacts of individuals who test positive for SARS-CoV-2 has been developed for the Mamal Pro system.[7] The system automatically sends a digital SMS notification to index cases' exposed contacts, which is anonymised to protect the index case's privacy, and their details to MOH district contact tracing unit for tracing.[7] The Mamal Pro app is used for COVID-19 testing (registration and obtaining results) in most facilities, however, in practice, the app is not used for contact tracing which is done manually.

This approach and its eventual scale-up at national levels would potentially bring a better detection rate for all contacts of SARS-CoV-2 infected index patients, enable an earlier management of infected persons thus leading to less SARS-CoV-2 transmission in the community and, lower SARS-CoV-2 incidence and mortality overall. The potential utility of the contact tracing module extends beyond that of control activities for COVID-19, as this module may also be adapted to support contact tracing for other infectious conditions such as tuberculosis (TB), influenza and syphilis.

The Cameroon MOH needs data about the costs associated with the use of the Mamal Pro digital contact tracing module to inform resource allocation for national deployment of this module. In this study, we assessed the total costs and costs per contact of tracing COVID-19 contacts using the Mamal Pro digital contact tracing feature (intervention arm, ITV) or phone-based contact tracing (standard of care, SOC arm).

METHODS

Study design

A cluster randomised trial comparing two models, SOC versus ITV, was implemented in 14 health facilities and 8 district testing units across 8 health districts in the Littoral region of Cameroon.[7] The randomisation was performed by the study statistician 2 months prior the start of enrolment. We collected subjects and cost data from October 2022 to March 2023.

Clusters corresponded to health districts with attached SARS-CoV-2 testing units and/or selected neighbouring health facilities offering SARS-CoV-2 testing to people living in the health district. We selected eight health districts in the Littoral region with the highest number of people registered in Mamal PRO App and tested for SARS-CoV-2 during the last 5 months preceding the development of the protocol.[7]

Participants were enrolled in 14 primary, secondary or tertiary health facilities and 8 COVID-19 testing units. All individuals registered in the Mamal PRO app for testing, who tested positive for SARS-CoV-2 in the selected SARS-CoV-2 testing sites were eligible for the study. All individuals who tested positive, and declared contacts within the preceding 15 days and the day of the test (index patients) were eligible and were enrolled in the study as well as all their declared contacts.

Models

Standard of care

This is the model recommended by the National COVID-19 Response Programme. In the SOC arm, individuals registered in the Mamal Pro app for testing, who tested positive for SARS-CoV-2 in the district testing units and health facilities, were seen by an HCW in charge of the management of SARS-CoV-2 positive cases. The HCW then completed a contact tracing paper form identifying the recent contacts (within the last 14 days from the test date) of the patient, including names, age, sex, occupation, residence area, link with the index case, type and exposure circumstances, and phone numbers. These forms were sent daily to the district unit responsible for contact tracing. At the district level, all the contact lists were pooled in an electronic tracker file. Based on this electronic tracker sheet, the head of the contact tracing unit opened one separate tracking form for each contact listed in the contact tracing forms by reporting the information of each contact. The contact tracing was carried out by teams made up of trained community health workers (CHWs) working under the supervision of the head of the contact tracing unit of the health district.

The CHW received, on a daily basis, the tracking forms of contacts of positive SARS-CoV-2 patients recently tested at the health facility or district testing unit level. They were responsible for notifying the contact cases that have been identified as close contact with a confirmed COVID-19 case, performing a symptom screening for COVID-19 and inviting contacts to take a test at designated sites.

Those who were unable or refused to come for testing were followed up by phone for 10 days for the occurrence of COVID-19 symptoms. Results of the tracing and communication with contacts were recorded in the contact tracking form.

Intervention

In the ITV arm, the MOH added the Mamal Pro digital contact tracing module to the Mamal Pro app. When individuals registered in the Mamal Pro app for testing, they completed a form in the app requiring them to list five close contacts and their phone numbers.

For all individuals who tested positive for SARS-CoV-2, the HCW added the person's demographic data and list of contacts to the Mamal Pro app and activated the digital contact tracing module. The app automatically sent the individual's list of contacts with phone numbers to the district unit responsible for carrying out the contact tracing. The system also sent a text message to all listed contacts to inform them they had been exposed (without identifying the index case) and were at risk of COVID-19 and encourage them to get tested as soon as possible.

The HCW called contacts and followed up those who did not test in the same manner as SOC. The app allows the district team to enter information about the results of the contact tracing into the Mamal Pro system. The contact information for individuals who test negative for SARS-CoV-2 is stored in the app and no subsequent contacting activities are carried out.

In both models, the contacts who tested positive for SARS-CoV-2 at the health facilities or district testing unit automatically went through the contact tracing process, as an index case, according to the procedure for the arm in which the testing unit was randomised.

In both arms, only contacts who tested for SARS-CoV-2 and were verified and confirmed by the contact tracers and registered in the Mamal Pro app were considered.

Costing

Cost data were captured where relevant and appropriate to quantify the costs associated with implementing the use of Mamal Pro contact tracing module for tracing SARS-CoV2 positive index case contacts. We only included in this evaluation the costs directly related to implementation of the tracing of SARS-CoV2 positive index case contacts in ITV and SOC arms; thus research, app development and integration costs were excluded.

Costs were extracted from MOH salary scales, Elizabeth Glaser Pediatric AIDS Foundation (EGPAF) financial database, detailed budgets and financial reports on actual expenditures. Costs were divided into three areas: human resources, capital and recurrent.

Human resources were divided across three categories: (1) site level, (2) above-site at health district and (3) regional delegation. Human resources costs were calculated based on level of effort (LOE) of each cadre or employee dedicated to activities associated with the contact tracing. The LOE was obtained from each employment cadre through a structured interview. Information collected from cadres included the time needed to complete the process in the Mamal Pro app with and without the tracing module, supervision, data management, etc. The total hours spent by each cadre on these activities were converted into a percentage of the total number of hours, and this percentage was then used along with the salaries for these cadre to calculate the cost of the LOE allocated to contact tracing. Only average salary data and aggregated patient-level data were used.

Training and equipment (tablets) were treated as capital costs. In both ITV and SOC arm, study personnel provided training to health staff on the Mamal Pro digital contact tracing module and supported its implementation. Total training costs were treated as capital costs and annualised over 3 years. We applied a discount rate of 3% according to WHO guidelines and annualised costs by dividing the total cost of the training by the annuity, as previously done.[8–10] Training costs included facilitator fee, meals, transport and training material. Tablets were annualised over 5 years using the methodology described above.

Recurrent costs comprised travel and supplies. Total costs of travel for supervisors from central (COUPS/MoH), regional level (DRSPL/MoH) and district levels (health district using digital module/MoH) were also included. For the contact tracing, supplies consisted mainly of internet and communication credit for facility staff, and an automated messaging package (valid for 6 months) for free texting notification of contacts.

Cost analysis

The costs were estimated from a health system's perspective. We used a microcosting method, combining top-down and bottom-up approaches to obtain resource use and costs per line item. All project costs were converted to US dollars (US$) using the average exchange rate from October 2022 to March 2023, as previously done.[11]

We recorded the total number of contacts identified, reached, tested and found positive for SARS-CoV-2. We defined contacts identified as the number of contacts listed by the index case, contacts reached as the number of contacts successfully reached telephonically by the district contact tracing team, contacts tested as the number of contacts who tested for SARS-CoV-2 and, SARS-CoV-2-positive contacts as the number of contacts who tested positive for SARS-CoV-2.

To obtain the cost per contact identified, successfully reached, tested and found positive for SARS-CoV-2, we calculated the total cost of implementing patient tracing in ITV or SOC arms and then divided it by the number of contacts identified, reached, tested and positive for SARS-CoV-2, respectively, in each arm. Our cost estimation methodology was modelled on that of Mwenge *et al*[12] and Vyas *et al*.[13]

Threshold analysis

Given that the cost per SARS-CoV-2-positive contact is higher in the ITV, we conducted threshold analysis to calculate the minimum number of SARS-CoV-2-positive contacts that need to be found in the ITV in order to equal the SOC's cost per SARS-CoV-2-positive contact. We divided the total cost of the ITV by the cost per SARS-CoV-2-positive contact of the SOC to calculate the number of SARS-CoV-2-positive contacts the ITV needs to find to equal the SOC's cost per SARS-CoV-2-positive contact.

We also calculated the maximum cost of ITV to equal the SOC cost per SARS-CoV-2-positive contact by multiplying the SOC's cost per SARS-CoV-2-positive contact and ITV's number of SARS-CoV-2-positive contacts. By dividing the minimum number of SARS-CoV-2-positive contacts in ITV to equal the SOC's cost per SARS-CoV-2-positive contact by the percentage of the contacts tested SARS-CoV-2-positive in the ITV, we calculated the minimum number of contacts that need to be tested (assuming the same positivity yield), and through dividing this number by the percentage of contacts tested for SARS-CoV-2, we calculated the minimum number of contacts that need to be reached in ITV to equal the SOC's cost per SARS-CoV-2-positive contact.

RESULTS

Total costs, cost per contact reached and tested

In the SOC arm, 849 contacts were identified, of whom 55% (463/849) were reached, 27% (123/463) were tested for SARS-CoV-2 and 4% (5/123) of those tested were found positive. In the ITV arm, 854 contacts were identified, of whom 94% (801/854) were reached, 23% (182/801) were tested for SARS-CoV-2 and 2% (4/182) of those tested were found positive (online supplemental table S1). In both arms, the biggest expenditure was on human resources with site-level personnel costs corresponding to 40% and 39% of the total cost of SOC and ITV, respectively (table 1 and online supplemental table S2a–f). At the site level, the biggest expenditure was on lab technicians in the SOC arm (US$11 433) whereas in the ITV arm was on nurses (US$9935) (online supplemental table S2b). At the above site—regional delegation, the biggest expenditure was on medical doctors (US$3532) and IT specialist (US$2990) in the SOC and ITV arms, respectively, whereas at the above site—health district the biggest expenditure in the SOC arm was on medical doctors (US$2038) and in the ITV arm was on nurses (US$3132) (online supplemental table S2b).

Both costs per contact reached and tested for SARS-CoV-2 were lower in the ITV arm, however, the cost per SARS-CoV-2-positive contact was lower in the SOC arm (table 2). In the ITV arm, the cost per contact reached, tested and SARS-CoV-2-positive were US$48, US$210 and US$9573, respectively. In the SOC arm, the cost per contact reached was US$70, tested was US$262 and SARS-CoV-2-positive was US$6437.

In both arms, in terms of staff expenditure, the biggest contributor to the cost per contact reached and tested for SARS-CoV-2 was site-level staff. However, activity monitoring staff expenditure was much higher in SOC

Table 1 Expenditure disaggregated by arm and category

	SOC		Intervention	
Category	**US$**	**%**	**US$**	**%**
Staff—site level	12 765	40	14 851	39
Staff—above site regional delegation	6274	19	4812	13
Information Technology (IT) technical assistance	493	1	2990	8
Activity monitoring	5781	18	1823	5
Staff—above site health district	7055	22	7845	20
Subtotal staff	26 094	81	27 508	72
Supplies	1977	6	3508	9
Annualised equipment	0	0	836	2
Travel	1854	6	1854	5
Annualised training	2259	7	4586	12
Total	32 184	100	38 291	100

IT, information technology; SOC, standard of care.

Table 2 Cost per contact reached and tested for SARS-CoV-2 disaggregated by arm

Category	SOC	Intervention
Total cost (US$)	32 184	38 291
# contacts reached	463	801
# contacts tested for SARS-CoV-2	123	182
# contacts tested positive for SARS-CoV-2	5	4
Cost/contact reached (US$)	69.51	47.80
Cost/contact tested for SARS-CoV-2 (US$)	262	210
Cost/contact tested positive for SARS-CoV-2 (US$)	6437	9573

SOC, standard of care.

whereas IT technical assistance staff was much higher in ITV (online supplemental figure S1).

Threshold analysis

The minimum number of SARS-CoV-2-positive contacts required in the ITV to equal SOC cost per SARS-CoV-2-positive contact was approximately 6, one more than the number of SARS-CoV-2-positive contacts in SOC. The maximum cost of ITV to equal SOC's cost per SARS-CoV-2-positive contact was approximately US$25 748 (if the number of SARS-CoV-2-positive contacts in ITV remains 4) (table 3). The minimum number of contacts that need to be tested and reached in ITV to equal the SOC's cost per SARS-CoV-2-positive contact were 271 and 1191, respectively (table 3).

Table 3 Threshold calculation of minimum number of SARS-CoV-2-positive contacts and maximum cost of ITV to equal SOC

Order	Threshold	Value
a.	Total cost—ITV (US$)	US$38 291
b.	Cost/contact tested positive for SARS-CoV-2 (US$)—SOC	US$6437
c.	Minimum number of SARS-CoV-2-positive contacts in ITV to equal SOC cost per SARS-CoV-2-positive contact (US$) (c=a/b)	5.9486
d.	# contacts tested positive for SARS-CoV-2—ITV	4
e.	Cost/contact tested positive for SARS-CoV-2 (US$)—SOC	US$6437
f.	Maximum cost of ITV to equal SOC cost per SARS-CoV-2-positive contact (US$) (f=e/d)	US$25 748
g.	% contacts tested SARS-CoV-2 positive—ITV	2.1978%
h.	Minimum number of contacts tested for SARS-CoV-2 ITV to equal SOC cost/contact tested positive for SARS-CoV-2 (h=d/g)	271
i.	% contacts tested for SARS-CoV-2 - ITV	22.7216%
J.	Minimum number of contacts reached in ITV to equal SOC cost/contact tested positive for SARS-CoV-2 (j=h/i)	1191

ITV, intervention; SOC, standard of care.

DISCUSSION

Contact tracing is an integral component of the fight against highly contagious diseases such as COVID-19 and aims to identify individuals infected with the disease so as to quarantine and/or treat them, thus limiting disease transmission. Contact tracing is often resource-intensive and time-consuming, however, information technology can be used to improve the efficiency of the process and the cost-effectiveness.[14 15]

Various manual, phone and digital-based strategies for contact tracing have been employed in sub-Saharan countries. In the current study, we assessed the costs of tracing COVID-19 contacts and the cost per contact traced using the Mamal Pro digital contact tracing feature (ITV) or paper-based contact tracing (SOC). ITV had lower cost per contact reached (US$48) and tested for SARS-CoV-2 (US$210) whereas SOC had the lower cost per SARS-CoV-2-positive contact.

The lower costs per contact reached and tested in ITV arm were mainly due to the fact that in this arm more contacts were reached and tested for SARS-CoV2, and these numbers have an inverse correlation with the cost per contact reached and tested, as shown sensitivity analysis elsewhere.[13] We estimated that if the ITV found two more SARS-CoV-2-positive contacts it would have the same cost per SARS-CoV-2-positive contact as SOC. Our data indicate that timing the contact tracing with COVID-19 waves when larger numbers of index cases and SARS-CoV-2-positive contacts are expected to be identified, would lower ITV's costs per contact reached, tested and found SARS-CoV-2-positive.

Furthermore, this was the first time that Mamal Pro digital contact tracing feature was used for tracing COVID-19 contacts and the staff was not fully proficient in the use of the app leading to a considerable number of contacts and index cases not being registered properly in the app. These issues may have negatively impacted the number of contacts tested for SARS-CoV-2. Following retraining, which were required during the implementation period to ensure staff could properly implement ITV activities, an increase in the number of contacts registered was observed. In future, it is expected that staff will become more proficient in the use of the app thus increasing the number of contacts reached and tested, leading to even higher cost-effectiveness and lower costs per contact.

This study had a number of limitations. Given the significant adaptation obstacles and related costs associated with the early stages of introducing a new digital ITV, a longer study duration would enable a more robust evaluation of cost efficiency. Vaccination is expected to reduce transmission of COVID-19,[16] however, in our study, we did not consider how it will impact the costs per contact of the ITV. In addition, due to health facility visits, patients' incurred transport costs and loss of income, which are two of the biggest barriers to accessing multiple healthcare ITVs including testing for infectious diseases at health facilities in sub-Saharan Africa.[17 18] Given the economic constraints, it is plausible that a considerable number of contacts did not visit the health facility to get tested for SARS-CoV-2, thus, to improve the number of contacts tested, there is a need to provide community-based testing.

Outside of modelling studies, there is limited economic evaluation of implementation of contact tracing in African countries during the COVID-19 pandemic response. However, a costing analysis conducted in Ethiopia found that the cost per COVID-19 case detected was 10% higher if contact tracing was involved to identify this case, compared with if the case was detected through standard health facility-based testing.[19] The study also identified personnel, and transportation required to physically reach contacts, as the main cost drivers, with the authors suggesting that digital contact tracing could reduce these costs by increasing the efficiency and quality of contact tracing. This study provides empirical evidence to support the use of digital technologies to improve cost-effectiveness of COVID-19 contact tracing, and these implications can be considered for other contact-tracing programmes such as TB which are often hampered by the resource-intensive manual approaches used in most settings.

CONCLUSION

In conclusion, the addition of a Mamal Pro digital contact tracing module increased the number of clients reached and tested for SARS-CoV-2 and has better value for money. The expansion of the use of the Mamal Pro digital contact tracing module would be a valuable tool to enable the identification of SARS-CoV-2 positive individuals promptly which is crucial for early isolation and patient management and limiting disease transmission.

However, when budgeting for the expansion of this ITV, a considerable percentage of it should be allocated to site-level staff. The estimation of the number of contacts to be traced must be as accurate as possible since changes in this number have a major effect on the total costs and cost per contact reached. Thus, the scale-up of this approach and increase in the number of contacts reached and tested is dependent on staff performance, time spent on different contact tracing-related activities and salaries.

Nationwide expansion of digital contact tracing not only for COVID-19 but also for other infectious diseases such as TB would be recommended. However, given that the ITV is more expensive, we recommend a budget impact analysis modelling the number of patients to be trace and tested, and total costs as percentage of the annual budget, similar to Bastos *et al*.[20]

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Contributors BTY, GW, BT, AT and LG formulated the study concept and designed the research. AM, BT and BTY developed the digital health tool and designed the intervention. BTY, GW, BT, RM, MS, AM, EE, TD, OA, RiK, PA, KS, AVK, LS, PNT, PT, A-CZ-KB and LG contributed to developing the study protocol. BTY and GW oversaw and executed the study. BYT, SZT and CMN managed the daily conduct of the study. SZT, MLAN, GB, PNT, RoK, GW and BTY oversaw recruitment and data collection. RoK and RM did the statistical analysis. MS and SM performed data analysis, wrote the manuscript and had primary responsibility for its final content. All authors interpreted the data, provided critical review and commentary on the draft manuscript and approved the final manuscript. MS is the guarantor of this manuscript and accepts full responsibility for the finished work, had access to the data and controlled the decision to publish.

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