

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<u>http://bmjopen.bmj.com</u>).

If you have any questions on BMJ Open's open peer review process please email <u>info.bmjopen@bmj.com</u>

## **BMJ Open**

#### Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda

Journal:	BMJ Open
Manuscript ID	bmjopen-2023-083410
Article Type:	Original research
Date Submitted by the Author:	19-Dec-2023
Complete List of Authors:	Nshimiyimana, Ladislas; Rwanda Biomedical Center, Bigirimana, Noella; Rwanda Biomedical Center Ngabonziza, Jean Claude; Rwanda Biomedical Center; University of Rwanda Rwabihama, Jean-Paul ; Republic of Rwanda Ministry of Health Rutayisire, Robert; Rwanda Biomedical Center Semakula, Muhammed; Republic of Rwanda Ministry of Health RUKUNDO, Gilbert ; Rwanda Biomedical Center Mugabo, Hassan; Rwanda Biomedical Center, Research Innovation and Data science Mutabazi, Josue; Independent consultant Mukamana, Beatrice; Rwanda Biomedical Center Mazarati, Jean-Baptiste ; FIND Kadam, Rigveda; FIND Akinwusi, Olukunle; FIND Suleiman, Khairunisa; FIND Muvunyi, Claude; Rwanda Biomedical Center; University of Rwanda Akugizibwe, Paula; FIND
Keywords:	COVID-19, Public health < INFECTIOUS DISEASES, Health Services
	•

#### SCHOLARONE<sup>™</sup> Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

terez oni

Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies

# BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text ining, Al training, and similar technologies

#### Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda Ladislas Nshimiyimana<sup>1</sup>, Noella Bigirimana<sup>1</sup>, Jean-Claude S. Ngabonziza<sup>1,2</sup>, Jean-Paul Rwabihama<sup>3</sup>, Robert Rutayisire<sup>1</sup>, Muhammed Semakula<sup>3</sup>, Gilbert Rukundo<sup>1</sup>, Hassan Mugabo<sup>1</sup>, Josue Mutabazi<sup>4</sup>, Beatrice Mukamana<sup>1</sup>, Jean-Baptiste Mazarati<sup>5</sup>, Rigveda Kadam<sup>5</sup>, Olukunle Akinwusi<sup>5</sup>, Khairunisa Suleiman<sup>5</sup>, Claude Mambo Muvunyi<sup>1,2</sup>, Paula Akugizibwe<sup>5</sup> <sup>1</sup>Rwanda Biomedical Centre, Kigali, Rwanda <sup>2</sup>University of Rwanda, Kigali, Rwanda <sup>3</sup>Ministry of Health, Kigali, Rwanda <sup>4</sup>Independent consultant, Kigali, Rwanda <sup>5</sup> FIND, Geneva, Switzerland \* Correspondence: Corresponding author ladi8n@gmail.com Word Count: 4951/5000 Keywords: COVID-19, diagnostics and tools, public health For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

#### 16 KEY MESSAGES

# 4 17 5 6 18 What is already known on this topic 7 8 10

- Community health workers play an indispensable role in increasing access to care, by
   extending delivery of prevention, diagnosis and treatment services beyond health facilities.
- Digital tools can facilitate community-based service delivery by providing decision support,
   strengthening data management and enhancing monitoring

#### 15 23 What this study adds16

This study demonstrates the value and feasibility of using a digital tool combined with
 antigen-based rapid diagnostic tests to support household-level SARS-CoV-2 detection by
 community health workers in Rwanda.

#### 2223 27 How this study might affect research, practice or policy

The learnings from this study are informing a digitally enabled approach to community-based point-of-care testing in Rwanda and can be used to support decentralized testing approaches for priority diseases.

BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

#### 32 Introduction

Antigen-based rapid diagnostic tests (Ag-RDTs) can improve the diagnosis, management and control
 of COVID-19, by bringing testing closer to patients. However, testing in decentralized settings
 presents challenges in terms of data reporting, linkage to care, and decision-making. In line with
 Rwanda's ambition to decentralize COVID-19 testing, this study evaluated the use of Ag-RDTs

- alongside a digital tool to deliver household-level COVID-19 testing by community health workers
   (CHWs).
- 15 39 **Methods**

This was an operational pilot study to evaluate the impact and operational characteristics of using the digital tool e-ASCov combined with Ag-RDTs to support COVID-19 symptom screening and rapid testing by CHWs across eight districts in Rwanda. A total of 800 CHWs selected from both rural and urban areas were trained in delivering Ag-RDTs for COVID-19 testing and using the e-ASCOV application for data capture on a smartphone. Laboratory technicians repeated a subset of Ag-RDTs and took samples for PCR testing, to assess the concordance of results obtained by CHWs. The study also assessed CHWs experience of the intervention using a mixed methods approach. 

#### **Results**

From February to May 2022, CHWs screened 19,544 participants, of whom 4575 (23.4%) had COVID-19 related symptoms or history of exposure to the infection. Among them, 86 (1.9%) were positive on Ag-RDTs. Concordance of Ag-RDT results between CHWs and laboratory technicians was 100%; PCR and Ag-RDT results were also fully concordant. Of the 800 trained CHWs, 746 (93.3%) were independently able to conduct household-based COVID-19 screening, perform the Ag-RDTs and send data to the central server. Most CHWs (>80%) found Ag-RDTs and e-ASCOV easy to use. 

#### 3536 54 Conclusion

This study demonstrated the feasibility of deploying a digital tool and Ag-RDTs for household-level SARS-CoV-2 detection in Rwanda. The findings support broader roll-out of digitally supported rapid

testing by CHWs to broaden access to testing for priority diseases.

#### <sup>42</sup> 58 Word count: 299/300

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

#### 59 INTRODUCTION

60 Across the globe, the COVID-19 pandemic highlighted that agile and resilient health systems rely on 61 the strength of primary and community health systems which present the point of entry for most

6 61 the strength of primary and community health systems which present the point of entry for most
 62 patients.<sup>12</sup> Implementation research evaluating health interventions is key to informing the effective
 63 64 complexity of the strength of the

- 63 and equitable design of these systems.<sup>3</sup> In Rwanda, the existence of a well-established community
- health worker (CHW) network prior to the onset of the COVID-19 pandemic offered unique non-portunities to ensure that services were brought as close to patients as possible during the
- $\begin{array}{c} 11 \\ 12 \\ 13 \end{array}$   $\begin{array}{c} 65 \\ 66 \end{array}$  opportunities to ensure that services were brought as close to patients as possible during the pandemic.
- As of 9 February 2022, Rwanda had reported 129,210 cases of COVID-19, out of over 4.5 million tests
   conducted, and 1449 deaths.<sup>4</sup> The bulk of cases were reported during three major waves in which rapid
   surges of infection took place in a short period of time, underscoring the importance of widespread
   testing to enable the rapid detection of SARS-CoV-2 and contain its transmission.

While the epidemic was initially concentrated in urban settings, with the capital city of Kigali accounting for 29.1% (28,267 of 97,190) of cumulative cases,<sup>5</sup> over time an increasing number of cases were detected in more rural areas of the country. Lower access to health facilities in less urbanized settings highlighted the need to expand community-based testing. Even outside of an emergency situation, the opportunity costs associated with travel to health facilities present significant barriers to care-seeking in many settings,<sup>6</sup> which were further heightened by movement restrictions and economic constraints during the COVID-19 pandemic.<sup>7</sup> 

The increased availability of point-of-care testing for COVID-19, specifically antigen-based rapid diagnostic tests (Ag-RDTs), created new opportunities to bring testing closer to patients. Decentralization of Ag-RDT testing was a priority in Rwanda's COVID-19 response. Ag-RDTs supplemented centralized, polymerase chain reaction (PCR) testing capacity, with widespread availability at lower levels of care, and a price cap of approximately US\$ 5 across public and private sectors to ensure affordability. 

Testing with Ag-RDTs in Rwanda was initially delivered by trained clinicians or laboratory professionals and had not been formally offered by CHWs directly in communities at the household level. However, the country's extensive network of CHWs were already involved in the diagnosis of other diseases, including symptom screening and referral for tuberculosis (TB). For example, between 2020 and 2021, 26.3% of the 5435 TB cases in Rwanda were referred by CHWs.<sup>8</sup> Consequently, there was a basis on which to review the COVID-19 testing process to consider expanding Ag-RDT testing at the community level through trained CHWs. Extending diagnostic ability in decentralized and community settings using CHWs promises tremendous potential for expanded access, but also presents challenges in terms of accurate and timely data reporting. 

<sup>53</sup> 93 Timely and accurate testing data are critical for the effective management of the COVID-19
94 response, particularly during periods of rapid transmission when such data provide early alerts of
95 impending waves and hotspots to which intensified resources should be directed. CHWs could thus
96 play a role not only in expanding access to diagnosis, but in supporting the development of

- 1
   2
   97 community health surveillance approaches, which the World Health Organization has highlighted as
   3
   98 a core pillar of pandemic preparedness.<sup>9</sup>
- Digital tools can play an important role in closing these gaps, by enabling the rapid transmission of data to support real-time monitoring and epidemiological surveillance. The pandemic response accelerated digitization of health data, including in Rwanda, where an integrated national digital architecture was established to support rapid reporting and data management in every area of COVID-19 management, including vaccination, diagnosis and home-based care.<sup>1011</sup> Experience from other settings has also demonstrated that the use of digital tools by CHWs to support delivery of COVID-19 services can lead to significant reductions in the costs associated with data management and reporting.12
- <sup>17</sup> 107 Beyond data benefits, technology can also play an important role in decision support, particularly for
- 108 CHWs who lack advanced clinical training but are required to make decisions with clinical
- 20 109 implications. Digital solutions can provide real-time guidance and standardization of processes at the
- point of care and at the management level, and enable visibility into procedures being implemented in decentralized sites.<sup>13</sup>
- There was therefore potential to leverage Rwanda's widespread CHW network for increased access to COVID-19 testing, and utilize digital tools to improve data reporting and decision-making. Consequently, a pilot project to evaluate the use of digital tools and Ag-RDT testing by CHWs was initiated in 2020 by the Rwanda Biomedical Centre (RBC, the country's health implementation agency) in collaboration with partners. The pilot was called the e-ASCov project, named after the country's CHWs who are known as "Agents de Santé Communataires" (ASCs). The pilot project was rolled out in two urban and two rural districts in Rwanda. Through the pilot, CHWs were trained and equipped with innovative digital technology to support their involvement in community-based screening and referral of people with symptoms and signs suggestive of COVID-19. RBC developed the e-ASCov mobile application, which was installed by participating CHWs on their phones to support them with COVID-19 symptom screening and referral, and to ensure that related data are systematically captured and rapidly transmitted to national data servers to guide national surveillance and response efforts.

This study sought to build on the original e-ASCov pilot, and the opportunities offered by the expansion of Ag-RDT testing, by expanding e-ASCov to include instructions and data capture for administration of Ag-RDTs, and mechanisms for real-time reporting. At the time it was designed, to the authors' knowledge this was the first study that evaluated the ability of CHWs, rather than trained healthcare providers, to perform SARS-CoV-2 Ag-RDT testing, and capture and transmit results in Rwanda and the broader African region. Thus, the study would provide grounds to review and update COVID-19 laboratory testing guiding principles in Rwanda vis-a-vis the possibility to decentralize RDT-based diagnosis at community level by trained CHWs. 

 

#### 134 METHODS

This was an operational pilot study to evaluate the impact and operational characteristics of using the
 digital tool e-ASCov combined with Ag-RDTs to support symptom screening and delivery of rapid
 testing by CHWs at the household level across eight districts in Rwanda.

#### 10 138 Study setting and population

The study took place in eight districts in four provinces in Rwanda, including the four districts selected in the e-ASCov pilot. Four additional districts were selected based on infection rates (those with the highest infection rates at the time the study began) and geographic location. In terms of geographic location, a spread of rural, urban and semi-urban districts were included, with prioritization of rural districts as residents have more restricted access to health facilities in these areas compared with the rest of the population. Districts with land borders were also prioritized due to a greater risk of COVID-19 transmission as a result of higher levels of movement between countries. 

A total of 800 CHWs were selected for this study across 34 health centres (100 per district), representing around 5% of the total CHW workforce in the studied districts. Villages were selected randomly depending on the number of CHWs required per health centre, with all active CHWs included from selected villages. Supplementary Table 1 provides an overview of the study districts and CHWs included in the project by district. Within these districts, the intervention was fully integrated into the CHWs' routine package of care, which is accessible to all residents. As a result, the eligible population for this project was any person resident in the study districts. 

#### <sup>32</sup> <sup>33</sup> 153 Digitally enabled screening and rapid testing

This study built on the e-ASCov pilot, described previously, in which CHWs identified individuals suspected to have COVID-19 and referred them for testing. The e-ASCov tool was an existing, field-tested mobile application for symptom screening to identify possible COVID-19 cases. CHWs verbally administered a screening questionnaire to individuals in their communities, which focused on signs and symptoms suggesting a risk of COVID-19, recording individual's response in the e-ASCov application. Based on the responses, an algorithm built into the application assigned participants to one of three risk levels (low risk, suspected case, and urgent case)—with the latter two categories being referred for Ag-RDT testing. 

The algorithm used for screening was updated to align with the latest guidance from Rwanda's
 Ministry of Health (Figure 1), with inbuilt skip logic determining which of the case categories an
 individual fell into.

1 2 2	168	
5 4 5	169	Figure 1. e-ASCov algorithm used in pilot study
6 7	170	
8 9 10	171	RDT, rapid diagnostic test.
11 12 13 14 15 16 17 18 19	172 173 174 175 176 177	For this study, the RDT toolkit (developed by Dimagi Inc) <sup>14 15</sup> was integrated into e-ASCov, to provide instructions for administering RDTs, a timer, and data capture for the test and result. Originally developed to support rapid diagnostic testing for malaria, the toolkit is readily customizable for different conditions for which RDTs are used. It was thus adapted to support delivery of the SARS-CoV-2 Ag-RDTs and translated to make instructions available in Kinyarwanda.
20 21 22 23 24 25	178 179 180 181	When a CHW was prompted to conduct a test after the e-ASCov questionnaire, the workflow automatically transitioned into the RDT toolkit without the CHW having to change applications. This presented a set of instructions in Kinyarwanda. The CHW collected the sample for the Ag-RDT using a nasal swab, then was instructed to start the timer after initiating the test.
26 27 28 29 30 31 32 33 34 35 36	182 183 184 185 186 187 188 189	Rapid testing by the CHWs was conducted according to manufacturer's instructions using a validated Ag-RDT (Panbio COVID-19 Ag Rapid Test Device, Abbott), which was already recommended by Rwanda's COVID-19 Laboratory Testing Guiding Principles and routinely used. <sup>16</sup> Using the timer on the application, CHWs read the Ag-RDT result after the processing time and recorded the result in the e-ASCov tool. There was also an option to capture and transmit images of the test result to enable validation of the result by the central team at RBC. As e-ASCov was fully integrated within the broader Ministry of Health digital system for reporting on COVID-19, data were subsequently transmitted to RBC servers in real time.
37 38 39 40 41 42	190 191 192 193	Figure 2. Study workflow
43	194	HMIS, health management information system; RBC, Rwanda Biomedical Centre; RDT, rapid diagnostic test.
<ul> <li>44</li> <li>45</li> <li>46</li> <li>47</li> <li>48</li> <li>49</li> <li>50</li> </ul>	195 196 197 198	Patients who tested positive on the Ag-RDTs were referred to a nearby facility if their risk was classified as "urgent" (Case 3 in Figure 1), or would otherwise be referred to the existing home-based care programme, which includes guidance on isolation and self-monitoring of symptoms. In addition, their contacts were registered and tested using the same procedure.
50 51 52	199	Concordance testing
52 53 54 55 56 57 58	200 201 202	To assess the concordance of Ag-RDT and PCR testing, a group of CHWs were randomly selected and shadowed by a laboratory technician for a period of time. During that time, the CHWs administered Ag-RDTs and read the result independently, with the result interpreted by the CHWs who were blinded

59

#### BMJ Open

to the laboratory technician. The laboratory technician then repeated the Ag-RDT and reported their result independently. Laboratory technicians also collected a sample for PCR testing among participants with symptoms of COVID-19 who tested negative by Ag-RDT, which was sent to the National Reference Laboratory (NRL) for testing. Ag-RDT results from CHWs and laboratory technicians were entered into e-ASCov for assessment, while the PCR results were transmitted from NRL for inclusion in the final study dataset.

#### 11 210 Assessment of the experience

The study assessed CHWs' experience of the intervention using a mixed methods approach. Firstly, a self-administered questionnaire with close-ended questions was provided to CHWs. Secondly, qualitative data were collected using focus group discussions with CHWs in four districts (Rubavu, Huye, Nyagatare and Gasabo). The questions focused on e-ASCov and the administration of Ag-RDTs, in terms of usability, satisfaction, enablers and barriers, and the perceived continuity of the intervention. Interviews were conducted in Kinyarwanda and recorded with the aid of smartphones and tablet devices, then later transcribed and translated in English. Copies of questions asked as part of the focus group discussions are available in the Supplementary methods. 

#### 25 219 Training and mentorship 26

CHWs and supervising staff at participating facilities underwent 1–2 days of theory and practical training at the district level. A refresher training was conducted on general COVID-19 information including the use of personal protective equipment (PPE), detecting symptoms of COVID-19, and follow-up of COVID-19 cases. CHWs were then further trained on screening and data capture using e-ASCov. Finally, qualified staff from the NRL provided training on how to conduct Ag-RDTs. This included a demonstration with the aid of a practical video, following which the CHWs conducted Ag-RDT testing under the supervision of facilitators. The community health supervisor and the training facilitators at the respective health centres were responsible for ensuring distribution of materials to the CHWs and accountability in the use of these materials. 

Pre- and post-training tests were conducted to confirm participants' level of knowledge. Trainees' feedback on the digital tool also informed further refinement of the application during the training process. During implementation, ongoing mentorship was provided through existing supervisors at facilities, with additional support from RBC, particularly for resolving any operational and technological issues that arose during the study. Refresher training and technical support around using the digital tool were provided as needed, and the proportion of CHWs who needed such support was monitored. 

#### <sup>50</sup> 236 **Data management and analysis**

<sup>52</sup><sub>53</sub> 237 Sample size and sampling techniques

The target sample size for Ag-RDT testing was determined by feasibility considerations, with a target of delivering up to 6816 tests to symptomatic individuals plus direct contacts of confirmed cases.

240 Based on data from the first pilot phase of e-ASCov, in which 30% of all individuals screened were
 241 eligible for testing based on symptoms, it was estimated that close to 20,000 individuals would need
 242 to be screened to achieve the testing target. Each CHW therefore aimed to screen 20–25 individuals

6 243 during the study period.

<sup>8</sup><sub>9</sub> 244 Data collection and sharing

Participants were given a unique number, which was used to identify the collected data. Demographic and clinical data, test results and images linked to these data were stored in e-ASCov and transmitted to the local RBC servers for integration into the national COVID-19 data system. The e-ASCov app included validation rules that prevented skipping of mandatory questions and therefore prevented missing data. 

All the information obtained in this study was kept and handled in accordance with applicable laws and/or regulations. Data were stored and archived to the RBC server in compliance with national data security guidelines per the Rwanda Information Security Authority, with only authorized personnel processing the information. Data encryption and anonymization principles were applied to safeguard confidentiality. Any access to and use of the data was subjected to the approved data sharing agreements between different institutions that formed the study team. 

<sup>27</sup><sub>28</sub> 256 Regulatory and ethical considerations

Ethical clearance to conduct this study was obtained from the Rwanda National Ethics Committee (RNEC) No.920/RNEC/2021. As this intervention was integrated into routine Ministry of Health programming included in the CHWs' package of services, RBC secured a formal waiver of informed consent for community members to take part in the household-level COVID-19 testing through the RBC's CHWs. Thus, no additional informed consent forms were required from individuals. However, the CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation. 

This study was conducted in accordance with the protocol and with consensus ethical principles derived from international guidelines, particularly the Declaration of Helsinki and Good Clinical Practice Guidelines: ICH GCP E6 (R2). Several measures were taken to minimize the risk of infection for CHWs or other members of the household during community-based testing, including previously described training and provision of PPE to CHWs. In addition, CHWs were trained on how to assess the households of individuals who were eligible for testing, to determine whether an appropriate space was available (in terms of size, distance from other household members, and adequate ventilation). If the household did not contain such a space, testing was conducted outside of the house, in the household compound. 

- An author reflexivity statement is provided in the supplementary methods.
- 276 Patient and public involvement

atients and the commune design of this study.	nity were involv	ved in the pilo	ot, with the expen	rience and find	lings used to inform
RESULTS					
Number tested and	screened				
total of 19,544 indiv COVID-19 (Table 1). (Infection and were thus)	iduals were en Of these, 4575 eligible for test	rolled in the (23.4%) had ing with Ag-2	study and scre l signs and sym RDTs (Table 1).	ened for signs ptoms sugges	s and symptoms of stive of COVID-19
Table 1. Number of particular	rticipants test	ed and scree	ned		
District	All screene	ed	Number with sy (eligible for test	mptoms ing)	Percentage screened eligible for testing
Gasabo (urban)	17	708	598		35.0%
Huye (semi-urban)	16	525	435		26.8%
Kirehe	30	)09	787		26.2%
Ausanze	25	549	563		22.1%
Nyagatare	24	198	465		18.6%
Nyarugenge (urban)	22	226	694		31.2%
Rusizi	32	254	359		11.0%
Rubavu	26	575	674		25.2%
ГОТАL	19	,544	4575	5	23.4%
TOTAL he proportion of those ith the highest rates of 1.2%) (Table 2). able 2. Testing outcor	19, screened who bserved around	544 reported sym the capital	4575 optoms of COVI city, Kigali, in (	D-19 was hig Gasabo (35.0%	23.4% hest in urban areas 6) and Nyarugeng
	Number	Negative	Positive	Invalid	Positivity rate *
District	tested				
<b>District</b> Gasabo (urban)	598	558	14	26	2.3%
<b>District</b> Gasabo (urban) Huye (semi-urban)	598 435	558 414	14 4	26 17	2.3% 0.9%

279	the design of this study.			
280				
281	RESULTS			
282				
283	Number tested and	screened		
284				
285	A total of 19,544 indiv	iduals were enrolled in	the study and screened for si	igns and symptoms of
286	COVID-19 (Table 1). (	Of these, 4575 (23.4%)	had signs and symptoms sug	gestive of COVID-19
287	infection and were thus	eligible for testing with	Ag-RDTs (Table 1).	
288				
289	Table 1. Number of particular	rticipants tested and so	creened	
290				
	District	All screened	Number with symptoms (eligible for testing)	Percentage screened eligible for testing
	Gasabo (urban)	1708	598	35.0%
	Huye (semi-urban)	1625	435	26.8%
	Kirehe	3009	787	26.2%
	Musanze	2549	563	22.1%
	Nyagatare	2498	465	18.6%
	Nyarugenge (urban)	2226	694	31.2%
	Rusizi	3254	359	11.0%
	Rubavu	2675	674	25.2%
	TOTAL	19,544	4575	23.4%
291				

#### Table 2. Testing outcomes

District	Number tested	Negative	Positive	Invalid	Positivity rate *
Gasabo (urban)	598	558	14	26	2.3%
Huye (semi-urban)	435	414	4	17	0.9%
Kirehe	787	717	8	62	1.0%

ТО	DTAL	4575	4245	86	244	1.9%
Rul	bavu	674	634	24	16	3.6%
Rus	sizi	359	345	1	13	0.3%
Nya	arugenge (urban)	694	621	21	52	3.0%
Nya	agatare	465	443	1	21	0.2%
Mu	Isanze	563	513	13	37	2.3%

The overall positivity rate in the study was 1.9%, and by district, was highest in the border district of Rubavu (3.6%) and Nyarungenge district (3.0%), which forms part of the capital city. A total of 244 tests, representing 5.3% of all tests conducted, were automatically flagged by e-ASCov as "Invalid: Control Failed", as over 20 minutes elapsed with no result being entered in the application. The test was repeated for individuals with invalid results. There were no missing data.

#### 20 305 Contribution to case-finding in districts 21

During the study period, a total of 378 COVID-19 cases were diagnosed in the eight districts. Of these,
86 were diagnosed through the study intervention, with CHWs thus accounting for 22.8% of all
diagnosed COVID-19 cases during the study period (Supplementary Figure 1).

#### <sup>27</sup> 309 **Concordance**

A total of 499 participants were tested for COVID-19 using Ag-RDT by CHWs and laboratory professionals for the concordance evaluation. Of these, three positive cases and 489 negative cases were identified by both CHWs and laboratory professionals. All the Ag-RDT results obtained by CHWs were confirmed by professional laboratory technicians, with a perfect agreement of 100% between results from the CHWs and the laboratory technicians (Cohen's kappa of 1.0) (Table 3). 

### 37 315 Table 3. Concordance of COVID-19 testing between community health workers, laboratory 38 316 technicians and PCR by the NRL

Re-testing by laboratory technicians and result by the NRL*			
Testing by community health worker	Positive	Negative	Invalid
Positive	3	0	0
Negative	0	496	0
Invalid	0	0	0
Total	3	496	0
Observed agreement (%)	100%		·

Page 13 of 36

	Expected agreement (%)	98.78%
	Cohen's kappa	1.0
317	*Only negative Ag-RDTs for patients with sympton	ms of COVID-19 were retested by PCR.
318	NRL, National Reference Laboratory; PCR, polym	erase chain reaction.
1 319	Similarly, PCR tests on the subset of patients v	vith symptoms suggestive of COVID-19 who tested
$3^{2}$ 320	negative by Ag-RDT confirmed complete agre	ement with the Ag-RDT test results (Table 3).
4 5 321 6	Feasibility	
<sup>7</sup> 322	Overall, 746 out of 800 CHWs (93.3%) wer	e able to independently conduct all study procedures
9 323	without support from supervisors. This ir	ncluded screening using the e-ASCov application
0 324	administering nasal swabs for the Ag-RDTs and	d conducting the test, reporting results and sending data
$\frac{1}{2}$ 325	to the national RBC server. The remaining pro-	oportion (6.7%) of CHWs required substantive support
3 326	to implement one or more of the above steps.	
5 327 6	Qualitative assessment: Satisfaction, u	usability and acceptability
7 8 328	Respondent profiles	
9 0 329	A total of 349 CHWs participated in qualitativ	ye assessments of the testing experience. The mean age
<sup>1</sup> 330	of these participants was 44 years with a range	of 20–72 years. Of these, 42.1% had completed primary
2 3 331	education and 44.1% had completed second	ary education. Only 4.3% had received a university
4 332	education, while 9.5% had undergone vocation	al training.
6 7 333	CHW perceptions of e-ASCov	
8 9 334	Respondents were asked a number of questions	s related to their experiences with using the digital tool,
0 335	with findings summarized in Supplementary T	Table 2. The majority reported positive feedback of the
$^{1}_{2}$ 336	experience, with main areas identified for impr	rovement including:
3 4 337	- Duration of training: 28.7% of participants b	believed the length of training was only partly sufficient,
5 338	while 16.3% believed that it was not sufficient	ient to cover all the skills they needed to learn.
<sup>b</sup> 339	- Access to internet: close to half (48.7%)	of participants reported only partial satisfaction with
s 340	internet access during the study.	
9 341	- Time taken to enter data: one in five respo	ondents stated that the time required for data entry was
<sup>0</sup> 342	long, while 1 in 3 did not believe that it wa	s short enough.
2 3 343	Despite these challenges, all respondents expr	ressed the need for future use of e-ASCov, with 99.7%
4 344 5	recommending that it should be scaled up to ot	ther disease areas.
6 7 345	CHW perceptions of CHW-led Ag-RDT	T testing
5 9	Ear poor raviou only http://bmia	12

A small proportion of respondents (0.9%) expressed challenges with administering tests, although the majority (89.6%) still believed this was easy and 9.5% indicated it was slightly easy. While only 57.8% responded that the training was sufficient, 93.9% still found it easy to read Ag-RDT results, while 84.8% found it easy to report results through e-ASCov (Supplementary Table 3). 

#### DISCUSSION

This study successfully leveraged previous investments in a screen-and-refer model to enable CHWs to deliver near-patient, high-quality screening and testing for COVID-19 in Rwanda using Ag-RDTs and a mobile application. Although implementation took place during a period of low COVID-19 transmission in Rwanda, nearly a quarter of the 19,544 participants screened had signs and symptoms of COVID-19. Rates of COVID-19 were particularly high in the Kigali metropolis, where over 30% of screened individuals were identified as potential COVID-19 cases. This indicated a higher frequency of respiratory and other symptoms in urban areas, highlighting a need for expanded and more targeted COVID-19 case finding in communities. Overall, 1.9% of tested individuals were positive for SARS-CoV-2—a significant decline from the earlier screen-and-refer e-ASCov pilot where the positivity rate was 7.5% preceding scale-up of Rwanda's COVID-19 vaccination programme. 

The CHWs demonstrated an excellent capacity to perform the COVID-19 Ag-RDT. There was full concordance (100%) between the rapid Ag-RDTs run by CHWs and those performed by laboratory professionals. Moreover, all patients with COVID-19 symptoms but negative Ag-RDTs (n=529) were also confirmed negative by PCR. This alignment in test results supports the reliability of Ag-RDTs in the field, and highlights their crucial role in the rapid and effective identification of COVID-19 cases in the community. Together, the findings support the broader use of Ag-RDTs by CHWs at the household level. 

Wide variations were observed in the Ag-RDT positivity rate in the study, with the highest rate found in Rubavu, a district at the border with the Democratic Republic of Congo. Across multiple disease areas, cross-border mobility has often been associated with increased spread of disease.<sup>17 18</sup> While this prompted widespread restrictions on international movement, especially in the earlier stages of the pandemic response, there is a lack of conclusive evidence on the effect of these restrictions on the incidence of COVID-19.19 Nevertheless, our study highlights the role of enhanced testing to better identify high transmission areas and evaluate what measures can most effectively reduce disease transmission. Expanding access to testing through CHW-led diagnosis, as was conducted in this study, is one such way to intensify testing, particularly in environments where there is a higher risk of transmission such as densely populated urban settings and border districts. 

The urban districts, Nyarugenge and Gasabo, also reported high COVID-19 positivity rates of 3.0% and 2.3%, respectively, at the time when the national positivity rate was below 1%. Community-based testing methods supported by digital tools, as deployed in this study, could be a useful approach to identify transmission hotspots such as these, which may require targeted public health interventions. 

<sup>2</sup> 384 During the study, the testing conducted by CHWs accounted for 22.8% of all cases identified in the

- study districts, although only 5% of the overall CHWs in the study districts were involved in the study. The disproportionately high contribution of CHWs to identifying COVID-19 cases illustrates the significant potential of this cadre of health workers to expand case finding for COVID-19 and other diseases if engaged at larger scale. The 100% concordance between CHWs and laboratory technicians further demonstrates that trained CHWs are capable of delivering RDTs with comparable quality to laboratory personnel, making the case for task-shifting of rapid diagnostic testing to the lowest levels
- <sup>11</sup> 391 of care providers.

The use of a digital tool played an important role enabling CHWs to carry out COVID-19 testing in
 the community, by providing decision support and facilitating data entry. The FGDs with CHWs
 provided insights into this experience.

- <sup>18</sup> 395 "[The testing process] was understandable and didn't take much time," pointed out one FGD
   <sup>20</sup> 396 participant "the way that tools were made makes everything easy so we were 100% confident."
- While some CHWs interviewed in the FGDs acknowledged that they initially faced difficulties with using the digital tool, and indicated the need for a longer period of training, most were comfortable with the tool by the end of the study. The training was delivered in most study sites within two days, but the speed of learning differed across the sites and between participants. Across CHWs, training first-time users of smartphones on how to navigate the telephone took the longest time.
- 402 It was observed that younger CHWs were the fastest learners due to strong digital literacy, while CHWs
   403 with more advanced age (60 years and above) faced more challenges and required closer support from
   404 the facilitators and supervisors.
- 405 "At first time the phones were going to be hard for us. Saving the information obtained from the people
  406 failed to work completely. They helped us and showed it to us how to proceed. We continued to try,
  407 and end up by becoming familiar with the system. I am 90% confident." An FGD respondent.
- In addition to expanding access to testing, the process used in this study – Ag-RDTs combined with a digital tool – strengthened surveillance systems, and decongested health facilities and laboratories in study areas. The ability of CHWs to report directly to the national database, using unique patient codes, which were part of Rwanda's testing architecture since the start of the pandemic, greatly enhanced the benefit of this intervention. Together the findings demonstrate the value of investing in strong digital health systems that can easily be built on to improve services.
- 48
   414 CHWs involved in the study agreed, almost unanimously, on the need for continued delivery of Ag 50
   51
   51
   52
   53
   5417 diseases for which testing is offered would enhance quality of life for the people in their communities.
- 54
   55 418 "This method of COVID testing I found is not a difficult thing, because otherwise we as CHW usually
   56 419 do malaria treatment...although performing malaria test and COVID-19 tests seems to be different, it

is not difficult...If you know that you're going to help a patient who comes to you to get better life,
that's something I found possible and we do, it's not too difficult. " – A FGD CHW respondent.

422 "I suggest to introduce the diseases that we are normally treating in the [e-ASCov] system...it will be
423 helpful and delivering information will be so quick." A FGD CHW respondent.

In other settings, the use of digital tools in community-based testing has demonstrated several benefits, including improving the assessment of disease risk based on embedded algorithms to guide appropriate triage of patients<sup>20</sup> and improve diagnostic accuracy.<sup>21</sup> The COVID-19 pandemic response also led to an unprecedented surge in the use of digital solutions to support healthcare delivery and decision-making.<sup>13 22</sup> However, the proliferation of different tools can increase fragmentation of the digital health architecture and contribute to misalignment between data systems,<sup>23</sup> limiting full visibility into patient data across different disease areas.<sup>24</sup> Hence, it is important to consider the fit and interoperability of digital tools within the existing digital health architecture before implementing new approaches. 

Inclusion of other diseases into e-ASCov to accelerate community-based testing would help to avoid the fragmentation of the digital health architecture and enable more efficient use of resources by facilitating the diagnosis of other diseases. Increasing the ease of differential diagnosis is particularly important, given that over one in five patients in this study had illness-related symptoms that were not diagnosed as COVID-19. Such people could benefit from point-of-care testing for other diseases that may be causing symptoms similar to COVID-19, particularly febrile and respiratory illnesses. Based on the findings of this study, and the national plan to digitize the CHWs services, we are jointly developing a robust integrated community health information system that will also incorporate the contents of e-ASCov. We intend to evaluate the effectiveness and impact of the planned integrated system once developed, particularly on conditions with overlapping clinical presentations such as TB, pneumonia, COVID-19 and malaria. Demonstrating the value of an integrated community health system in Rwanda can set a precedent for other nations in Africa and in other regions to implement similar systems. 

Limitations of the study include that it did not evaluate the cost-effectiveness of the evaluation, as its primary objective was to investigate if non-conventional medical staff can perform Ag-RDT testing for COVID-19, to bring testing closer to the community. Future studies would be valuable to assess the cost-effectiveness of the intervention. Although the study provides a general demonstration of the value of using CHWs to deliver community-based testing, the specifics of the intervention (e.g. the number of CHWs, training required) would need to be tailored to the specific setting if rolled out more broadly. 

Point-of-care diagnostics, such as Ag-RDTs, are also critical to expand access to testing and have been successfully applied as part of testing approaches for other diseases, including HIV. Evidence from systematic reviews of HIV point-of-care testing by non-laboratory workers and lay workers have demonstrated the value of point-of-care diagnostics in expanding access to health services, <sup>25 26</sup> reducing diagnosis delays, allowing timely treatment initiation, and facilitating linkage to care.<sup>27</sup> 

- Beyond its immediate benefits for detecting diseases like COVID-19, improved community surveillance could also be used to predict and potentially avert epidemic outbreaks in the future. For
- example, in India's early COVID-19 response, regular analysis of syndromic data deepened the
- precision of hotspot predictions.<sup>28</sup> Establishing systems for routine collection of such data could thus
- be beneficial for overall pandemic preparedness.

In summary, this study demonstrated the value of a digital tool combined with Ag-RDT testing to support household-level SARS-CoV-2 detection and contact tracing by CHWs in Rwanda. The study fed into Rwanda's vision for decentralizing COVID-19 services and healthcare more broadly. It also provides evidence to support the inclusion of COVID-19 rapid testing within the portfolio of diagnostic services that are already provided by CHWs in the country. The operational model - namely, point-of-care tests by CHWs, supported by digital tools for real-time clinical guidance, process management and data capture and transmission - could be scaled up nationally to enable greater access to decentralized testing for COVID-19 and other diseases across the rest of the country. Together, the findings indicate an opportunity to roll out digitally supported rapid testing for COVID-19 and other ce delivery c. diseases to support healthcare service delivery closer to the community and evidence-based decision-making. 

1 2 3	474	ACKNOWLEDGEMENTS
4	475	The authors would like to thank the community health workers who participated in the intervention
5 6	476	as well as the district teams, Rwanda National Referral Laboratory, community health workers who
7	477	supported the field data collection, local leaders, community members, and heads of health facilities.
8	478	RBC, Ministry of Health and FIND for their support. The authors would also like to thank Dimagi
9 10	479	for the support with the technical documentation and integration of the RDT-Toolkit, and the e-
11	480	ASCov project group who conducted the preceding pilot in 4 districts with financial support from the
12	481	French National Agency for Research on AIDS and Emerging Infectious Diseases (ANRS COV17).
13 14	482	Medical writing support was provided by Talya Underwood, Principal Writer, of Anthos
15	483	Communications Ltd, according to Good Publication Practice guidelines.
16		
17 18	484	
19	40.5	
20	485	DATA AVAILABILITY STATEMENT
21 22	486	Data are available on reasonable request addressed to Rwanda Ministry of Health
23		
24	487	I Ses
25 26		
27	488	ETHICS STATEMENTS
28	400	Detions concept for publication
29 30	489	Fatient consent for publication
31	490	Not applicable.
32 33		datt datt
34	491	
35	402	COMPETING INTEDESTS
36 37	492	COMPETING INTERESTS ≥
38	493	The authors J.B.M, O.A, K.S, P.A and R.K disclose that they are employed by FIND. The other
39	494	authors declare that no conflicts of interest exist.
40 41		ਬੈ.
42	495	
43	106	
44 45	490	
46	497	The study was funded by FIND, United Kingdom (FCDO 40105983), Switzerland (81066910),
47 49	498	Netherlands (SDD 4000004160), Canada (DFATD 7429348), The Kingdom of Saudi Arabia (FIND
48 49	499	– ACT-A DX PARTNERSHIP 20.08.2020), The Rockefeller Foundation (2020 HTH 059), Germany
50	500	(BMZ Covid-19 Diagnostic and Surveillance Response 27.07.2021), Australia (DFAT 76442),
51	501	Kuwait (M239/2020), and The Government of Portugal and Partners (ANF, BCP, CGF,
52 53	502	APIFARMA). Medical writing support was funded by FIND, according to Good Publication Practice
54	503	guidelines.
55		
56 57	504	-
58		-
59		For poor roview only http://bmice.on.hmi.com/site/about/avidalines.yhtml 17
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xntmi

1 2 2	505	AUTHOR CONTRIBUTIONS
5 6 7 8 9 10	506 507 508 509 510	Conceptualization: LN, NB, PA, RK, OA, JB, JPR; Data curation: NB, HM, JM, PA, OA; Formal Analysis: NB, PA, HM, GR; Funding Acquisition: RK; Investigation: LN, JB, PA, JCSN, RR, HM, GR, BM; Methodology: PA, LN; Project Administration: LN; Resources: LN, JB, PA, JCSN, CMM NB; Software: JM, OA, GR, HM; Supervision: LN, JB, PA, KS; Validation: PA; Visualization: LN; Writing – Original Draft Preparation: LN, PA; Writing – Review & Editing: All authors.
11 12 13		
14 15		
16 17		
18 19 20		
20 21 22		
23 24		
25 26 27		
27 28 29		
30 31		
32 33		
34 35 36		
37 38		
39 40 41		
41 42 43		
44 45		
46 47 49		
40 49 50		
51 52		
53 54		
55 56 57		
58 59		10
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

#### 511 **REFERENCES**

#### 4 5 512

1 2

3

6

7 8

9

10

11

18

23

35

41 42

43

44

45 46

47

- 513 1. van Ryneveld M, Whyle E, Brady L. What Is COVID-19 Teaching Us About Community Health
  514 Systems? A Reflection From a Rapid Community-Led Mutual Aid Response in Cape Town,
  515 South Africa. *Int J Health Policy Manag* 2022;11(1):5-8. doi: 10.34172/ijhpm.2020.167
  516 [published Online First: 2020/09/07]
- 12
   13 517
   14 518
   15 519
   16 520
   2. OECD. Strengthening the frontline: How primary health care helps health systems adapt during the COVID 19 pandemic 2021 [Available from: https://www.oecd.org/coronavirus/policy 15 519
   16 520
   17 520
   2. OECD. Strengthening the frontline: How primary health care helps health systems adapt during the during-the-frontline-how-primary-health-care-helps-health-systems-adapt 18 during-the-covid-19-pandemic-9a5ae6da/ accessed 8 June 2023.
- Section 20
   Section 20
- 4. Rwanda Biomedical Centre. Coronavirus Disease COVID-19 [Available from: https://rbc.gov.rw/index.php?id=727 accessed 25 May 2022.
- 526
  527
  528
  528
  528
  527
  527
  528
  528
  529
  527
  529
  527
  528
  529
  529
  529
  529
  520
  520
  520
  521
  521
  522
  522
  522
  523
  524
  525
  526
  526
  527
  528
  528
  529
  529
  529
  529
  529
  520
  520
  520
  520
  520
  521
  521
  522
  522
  522
  523
  524
  524
  525
  526
  526
  527
  528
  528
  528
  529
  529
  528
  528
  528
  529
  529
  529
  528
  528
  529
  529
  529
  529
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
  520
- 528
   528
   529
   6. World Health Organization. National surveys of costs faced by tuberculosis patients and their households 2015-2021 2023 [Available from: https://www.who.int/publications/i/item/9789240065536 accessed 17 October 2023.
- 7. Ahmed SAKS, Ajisola M, Azeem K, et al. Impact of the societal response to COVID-19 on access to healthcare for non-COVID-19 health issues in slum communities of Bangladesh, Kenya, Nigeria and Pakistan: results of pre-COVID and COVID-19 lockdown stakeholder
   534 engagements. *BMJ Global Health* 2020;5(8):e003042. doi: 10.1136/bmjgh-2020-003042
  - 8. Republic of Rwanda Ministry of Health. National tuberculosis and other respiratory communicable diseases program: Annual report 2020-2021 2023 [Available from: <u>https://www.ccm.rw/fileadmin/user\_upload/Annual%20report%20TB%20%20ORD%202020</u>
    %202021.pdf accessed 17 October 2023.
- 9. Ihekweazu C. WHO Hub for Pandemic and Epidemic Intelligence [Available from: <u>https://cdn.who.int/media/docs/default-source/blue-print/07\_chikwe-ihekwazu\_day-</u>
  541 <u>1\_who\_grif\_24-25feb2022.pdf?sfvrsn=5aacbcdf\_7</u> accessed 8 June 2023.
- 53
   542
   543
   543
   543
   543
   543
   543
   543
   544
   5543
   544
   5544
   545
   545
   545
   545
   545
   546
   547
   545
   548
   549
   549
   540
   540
   541
   541
   542
   542
   542
   543
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   545
   546
   547
   548
   548
   548
   549
   549
   540
   540
   541
   541
   542
   542
   542
   541
   542
   542
   542
   542
   542
   544
   544
   545
   545
   546
   547
   548
   548
   548
   548
   549
   549
   549
   549
   549
   540
  - For peer review only http://bmjopen.bmj.com/site/about/guidelines.xhtml

1		
2	546	11 COVID-19 Vaccine Delivery Partnership, Rwanda: leveraging the existing digital infrastructure
3	547	for the COVID 10 vaccination response 2023 [Available from:
4	540	for the CO $\sqrt{10^{-1}}$ vacemation response 2025 [Avanable from:
5	548	https://www.wno.int/docs/default-source/coronaviruse/rwanda_case-study_digital-
6	549	solutions_en1672760274.pdf?sfvrsn=b256716b_3&download=true accessed 17 October
7	550	2023.
/ 0		
0 0		
9 10	551	12. UNDP. Lesotho Village Health Workers' Road to a Digital Era 2021 [Available from:
10	552	https://www.undp.org/lesotho/blog/lesotho-village-health-workers-road-digital-era accessed 8
11	553	June 2023
12	000	
13		
14	554	13. Majam M, Msolomba V, Venter F, et al. Monitored Implementation of COVID-19 Rapid Antigen
15	555	Screening at Taxi Ranks in Johannesburg, South Africa, <i>Diagnostics (Basel)</i> 2022;12(2) doi:
16	556	10 3390/diagnostics12020402 [nublished Online First: 2022/02/26]
17	550	
18		
19	557	14. Dimagi, FIND – Digital Solution for COVID-19 RDTs 2021 [Available from:
20	558	https://www.dimagi.com/blog/find-covid-19-rdt-solution/accessed 17 October 2023
21	550	
22		
23	559	15. CommCare. COVID-19 Template App: COVID-19 RDT Tracking [Available from:
24	560	https://confluence.dimagi.com/display/commcarepublic/COVID-
25	561	$\frac{10+10}{10+10} = \frac{10}{10} $
26	501	19 + 10000000000000000000000000000000000
27	302	$\frac{19+\text{KD}1+1130\text{King}(2000)}{1000000000000000000000000000000000$
28	563	accessed 17 October 2023.
29		
30	561	16 Ministry of Health Pwanda, COVID 10 Clinical Management Guidelines, 3rd Edition September
31	504	10. Ministry of Health Kwanua. COVID-19 Chincal Management Outdennes. Stu Eution September
32	565	2021 ed, 2021.
33		
34	566	17 Suk IF. Van Cangh T. Beauté I. et al. The interconnected and cross-border nature of risks posed
35	500	17. Suk JE, Van Cangir I, Deaute J, et al. The interconnected and cross-border nature of fisks posed
36	30/	by infectious diseases, 2015.
20 27		
20	568	18 Ehrlich R Montgomery A Akugizihwe P et al Public health implications of changing natterns
20	560	of recruitment into the South A fricen mining industry 1072 2012: a detabase englysis <i>BMC</i>
29 40	309	D Lik LL 2017 10(1) 02 1 i 10 110(1 12000 017 4(10 1 1 1) 1 0 1i 10 1)
40	570	<i>Public Health</i> 2017;18(1):93. doi: 10.1186/s12889-017-4640-x [published Online First:
41	571	2017/08/05]
42		
43	570	10 Emoto TL Alala EQ Ilacommi QC Evaluation of the offect of header also are COVID 10
44	3/2	19. Effeto 11, Alete FO, flesanini OS. Evaluation of the effect of border closure on COVID-19
45	573	incidence rates across nine African countries: an interrupted time series study. Transactions
46	574	of The Royal Society of Tropical Medicine and Hygiene 2021;115(10):1174-83. doi:
47	575	10.1093/trstmh/trab033
48	- / -	
49		
50	576	20. Roy T, Marcil L, Chowdhury RH, et al. The BRAC Manoshi Approach 2011 [Available from:
51	577	https://brac.net/sites/default/files/portals/Manoshi-book-v3-1.pdf accessed 8 June 2023.
52		
53		
54	578	21. Laktabai J, Platt A, Menya D, et al. A mobile health technology platform for quality assurance
55	579	and quality improvement of malaria diagnosis by community health workers. PLoS One
56	580	2018;13(2):e0191968. doi: 10.1371/iournal.pone.0191968 [published Online First:
57	581	2018/02/02]
58	501	
59		20
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 20

1 2 3 4 5 6	582 583 584 585	22. Karanja S, Aduda J, Thuo R, et al. Utilization of digital tools to enhance COVID-19 and tuberculosis testing and linkage to care: A cross-sectional evaluation study among Bodaboda motorbike riders in the Nairobi Metropolis, Kenya. <i>PLOS ONE</i> 2023;18(9):e0290575. doi: 10.1371/journal.pone.0290575
7 8 9 10 11	586 587 588	23. Atun R, de Jongh T, Secci F, et al. Integration of targeted health interventions into health systems: a conceptual framework for analysis. <i>Health Policy Plan</i> 2010;25(2):104-11. doi: 10.1093/heapol/czp055 [published Online First: 2009/11/18]
12 13 14 15 16	589 590 591	<ol> <li>Muinga N, Magare S, Monda J, et al. Digital health Systems in Kenyan Public Hospitals: a mixed-methods survey. <i>BMC Med Inform Decis Mak</i> 2020;20(1):2. doi: 10.1186/s12911-019- 1005-7 [published Online First: 2020/01/08]</li> </ol>
17 18 19 20 21	592 593 594	25. Vojnov L, Taegtmeyer M, Boeke C, et al. Performance of non-laboratory staff for diagnostic testing and specimen collection in HIV programs: A systematic review and meta-analysis. <i>PLOS ONE</i> 2019;14(5):e0216277. doi: 10.1371/journal.pone.0216277
22 23 24 25 26 27	595 596 597 598	26. Kennedy CE, Yeh PT, Johnson C, et al. Should trained lay providers perform HIV testing? A systematic review to inform World Health Organization guidelines. <i>AIDS Care</i> 2017;29(12):1473-79. doi: 10.1080/09540121.2017.1317710 [published Online First: 2017/04/25]
28 29 30 31 32	599 600 601	27. Pham MD, Agius PA, Romero L, et al. Acceptability and feasibility of point-of-care CD4 testing on HIV continuum of care in low and middle income countries: a systematic review. <i>BMC</i> <i>Health Services Research</i> 2016;16(1):343. doi: 10.1186/s12913-016-1588-y
33 34 35 36 37 38	602 603 604 605	28. FIND. Use of digital tools and data science to strengthen COVID-19 management: India case study 2021 [Available from: <u>https://www.finddx.org/wp-content/uploads/2023/05/20210501_digital_health_report_india_FV_EN.pdf</u> accessed 18 October 2023.
39 40 41	606	
42 43 44		
45 46 47		
47 48 40		
49 50		
52		
53 54		
55 56		
57 58		
59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 21



168x210mm (96 x 96 DPI)

Page 24 of 36

**BMJ** Open





168x52mm (144 x 144 DPI)

	Ψ.	Φ	e	۲.	د	<u> </u>
				ž	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
	~	_	-	7	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
	~		-	7	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
0	~	-		<u> </u>	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiq Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
л Г	×	ž	<u> </u>		Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographic Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographic Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
ne	Ľ.	Ę	Ĺ	_	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographi Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographi Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
que	dn	dri	qu	q	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograph Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograph Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ique	iqu	iqu	iqu	iq	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograp Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograp Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
nique	nique	niqu	niqu	וiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograt Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliograt Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
hique	hiqu	hiqu	hiqu	hiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliogra Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliogra Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ohique	ohique	ohiqu	ohiqu	ohiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliogr: Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliogr: Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
3phique	3phique	aphiqu	3phiqu	₃phiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliog Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliog Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
aphique.	.aphique	aphiqu	aphiqu.	aphiqu.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Biblio Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Biblio Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
yraphique	yraphiqu	yraphiqu	yraphiqu	yraphiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Biblic Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Biblic Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
ographique	ographique	ographiqu	ographiqu	ographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibl Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibl Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ographique	ographiqu	ographiqu	ographiqu	ographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bib Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bib Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
liographique	liographique	liographiqu	liographiqu	liographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bi Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bi Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
bliographique	bliographiqu	bliographiqu	bliographiqu	bliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence E Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence E Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
3ibliographique	3ibliographique	3ibliographiqu	Sibliographiqu	3ibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
Bibliographique	Bibliographique	Bibliographiqu	Bibliographiqu	Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agenci Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agenci Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
e Bibliographique	e Bibliographiqu	e Bibliographiqu	e Bibliographiqu	e Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agen Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agen Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ce Bibliographique	ce Bibliographiqu	ce Bibliographiqu	ce Bibliographiqu	ce Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Age Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Age Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
nce Bibliographique	nce Bibliographiquŧ	nce Bibliographiqu	nce Bibliographiqu	nce Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Ag Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Ag Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ence Bibliographique	ence Bibliographiqu	ence Bibliographiqu	ence Bibliographiqu	ence Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Average in the second	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Av Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
gence Bibliographique	gence Bibliographiqu	gence Bibliographiqu	gence Bibliographiqu	gence Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at / Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at / Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
Agence Bibliographique	Agence Bibliographique	Agence Bibliographiqu	\gence Bibliographiqu	Agence Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.
Agence Bibliographique	Agence Bibliographique	Agence Bibliographiqu	Agence Bibliographiqu	Agence Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 <i>a</i> Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 <i>a</i> Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.
ıt Agence Bibliographique	ıt Agence Bibliographiqu	ıt Agence Bibliographiqu	ıt Agence Bibliographiqu	ıt Agence Bibliographiqı	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies
at Agence Bibliographique <sup>5.</sup>	at Agence Bibliographiqu« <sup>չ</sup> .	at Agence Bibliographiqu <sup>,</sup> <sup>;</sup> .	at Agence Bibliographiqu <sup>5.</sup>	at Agence Bibliographiqu ;.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 202 Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar technologi	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 202 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologi
5 at Agence Bibliographique ›s.	5 at Agence Bibliographiqu« ›s.	5 at Agence Bibliographique ›s.	5 at Agence Bibliographiqu ›s.	5 at Agence Bibliographiqu ›s.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 20 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technolog	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 20 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technolog
l25 at Agence Bibliographique ∖ies.	l25 at Agence Bibliographiqu∉ ∖ies.	l25 at Agence Bibliographiqur ∖ies.	l25 at Agence Bibliographiqu ∖ies.	l25 at Agence Bibliographiqu ∖ies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from htt <del>p://bmjopen.bmj.com/</del> on June 11, 2 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technolo	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technolo
025 at Agence Bibliographique gies.	025 at Agence Bibliographique gies.	025 at Agence Bibliographique	025 at Agence Bibliographiqu gies.	025 at Agence Bibliographiqu gies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar techno	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar techno
2025 at Agence Bibliographique ogies.	2025 at Agence Bibliographique	2025 at Agence Bibliographique	2025 at Agence Bibliographiqu ogies.	2025 at Agence Bibliographiqu ogies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 1 <sup>,</sup> Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar techn	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 1 Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar techn
l, 2025 at Agence Bibliographique ɔlogies.	l, 2025 at Agence Bibliographique ologies.	l, 2025 at Agence Bibliographiqui ologies.	l, 2025 at Agence Bibliographiqu ɔlogies.	ا, 2025 at Agence Bibliographiqu blogies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June ' Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar tech	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June ' Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar tech
11, 2025 at Agence Bibliographique nologies.	11, 2025 at Agence Bibliographique nologies.	11, 2025 at Agence Bibliographiqu 10logies.	11, 2025 at Agence Bibliographiqu 1ologies.	11, 2025 at Agence Bibliographiqu nologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar tecl	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar tecl
11, 2025 at Agence Bibliographique mologies.	11, 2025 at Agence Bibliographique	11, 2025 at Agence Bibliographique nologies.	11, 2025 at Agence Bibliographiqu mologies.	11, 2025 at Agence Bibliographiqu mologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Jun Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar te	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Jun Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar te
e 11, 2025 at Agence Bibliographique chnologies.	e 11, 2025 at Agence Bibliographiqu¢ chnologies.	e 11, 2025 at Agence Bibliographiqu chnologies.	e 11, 2025 at Agence Bibliographiqu chnologies.	e 11, 2025 at Agence Bibliographiqu chnologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Ju Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and similar t	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Ju Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar t
ne 11, 2025 at Agence Bibliographique echnologies.	ne 11, 2025 at Agence Bibliographique echnologies.	ne 11, 2025 at Agence Bibliographiqu echnologies.	ne 11, 2025 at Agence Bibliographiqu echnologies.	ne 11, 2025 at Agence Bibliographiqu echnologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on J Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on J Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar
lune 11, 2025 at Agence Bibliographique technologies.	lune 11, 2025 at Agence Bibliographiqu« technologies.	lune 11, 2025 at Agence Bibliographiqui technologies.	une 11, 2025 at Agence Bibliographiqu technologies.	une 11, 2025 at Agence Bibliographiqu technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and simila	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and simila
June 11, 2025 at Agence Bibliographique ar technologies.	June 11, 2025 at Agence Bibliographique ar technologies.	June 11, 2025 at Agence Bibliographique ar technologies.	June 11, 2025 at Agence Bibliographiqu ır technologies.	June 11, 2025 at Agence Bibliographiqu ar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ o Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and simi	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ o Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and simi
ו June 11, 2025 at Agence Bibliographique lar technologies.	ו June 11, 2025 at Agence Bibliographique lar technologies.	ר June 11, 2025 at Agence Bibliographiqu ar technologies.	ר June 11, 2025 at Agence Bibliographiqu lar technologies.	ר June 11, 2025 at Agence Bibliographiqu lar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and sin	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and sin
on June 11, 2025 at Agence Bibliographique ⊪lar technologies.	on June 11, 2025 at Agence Bibliographiqu⊮ ⊪lar technologies.	on June 11, 2025 at Agence Bibliographiqu ⊪lar technologies.	on June 11, 2025 at Agence Bibliographiqu ⊮lar technologies.	ɔn June 11, 2025 at Agence Bibliographiqı ⊮lar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and si	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and si
on June 11, 2025 at Agence Bibliographique nilar technologies.	on June 11, 2025 at Agence Bibliographique nilar technologies.	on June 11, 2025 at Agence Bibliographique nilar technologies.	on June 11, 2025 at Agence Bibliographiqu nilar technologies.	on June 11, 2025 at Agence Bibliographiqu nilar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.con Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and s	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.con Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and s
າ⁄ on June 11, 2025 at Agence Bibliographique ⊫milar technologies.	າ⁄ on June 11, 2025 at Agence Bibliographiqu∉ ⊯milar technologies.	າ⁄ on June 11, 2025 at Agence Bibliographiqu ⊫milar technologies.	າ⁄ on June 11, 2025 at Agence Bibliographiqu ⊫milar technologies.	າ⁄ on June 11, 2025 at Agence Bibliographiqu ⊫milar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.co Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.co Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and
m/ on June 11, 2025 at Agence Bibliographique similar technologies.	m/ on June 11, 2025 at Agence Bibliographiqu« similar technologies.	m/ on June 11, 2025 at Agence Bibliographique similar technologies.	m/ on June 11, 2025 at Agence Bibliographiqu similar technologies.	m/ on June 11, 2025 at Agence Bibliographiqu similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.c Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.c Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, and
om/ on June 11, 2025 at Agence Bibliographique d similar technologies.	om/ on June 11, 2025 at Agence Bibliographiqu« d similar technologies.	om/ on June 11, 2025 at Agence Bibliographiqu d similar technologies.	om/ on June 11, 2025 at Agence Bibliographiqu d similar technologies.	om/ on June 11, 2025 at Agence Bibliographiqu d similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj. Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, ar	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj. Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training, ar
<mark>com∕</mark> on June 11, 2025 at Agence Bibliographique ıd similar technologies.	<mark>com∕</mark> on June 11, 2025 at Agence Bibliographiqu« ≀d similar technologies.	<mark>com∕</mark> on June 11, 2025 at Agence Bibliographiqu ıd similar technologies.	<mark>com∕</mark> on June 11, 2025 at Agence Bibliographiqu ıd similar technologies.	com/ on June 11, 2025 at Agence Bibliographiqu ıd similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bm Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, a	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bm Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, a
.com/ on June 11, 2025 at Agence Bibliographique Ind similar technologies.	.com/ on June 11, 2025 at Agence Bibliographique	.com/ on June 11, 2025 at Agence Bibliographique ind similar technologies.	.com/ on June 11, 2025 at Agence Bibliographiqu Ind similar technologies.	.com/ on June 11, 2025 at Agence Bibliographiqu	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bn Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bn Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al training.
ij.com/ on June 11, 2025 at Agence Bibliographique and similar technologies.	ıj.com/ on June 11, 2025 at Agence Bibliographiqu« and similar technologies.	nj.com/ on June 11, 2025 at Agence Bibliographiqu and similar technologies.	nj.com/ on June 11, 2025 at Agence Bibliographiqu and similar technologies.	nj.com/ on June 11, 2025 at Agence Bibliographiqu and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.b Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al training	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.b Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training
mj.com/ on June 11, 2025 at Agence Bibliographique , and similar technologies.	mj.com/ on June 11, 2025 at Agence Bibliographique , and similar technologies.	mj.com/ on June 11, 2025 at Agence Bibliographique , and similar technologies.	mj.com/ on June 11, 2025 at Agence Bibliographiqu , and similar technologies.	mj.com/ on June 11, 2025 at Agence Bibliographiqu , and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen. Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al trainin	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen. Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al trainin
bmj.com/ on June 11, 2025 at Agence Bibliographique g, and similar technologies.	bmj.com/ on June 11, 2025 at Agence Bibliographique g, and similar technologies.	bmj.com/ on June 11, 2025 at Agence Bibliographiqu g, and similar technologies.	bmj.com/ on June 11, 2025 at Agence Bibliographiqu g, and similar technologies.	bmj.com/ on June 11, 2025 at Agence Bibliographiqu g, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjoper Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al traini	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjoper Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al traini
I.bmj.com/ on June 11, 2025 at Agence Bibliographique ng, and similar technologies.	I.bmj.com/ on June 11, 2025 at Agence Bibliographique ng, and similar technologies.	bmj.com/ on June 11, 2025 at Agence Bibliographique ng, and similar technologies.	I.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ng, and similar technologies.	I.bmj.com/ on June 11, 2025 at Agence Bibliographiques, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjope Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al trair	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjope Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al trair
in.bmj.com/ on June 11, 2025 at Agence Bibliographique ling, and similar technologies.	in.bmj.com/ on June 11, 2025 at Agence Bibliographique ling, and similar technologies.	in.bmj.com/ on June 11, 2025 at Agence Bibliographiqui iing, and similar technologies.	in.bmj.com/ on June 11, 2025 at Agence Bibliographiqu iing, and similar technologies.	in.bmj.com/ on June 11, 2025 at Agence Bibliographiquing, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjop Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al tra	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjop Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al tra
ien.bmj.com/ on June 11, 2025 at Agence Bibliographique	ien.bmj.com/ on June 11, 2025 at Agence Bibliographique	ining, and similar technologies.	ien.bmj.com/ on June 11, 2025 at Agence Bibliographiqu	ining, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjo Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al tr	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjo Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining. Al tr
pen.bmj.com/ on June 11, 2025 at Agence Bibliographique aining, and similar technologies.	pen.bmj.com/ on June 11, 2025 at Agence Bibliographique aining, and similar technologies.	ipen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui aining, and similar technologies.	i <mark>pen.bmj.com/</mark> on June 11, 2025 at Agence Bibliographiqu aining, and similar technologies.	pen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu aining, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmj Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, AI t	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmj Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, AI 1
open.bmj.com/ on June 11, 2025 at Agence Bibliographique raining, and similar technologies.	open.bmj.com/ on June 11, 2025 at Agence Bibliographique raining, and similar technologies.	open.bmj.com/ on June 11, 2025 at Agence Bibliographique raining, and similar technologies.	open.bmj.com/ on June 11, 2025 at Agence Bibliographiqu raining, and similar technologies.	open.bmj.com/ on June 11, 2025 at Agence Bibliographiquraining, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bn Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bn Enseignement Superieur (ABES). Protected by copyright, including for uses related to text and data mining, Al
ijopen.bmj.com/ on June 11, 2025 at Agence Bibliographique training, and similar technologies.	ijopen.bmj.com/ on June 11, 2025 at Agence Bibliographique training, and similar technologies.	ijopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu training, and similar technologies.	<mark>ijopen.bmj.com/</mark> on June 11, 2025 at Agence Bibliographiqu training, and similar technologies.	<mark>ijopen.bmj.com/</mark> on June 11, 2025 at Agence Bibliographiqu training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://b Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, <i>i</i>	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://b Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, <i>i</i>
mjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Al training, and similar technologies.	mjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Al training, and similar technologies.	mjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu	mjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Al training, and similar technologies.	mjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http:// Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining.	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http:// Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining.
bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Al training, and similar technologies.	bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu« Al training, and similar technologies.	bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Al training, and similar technologies.	bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Al training, and similar technologies.	bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http: Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mininc	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http: Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mininc
//bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique , Al training, and similar technologies.	//bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique , Al training, and similar technologies.	//bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu	//bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu , Al training, and similar technologies.	//bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu , Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data minin	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data minin
://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique g, Al training, and similar technologies.	://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ; g, Al training, and similar technologies.	://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ; g, Al training, and similar technologies.	://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu g, Al training, and similar technologies.	://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu g, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from htt Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mini	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from htt Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mini
p://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ng, Al training, and similar technologies.	p://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ng, Al training, and similar technologies.	p://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ng, Al training, and similar technologies.	p://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ng, Al training, and similar technologies.	p://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ng, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from ht Enseignement Superieur (ABES Protected by copyright, including for uses related to text and data mir	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from ht Enseignement Superieur (ABES Protected by copyright, including for uses related to text and data mir
tp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique <sup>i)</sup> . ing, Al training, and similar technologies.	tp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique i) . ing, Al training, and similar technologies.	tp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu <sup>(</sup> ) <sup>(</sup> ) ing, Al training, and similar technologies.	tp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu <sup>i)</sup> . ing, Al training, and similar technologies.	tp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu i) . ing, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from t Enseignement Superieur (ABE Protected by copyright, including for uses related to text and data mi	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from t Enseignement Superieur (ABE Protected by copyright, including for uses related to text and data mi
ttp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique S) . ving, Al training, and similar technologies.	ttp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique S) . ving, Al training, and similar technologies.	ttp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu S) . ving, Al training, and similar technologies.	ttp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu S) . ving, Al training, and similar technologies.	ttp://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu S) . ving, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from Enseignement Superieur (ABI Protected by copyright, including for uses related to text and data m	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from Enseignement Superieur (ABI Protected by copyright, including for uses related to text and data m
http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique :S) . Ining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique S) . Ining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique S) . Ining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu :S) . Ining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu S) . Ining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from Enseignement Superieur (AE Protected by copyright, including for uses related to text and data n	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from Enseignement Superieur (AE Protected by copyright, including for uses related to text and data n
http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ES) . iining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ES) . iining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu/ ES) . iining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ES) . iining, Al training, and similar technologies.	http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ES) . iining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fror Enseignement Superieur (Al Protected by copyright, including for uses related to text and data	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fror Enseignement Superieur (Al Protected by copyright, including for uses related to text and data
ı http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique 3ES) . nining, Al training, and similar technologies.	ı http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique 3ES) . nining, Al training, and similar technologies.	ı http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu 3ES) . nining, Al training, and similar technologies.	ı http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu 3ES) . nining, Al training, and similar technologies.	ı http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu 3ES) . nining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fro Enseignement Superieur (A Protected by copyright, including for uses related to text and data	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fro Enseignement Superieur (A Protected by copyright, including for uses related to text and data
n http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique BES) . mining, Al training, and similar technologies.	n http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique BES) . mining, Al training, and similar technologies.	n http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu BES) . mining, Al training, and similar technologies.	n http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu BES) . mining, Al training, and similar technologies.	n http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu BES) . mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded frc Enseignement Superieur (/ Protected by copyright, including for uses related to text and data	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded frc () Protected by copyright, including for uses related to text and data
m http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique \BES) . mining. Al training, and similar technologies.	m http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique \BES) . mining, Al training, and similar technologies.	m http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique \BES) . mining, Al training, and similar technologies.	m http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu \BES) . mining, Al training, and similar technologies.	m http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu \BES) . mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fr Enseignement Superieur ( Protected by copyright, including for uses related to text and dat	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded fr Enseignement Superieur ( Protected by copyright, including for uses related to text and dat
om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ABES) . a mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu« ABES) . ז mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ABES) . a mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ABES) . a mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ABES) . a mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded f Enseignement Superieur Protected by copyright, including for uses related to text and da	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded f Enseignement Superieur Protected by copyright, including for uses related to text and da
om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique (ABES) . ta mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique (ABES) . ta mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu (ABES) . ta mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu (ABES) . ta mining, Al training, and similar technologies.	om http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu (ABES) . ta mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded Enseignement Superieu Protected by copyright, including for uses related to text and d	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded Enseignement Superieu Protected by copyright, including for uses related to text and d
from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique (ABES) . ata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique (ABES) . ata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique (ABES) . ata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu (ABES) . ata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu (ABES) . ata mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloadec Enseignement Superieu Protected by copyright, including for uses related to text and o	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloadec Enseignement Superieu Protected by copyright, including for uses related to text and o
from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique r (ABES) . lata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu« r (ABES) . lata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu r (ABES) . lata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu r (ABES) . lata mining, Al training, and similar technologies.	from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu r (ABES) . lata mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloade Enseignement Superie Protected by copyright, including for uses related to text and	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloade Enseignement Superie Protected by copyright, including for uses related to text and
1 from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ır (ABES) . data mining, Al training, and similar technologies.	<pre>1 from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique .r (ABES) . data mining, Al training, and similar technologies.</pre>	1 from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ur (ABES) . data mining, Al training, and similar technologies.	<pre>1 from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ur (ABES) . data mining, Al training, and similar technologies.</pre>	I from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu rr (ABES) . data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloadt Enseignement Superic Protected by copyright, including for uses related to text anc	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Download¢ Enseignement Superic Protected by copyright, including for uses related to text anc
d from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ur (ABES) . data mining, Al training, and similar technologies.	d from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ur (ABES) . data mining, Al training, and similar technologies.	d from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ur (ABES) . data mining, Al training, and similar technologies.	d from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ur (ABES) . data mining, Al training, and similar technologies.	d from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiquur (ABES) . data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Download Enseignement Super Protected by copyright, including for uses related to text an	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Download Enseignement Super Protected by copyright, including for uses related to text an
ed from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique eur (ABES) . 1 data mining, Al training, and similar technologies.	ed from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu« eur (ABES) . 1 data mining, Al training, and similar technologies.	ed from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu/ eur (ABES) . 1 data mining, Al training, and similar technologies.	ed from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu eur (ABES) . 1 data mining, Al training, and similar technologies.	ed from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu eur (ABES) . 1 data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloa Enseignement Supe Protected by copyright, including for uses related to text ar	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloa Enseignement Supe Protected by copyright, including for uses related to text ar
ded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ieur (ABES) . ıd data mining, Al training, and similar technologies.	ded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ieur (ABES) . Id data mining, Al training, and similar technologies.	ded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui ieur (ABES) . ıd data mining, Al training, and similar technologies.	ded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ieur (ABES) . ıd data mining, Al training, and similar technologies.	ded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ieur (ABES) . ıd data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downlo: Enseignement Supe Protected by copyright, including for uses related to text a	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downlo: Enseignement Supe Protected by copyright, including for uses related to text a
ided from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique rrieur (ABES) . nd data mining, Al training, and similar technologies.	ided from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique rrieur (ABES) . nd data mining, Al training, and similar technologies.	ided from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique rrieur (ABES) . nd data mining, Al training, and similar technologies.	ided from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu rrieur (ABES) . nd data mining, Al training, and similar technologies.	ided from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu rrieur (ABES) . nd data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downlc Enseignement Sup Protected by copyright, including for uses related to text	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downlc Enseignement Sup Protected by copyright, including for uses related to text
aded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique erieur (ABES) . and data mining, Al training, and similar technologies.	aded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique erieur (ABES) . and data mining, Al training, and similar technologies.	aded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui erieur (ABES) . and data mining, Al training, and similar technologies.	aded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu erieur (ABES) . and data mining. Al training, and similar technologies.	aded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu erieur (ABES) . and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downl Enseignement Su Protected by copyright, including for uses related to tex	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downl Enseignement Su Protected by copyright, including for uses related to tex
oaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique perieur (ABES) . <sup>t</sup> and data mining, Al training, and similar technologies.	oaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique perieur (ABES) . <sup>t</sup> and data mining, Al training, and similar technologies.	oaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui perieur (ABES) . <sup>t</sup> and data mining, Al training, and similar technologies.	oaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu perieur (ABES) . <sup>t</sup> and data mining, Al training, and similar technologies.	oaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu perieur (ABES) . <sup>t</sup> and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Dowr Enseignement S Protected by copyright, including for uses related to te:	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Dowr Enseignement S Protected by copyright, including for uses related to te:
lloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique uperieur (ABES) . ‹t and data mining, Al training, and similar technologies.	lloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu« uperieur (ABES) . ‹t and data mining, Al training, and similar technologies.	lloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu uperieur (ABES) . ‹t and data mining, Al training, and similar technologies.	lloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu uperieur (ABES) . ‹t and data mining, Al training, and similar technologies.	Iloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiquuperieur (ABES) . (t and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Dow Enseignement : Protected by copyright, including for uses related to to	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Dow Enseignement : Protected by copyright, including for uses related to t
nloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Superieur (ABES) . ext and data mining, Al training, and similar technologies.	nloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Superieur (ABES) . ext and data mining, Al training, and similar technologies.	nloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu/ Superieur (ABES) . ext and data mining, Al training, and similar technologies.	nloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Superieur (ABES) . ext and data mining, Al training, and similar technologies.	nloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Superieur (ABES) . ext and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Do Enseignement Protected by copyright, including for uses related to	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Do Enseignement Protected by copyright, including for uses related to
wnloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Superieur (ABES) . text and data mining, Al training, and similar technologies.	wnloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Superieur (ABES) . text and data mining, Al training, and similar technologies.	wnloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Superieur (ABES) . text and data mining, Al training, and similar technologies.	wnloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Superieur (ABES) . text and data mining, Al training, and similar technologies.	wnloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Superieur (ABES) . text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. D Enseignemei Protected by copyright, including for uses related to	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. D Enseignemer Protected by copyright, including for uses related to
ownloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique it Superieur (ABES) . ) text and data mining, Al training, and similar technologies.	ownloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique it Superieur (ABES) . ) text and data mining, Al training, and similar technologies.	ownloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique it Superieur (ABES) . ) text and data mining, Al training, and similar technologies.	ownloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu it Superieur (ABES) . ) text and data mining, Al training, and similar technologies.	ownloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiquit Superieur (ABES) . • text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. I Enseigneme Protected by copyright, including for uses related	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. I Enseigneme Protected by copyright, including for uses related
Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique nt Superieur (ABES) . to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ant Superieur (ABES) . to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ant Superieur (ABES) . to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu nt Superieur (ABES) . to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiquent Superieur (ABES). Int Superieur (ABES) . Ito text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Enseignen Protected by copyright, including for uses relatec	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Enseignen Protected by copyright, including for uses relatec
Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique nent Superieur (ABES) . I to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique nent Superieur (ABES) . I to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui ient Superieur (ABES) . I to text and data mining, Al training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu nent Superieur (ABES) . I to text and data mining, AI training, and similar technologies.	Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiquent Superieur (ABES) . I to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 202- Enseigne Protected by copyright, including for uses relate	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 202- Enseigne Protected by copyright, including for uses relate
4. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ment Superieur (ABES) . vd to text and data mining, Al training, and similar technologies.	<ol> <li>Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ment Superieur (ABES).</li> <li>to text and data mining, Al training, and similar technologies.</li> </ol>	<ol> <li>Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ment Superieur (ABES).</li> <li>to text and data mining, Al training, and similar technologies.</li> </ol>	4. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ment Superieur (ABES).	<ol> <li>Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqument Superieur (ABES).</li> <li>to text and data mining, Al training, and similar technologies.</li> </ol>	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 20 Enseign Protected by copyright, including for uses rela	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 20. Enseign Protected by copyright, including for uses rela
24. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ement Superieur (ABES) . ted to text and data mining, Al training, and similar technologies.	24. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ement Superieur (ABES) . ted to text and data mining, Al training, and similar technologies.	24. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui ement Superieur (ABES) . ted to text and data mining, Al training, and similar technologies.	24. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ement Superieur (ABES) . ted to text and data mining, Al training, and similar technologies.	24. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique ment Superieur (ABES) . ted to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2 Enseig Protected by copyright, including for uses rel	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2 Enseig Protected by copyright, including for uses rel
024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique nement Superieur (ABES) . ated to text and data mining, Al training, and similar technologies.	024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique nement Superieur (ABES) . ated to text and data mining, Al training, and similar technologies.	024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui nement Superieur (ABES) . ated to text and data mining, Al training, and similar technologies.	024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu nement Superieur (ABES) . ated to text and data mining, Al training, and similar technologies.	024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu nement Superieur (ABES) . ated to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 October Ensei Protected by copyright, including for uses re	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October Ensei Protected by copyright, including for uses re
2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique gnement Superieur (ABES) . ⊮ated to text and data mining, Al training, and similar technologies.	2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique gnement Superieur (ABES) . slated to text and data mining, Al training, and similar technologies.	2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui gnement Superieur (ABES) . slated to text and data mining, Al training, and similar technologies.	2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu gnement Superieur (ABES) . ⊮ated to text and data mining, Al training, and similar technologies.	2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu gnement Superieur (ABES) . slated to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octobe Ense Protected by copyright, including for uses	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octobe Ense Protected by copyright, including for uses
<sup>·</sup> 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique signement Superieur (ABES) . ·elated to text and data mining, Al training, and similar technologies.	<sup>·</sup> 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique signement Superieur (ABES) . ·elated to text and data mining, Al training, and similar technologies.	<sup>·</sup> 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui signement Superieur (ABES) . ·elated to text and data mining, Al training, and similar technologies.	<sup>.</sup> 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu ignement Superieur (ABES) . ·elated to text and data mining, Al training, and similar technologies.	<sup>.</sup> 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu signement Superieur (ABES) . ·elated to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octob Ens Protected by copyright, including for uses	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octoby Ens Protected by copyright, including for uses
rr 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique æignement Superieur (ABES) . . related to text and data mining, Al training, and similar technologies.	rr 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique æignement Superieur (ABES) . . related to text and data mining, Al training, and similar technologies.	rr 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui æignement Superieur (ABES) . . related to text and data mining, Al training, and similar technologies.	rr 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu æignement Superieur (ABES) . . related to text and data mining, Al training, and similar technologies.	rr 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique reignement Superieur (ABES) . related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octob Er Protected by copyright, including for use	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octob Er Protected by copyright, including for use
er 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique iseignement Superieur (ABES) . is related to text and data mining, Al training, and similar technologies.	er 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique iseignement Superieur (ABES) . is related to text and data mining, Al training, and similar technologies.	er 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui seignement Superieur (ABES) . .s related to text and data mining. Al training, and similar technologies.	er 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu seignement Superieur (ABES) . s related to text and data mining. Al training, and similar technologies.	er 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiques is eignement Superieur (ABES). S related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octc E Protected by copyright, including for us	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Octc E Protected by copyright, including for us
ber 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique inseignement Superieur (ABES) . es related to text and data mining, Al training, and similar technologies.	ber 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique inseignement Superieur (ABES) . .es related to text and data mining, Al training, and similar technologies.	ber 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui inseignement Superieur (ABES) . .es related to text and data mining, Al training, and similar technologies.	ber 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu inseignement Superieur (ABES) . .es related to text and data mining, Al training, and similar technologies.	ber 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu inseignement Superieur (ABES) . .es related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Oc Protected by copyright, including for u	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Oc Protected by copyright, including for u
tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Ises related to text and data mining, Al training, and similar technologies.	tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Ises related to text and data mining, Al training, and similar technologies.	tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Ises related to text and data mining. Al training, and similar technologies.	tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) Ises related to text and data mining. Al training, and similar technologies.	tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Ises related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 O Protected by copyright, including for	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 O Protected by copyright, including for
ctober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . uses related to text and data mining, Al training, and similar technologies.	ctober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . uses related to text and data mining, Al training, and similar technologies.	ctober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . uses related to text and data mining, Al training, and similar technologies.	:tober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . uses related to text and data mining, Al training, and similar technologies.	ctober 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES).	Open: first published as 10.1136/bmjopen-2023-083410 on 1 ( Protected by copyright, including fo	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 ( Protected by copyright, including fo
October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . r uses related to text and data mining, Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . r uses related to text and data mining, Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . r uses related to text and data mining, Al training, and similar technologies.	October 2024. Downloaded from <a href="http://bmjopen.bmj.com/">http://bmjopen.bmj.com/</a> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . r uses related to text and data mining. Al training, and similar technologies.	October 2024. Downloaded from <a href="http://bmjopen.bmj.com/">http://bmjopen.bmj.com/</a> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . r uses related to text and data mining. Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on 1 Protected by copyright, including f	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 Protected by copyright, including f
October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . or uses related to text and data mining. Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . or uses related to text and data mining. Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . or uses related to text and data mining. Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . or uses related to text and data mining, Al training, and similar technologies.	October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . or uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on Protected by copyright, including	J Open: first published as 10.1136/bmjopen-2023-083410 on Protected by copyright, including
1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) for uses related to text and data mining, Al training, and similar technologies.	1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . for uses related to text and data mining, Al training, and similar technologies.	1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . for uses related to text and data mining, Al training, and similar technologies.	1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . for uses related to text and data mining, Al training, and similar technologies.	1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . for uses related to text and data mining. Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 on Protected by copyright, includin	J Open: first published as 10.1136/bmjopen-2023-083410 on Protected by copyright, includin
<ol> <li>October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES).</li> <li>for uses related to text and data mining, Al training, and similar technologies.</li> </ol>	<ol> <li>October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES).</li> <li>for uses related to text and data mining, Al training, and similar technologies.</li> </ol>	<ol> <li>October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES)</li> <li>for uses related to text and data mining. Al training, and similar technologies.</li> </ol>	<ol> <li>October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES)</li> <li>for uses related to text and data mining, Al training, and similar technologies.</li> </ol>	<ol> <li>October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES).</li> <li>for uses related to text and data mining, Al training, and similar technologies.</li> </ol>	Open: first published as 10.1136/bmjopen-2023-083410 o Protected by copyright, includir	J Open: first published as 10.1136/bmjopen-2023-083410 o Protected by copyright, includir
n 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . g for uses related to text and data mining, Al training, and similar technologies.	n 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . g for uses related to text and data mining, Al training, and similar technologies.	n 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . In for uses related to text and data mining, Al training, and similar technologies.	n 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . g for uses related to text and data mining, Al training, and similar technologies.	n 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . g for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-083410 Protected by copyright, includ	J Open: first published as 10.1136/bmjopen-2023-083410 Protected by copyright, includ
on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ng for uses related to text and data mining. Al training, and similar technologies.	on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ng for uses related to text and data mining. Al training, and similar technologies.	on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ng for uses related to text and data mining. Al training, and similar technologies.	on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ng for uses related to text and data mining, Al training, and similar technologies.	on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ng for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-08341( Protected by copyright, inclu	J Open: first published as 10.1136/bmjopen-2023-08341( Protected by copyright, includ
) on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Jing for uses related to text and data mining, Al training, and similar technologies.	) on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Jing for uses related to text and data mining, Al training, and similar technologies.	) on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Jing for uses related to text and data mining, Al training, and similar technologies.	) on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Jing for uses related to text and data mining, Al training, and similar technologies.	) on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Jing for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-08341 Protected by copyright, inclu	J Open: first published as 10.1136/bmjopen-2023-08341 Protected by copyright, inclu
0 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Iding for uses related to text and data mining. Al training, and similar technologies.	0 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Iding for uses related to text and data mining. Al training, and similar technologies.	0 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Iding for uses related to text and data mining. Al training, and similar technologies.	0 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Iding for uses related to text and data mining, Al training, and similar technologies.	0 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Iding for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-0834 Protected by copyright, inc	J Open: first published as 10.1136/bmjopen-2023-0834 Protected by copyright, inc
10 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . luding for uses related to text and data mining, Al training, and similar technologies.	10 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . luding for uses related to text and data mining, Al training, and similar technologies.	10 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Iuding for uses related to text and data mining, Al training, and similar technologies.	<sup>1</sup> 10 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . luding for uses related to text and data mining, Al training, and similar technologies.	<sup>1</sup> 10 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Iuding for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-08: Protected by copyright, in	J Open: first published as 10.1136/bmjopen-2023-08: Protected by copyright, in
3410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . cluding for uses related to text and data mining. Al training, and similar technologies.	3410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . cluding for uses related to text and data mining. Al training, and similar technologies.	3410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) cluding for uses related to text and data mining. Al training, and similar technologies.	3410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES). cluding for uses related to text and data mining, Al training, and similar technologies.	3410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . cluding for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-0\ Protected by copyright, i	J Open: first published as 10.1136/bmjopen-2023-0\ Protected by copyright, i
33410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ncluding for uses related to text and data mining, Al training, and similar technologies.	33410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ncluding for uses related to text and data mining, Al training, and similar technologies.	33410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ncluding for uses related to text and data mining, Al training, and similar technologies.	33410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ncluding for uses related to text and data mining, Al training, and similar technologies.	33410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) ncluding for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023-i Protected by copyright.	J Open: first published as 10.1136/bmjopen-2023- Protected by copyright.
083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . , including for uses related to text and data mining, Al training, and similar technologies.	083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) , including for uses related to text and data mining, Al training, and similar technologies.	083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . , including for uses related to text and data mining. Al training, and similar technologies.	083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . , including for uses related to text and data mining, Al training, and similar technologies.	083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . , including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2023 Protected by copyrigh	J Open: first published as 10.1136/bmjopen-2023 Protected by copyrigh
-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . t, including for uses related to text and data mining, Al training, and similar technologies.	-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) t, including for uses related to text and data mining, Al training, and similar technologies.	-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui Enseignement Superieur (ABES) . t, including for uses related to text and data mining, Al training, and similar technologies.	-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . t, including for uses related to text and data mining, Al training, and similar technologies.	-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . t, including for uses related to text and data mining. Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-20ź Protected by copyric	J Open: first published as 10.1136/bmjopen-20ź Protected by copyric
:3-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ht, including for uses related to text and data mining. Al training, and similar technologies.	:3-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ht, including for uses related to text and data mining. Al training, and similar technologies.	:3-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqui Enseignement Superieur (ABES) . ht, including for uses related to text and data mining, Al training, and similar technologies.	:3-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ht, including for uses related to text and data mining, Al training, and similar technologies.	3-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ht, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen-2( Protected by copyr	J Open: first published as 10.1136/bmjopen-2( Protected by copyr
)23-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ight, including for uses related to text and data mining, Al training, and similar technologies.	)23-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ight, including for uses related to text and data mining, Al training, and similar technologies.	)23-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ight, including for uses related to text and data mining, Al training, and similar technologies.	)23-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ight, including for uses related to text and data mining. Al training, and similar technologies.	)23-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ight, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopen- Protected by copy	J Open: first published as 10.1136/bmjopen- Protected by copy
2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . /right, including for uses related to text and data mining, Al training, and similar technologies.	2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . /right, including for uses related to text and data mining, Al training, and similar technologies.	2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . /right, including for uses related to text and data mining, Al training, and similar technologies.	2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . /right, including for uses related to text and data mining, Al training, and similar technologies.	2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . /right, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjoper Protected by co	J Open: first published as 10.1136/bmjoper Protected by co
-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ovright, including for uses related to text and data mining, Al training, and similar technologies.	-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ovright, including for uses related to text and data mining, Al training, and similar technologies.	-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ovright, including for uses related to text and data mining, Al training, and similar technologies.	-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ovright, including for uses related to text and data mining, Al training, and similar technologies.	-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ovright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjopv Protected by c	J Open: first published as 10.1136/bmjopo Protected by c
an-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . opyright, including for uses related to text and data mining, Al training, and similar technologies.	an-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . opyright, including for uses related to text and data mining, Al training, and similar technologies.	an-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . opyright, including for uses related to text and data mining, Al training, and similar technologies.	an-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . opyright, including for uses related to text and data mining, Al training, and similar technologies.	an-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . opyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmjo Protected by	J Open: first published as 10.1136/bmjo Protected by
ɔen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . copγright, including for uses related to text and data mining. Al training, and similar technologies.	copyright, including for uses related to text and data mining. Al training, and similar technologies.	copyright, including for uses related to text and data mining. Al training, and similar technologies.	copyright, including for uses related to text and data mining, Al training, and similar technologies.	copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/bmj Protected b	J Open: first published as 10.1136/bmj Protected b
open-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . / copyright, including for uses related to text and data mining, Al training, and similar technologies.	open-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . / copyright, including for uses related to text and data mining, Al training, and similar technologies.	open-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . / copyright, including for uses related to text and data mining, Al training, and similar technologies.	open-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . / copyright, including for uses related to text and data mining, Al training, and similar technologies.	open-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . / copyright, including for uses related to text and data mining. Al training, and similar technologies.	Open: first published as 10.1136/bn Protected	J Open: first published as 10.1136/bn Protected
jopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . by copyright, including for uses related to text and data mining, Al training, and similar technologies.	jopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . by copyright, including for uses related to text and data mining, Al training, and similar technologies.	jopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . by copyright, including for uses related to text and data mining, Al training, and similar technologies.	jopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . by copyright, including for uses related to text and data mining, Al training, and similar technologies.	jopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136/b Protecte	J Open: first published as 10.1136/b Protecte
mjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . I by copyright, including for uses related to text and data mining, Al training, and similar technologies.	mjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . I by copyright, including for uses related to text and data mining. Al training, and similar technologies.	mjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . I by copyright, including for uses related to text and data mining, Al training, and similar technologies.	mjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . I by copyright, including for uses related to text and data mining, Al training, and similar technologies.	mjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . I by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1136 Protect	J Open: first published as 10.1136 Protect
bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . d by copyright, including for uses related to text and data mining, Al training, and similar technologies.	bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . d by copyright, including for uses related to text and data mining, Al training, and similar technologies.	bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . d by copyright, including for uses related to text and data mining, Al training, and similar technologies.	'bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . od by copyright, including for uses related to text and data mining, Al training, and similar technologies.	bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . od by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.113 Protec	J Open: first published as 10.113 Protec
5/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	5/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ted by copyright, including for uses related to text and data mining. Al training, and similar technologies.	5/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	5/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	5/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com</u> / on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.11 Prote	J Open: first published as 10.11 Prote
36/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . cted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	36/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . cted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	36/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . cted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	36/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . cted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	36/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . cted by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10.1 Pro	J Open: first published as 10.1 Pro
136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . ected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com</u> / on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . ected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as 10. Pr	J Open: first published as 10 Pr
1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . otected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . otected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . otected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . otected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . otected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	Open: first published as 1 F	J Open: first published as 1 F
0.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . rotected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	0.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . rotected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	0.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . rotected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	0.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . rotected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	0.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . rotected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published as	J Open: first published as
10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published a	J Open: first published a
s 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	s 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	s 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	s 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	s 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first published	J Open: first published
as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first publishe	J Open: first publishe
d as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	d as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	d as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	d as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	d as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	Open: first publish	J Open: first publish
ed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first publis	J Open: first publis
hed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	hed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique. Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	hed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	hed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	hed as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first publ	J Open: first publ
ished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first pu	J Open: first pu
bished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	bished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	bished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	bished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	bished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: first p	J Open: first p
ublished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ublished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ublished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ublished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	ublished as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	Open: first	J Open: first
published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: fir	J Open: fir
st published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	st published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	st published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	st published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	st published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open: 1	J Open: 1
irst published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	irst published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	irst published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	irst published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	irst published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com</u> / on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Open	J Open
: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Ope	J Op
n: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	n: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	n: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu، Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	n: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	n: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	0	ے o
pen: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining. Al training, and similar technologies.	pen: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	pen: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	pen: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from <u>http://bmjopen.bmj.com/</u> on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	pen: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographiqu Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.		د

면

#### 1 SUPPLEMENTAL MATERIAL

#### 2 Supplementary methods

#### 4 Focus group discussions (FGDs) at the study site: community health workers (CHWs)

5 N=64; 2 FGDs per each of the four selected districts, 8 participants per each FGD.

## Experiences on the use of the e-ASCov application for screening and testing COVID-19 using RDTs by CHWs (perception and satisfaction of CHWs on their role).

**English:** Thank you for agreeing to participate today and give your informed consent. I would like to ask you about your experiences on the use of the e-ASCov application and testing COVID-19 by Community Health Workers using RDTs. All your answers will remain confidential and you do not have to answer to questions that you do not want. There is no right or wrong answer to these questions. Please feel free to ask questions anytime during the interview and we can stop at any time. Thank you again for your participation 

Kinyarwanda : Murakoze kwemera kwitabira iki kiganiro uyu munsi no kwemera kugira uruhare muri ubu bushakashatsi nyuma yo gusobanurirwa. Nifuzaga kubabaza kubijyanye n'ubumenyi mufite kw'ikoreshwa ry'ikoranabuhanga mu gufata amakuru no gupima COVID-19 bikozwe n'abajyanama b'ubuzimamuri. Ibisubizo byanyu bigirwa ibanga kandi mufite uburenganzira bwo guhitamo kudasubiza bimwe mu bibazo mubazwa igihe mwumva bibabangamiye. Nta gisubizo kiri cyo cyangwa se gipfuye. Mwisanzure mubaze ikibazo cyose mwagira mugihe turi kuganira, kandi dushobora guhagarika iki kiganiro igihe icyo aricyo cyose mubyifuje. Murakoze cyane nanone kwitabira iki kiganiro. 

**Note:** *Record the District of residence, age, sex, level of education, and occupation for each participant* 

**SECTION A: USE OF E-ASCOV** 

Knowledge of the e-ASCOV application /Ubumenyi rusange ku ikoranabunga rya e-ASCOV mu gufata amakuru no guhangana n'icyorezo cya COVID-19

**1.** What do you think in general on the use of digital tool (e-ASCOV application) by CHWs for COVID-19 response?

Muri rusange mwadusngiza icyo mutekekereza ku ikoreshwas ry' ikoranabuhanga n'abajyanama bubuzima mu guhangana n'icyorezo cya COVID-19 ?

2. What expectations do you or did you have regarding e-ASCOV app?

	Ni iki mwari mwiteze cyangwa se nubu mucyiteze ku ikoreshwa ry'ubu buryo bwa e-Ascov ?
3.	How confident are you with the use of e-ASCOV app by CHWs?
	Mwumva mwifitiye icyizere kingana iki (Ku ruhe rugero) kw'ikoreshwa neza ry'iri koranabunga e ASCOV?
Per	ceived benefits, barriers and facilitators e-ASCOV
Iny	ungu , inzitizi n'ibishyigikira
4. M ut kv	Can you describe the positive (perceived benefits) of e-ASCOV app? (Probe: contribution of e-ASCOV app in COVID-19 prevention and control) (ukurikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mwabonye mu gukoresha ou buryo bwa e-ASCOV? (Aha ndashaka kuvuga icyo ubu buryo bwaba bwarafashije mu wirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19?
5. •	What do you think are the negative experiences with e-ASCOV app? Ni iki mwumva cyangwa se mubona kitagenze neza mugihe mwakoreshaga ubu buryo bwa e-ASCOV?
6. A	What are the factors hindering (barriers) the use of e-ASCOV app? Mukurikije uko mubyumva, ni izihe mbogamizi mubona ku ikoreshwa ry'ubu buryo bwa e– SCOV ?
7. M ry	Wat are the factors facilitating (enablers) the use of e-ASCOV app? lukurikije uko mubyumva, ni iki mubona cyaba gifasha cyane cyangwa cyoroshya ikoreshwa ''ubu buryo bwa e ASCOV ?
Sati	isfaction vis-à-vis the use of e-ASCOV app
Ku	nyurwa n'imikoreshereze y'ikoranabuhanga e-ASCOV
<b>8.</b> ●	What do you think about the use e-ASCOV app in the future? Do you have any suggestions for improvement? Mutekereza iki ku ikoreshwa ry'ubu buryo bwa e- ASCOV mugihe kiri imbere ? hari icyo mutekereza cyakogerwaho cyangwa cyakurwaho kuri ubu buryo bwa e-ASCOV kugirango burusheho gukora neza?
SE(	CTION B: TESTING COVID-19 DONE BY CHWS
	noral normantian on COVID 10 testing by CHWa/Cusuruma COVID 10 bilegray
Ger n'al	bajyanama b'ubuzima

	o ubuzima?
10.	What expectations do you or did you have regarding testing Covid-19 by CHWs?
	Ni iki mwari mwiteze cyangwa se nubu mucyiteze ku gusuzuma COVID-19 bikozwe n'abajyanama b'ubuzima?
11.	How confident are you with the use of e-ASCOV app by CHWs?
	Mwumva mwifitiye icyizere kingana iki (kuruhe rugero) ku gupima COVID-19 bikozwa n'abajyanama b'ubuzima?
Per	rceived benefits, barriers and facilitators e-ASCOV
1.	Inyungu , inzitizi n'ibishyigikira
12.	Can you describe the positive (perceived benefits) of testing COVID-19 by CHWs? (a contribution of COVID-19 testing by CHWs to COVID-19 prevention, control, and management)
•	Mukurikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mubona mu gusuzu COVID-19 bikozwe n'abajyanama b'ubuzima? ( ahan ndashaka kuvuga icyo ubu buryo b bwarafashije mu kwirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19 n'akamaro bifitiye abaturaRwanda)
13. •	What do you think are the negative experiences with testing COVID-19 by CHWs?? Mukurikije uko mubyumva ni iki mubona kitagenze neza mu gusuzuma COVID-19 biko n'abajyanama b'ubuzima?
14. •	What are the factors hindering (barriers) the testing COVID-19 by CHWs? Mukurikije uko mubyumva, ni izihe mbogamizi mubona mu gusuzuma COVID-19 biko n'abajyanama b'ubuzima?
15.	Wat are the factors facilitating (enablers) the testing COVID-19 by CHWs?
•	Mukurikije uko mubyumva, ni iki mubona cyaba gifasha cyane cyangwa cyoroshya gusu COVID-19 bikozwe n'abajyanama b'ubuzima
16.	What do you think about the testing of COVID-19 by CHWs in the future? Do you hav suggestions for improvement?
•	Mutekereza iki ku gupima COVID-19 bikozwe n'abajyana b'ubuzima mugihe kiri imbera hari icyo mutekereza cyakogerwaho cyangwa cyakurwaho mu buryo bwo gupima COVII bikozwe n'abajyana b'ubuzima kugirango burusheho gukora neza?
	END OF THE
IN	TERVIEW

## $\begin{array}{cccc} 1 & & \\ 2 & 25 \\ 3 & & \\ 4 & & \\ 5 & 26 & & \\ \end{array}$

25 Author reflexivity statement

This study was conceptualized, designed and led in collaboration with Rwanda Biomedical Centre and
Rwanda's Ministry of Health. Members of Rwanda Biomedical Centre and the Ministry of Health who
led this work are included as authors. The position of first author reflects the contribution of Ladislas
Nshimiyimana, NTD Research Senior Officer at Rwanda Biomedical Centre, to the work.

The study addresses local research and policy priorities in Rwanda. Rwanda's health system has a
 Vision for decentralized COVID-19 testing and there was interest in utilizing the country's strong CHW
 capacity to increase access to testing. This study aimed to realize these ambitions and the team designed
 an intervention that utilized the country's CHW workforce to deliver decentralized COVID-19 testing.

The study has contributed to improvements in local infrastructure, through the development and updating of a mobile application ("e-ASCov") to enable community-based screening and testing for COVID-19. The project also trained CHWs on using the digital tool and rapid tests to detect COVID-19 at the household-level.

Safeguarding procedures were implemented to protect local study participants and researchers. Firstly, the screening and testing intervention was conducted as part of routine Ministry of Health programming included in the CHW package of services. Several measures were taken to minimize the risk of infection for CHWs and other members of the household during community-based testing, as described in the manuscript. All CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation. 

#### **Supplementary Tables and Figures**

#### Supplementary Table 1. Overview of study districts

	COVID-19 positivity rate (%)*	District population	Number of CHWs in district	Number of CHWs selected for the project (%)
Gasabo (urban)	2.0	530,907	1731	102 (6)
Nyarugenge (urban)	1.2	284,561	1135	100
Kirehe (Rural)	1.6	382,932	2587	99
Rusizi (Rural)	2.5	483,615	2298	99
Rubavu (Rural)	1.3	403,662	1990	100
Musanze (Rural)	5.9	368,267	1715	99
Nyagatare (Rural)	4.4	530,907	2531	100
Huye (Semi-urban)	8.3	328,398	2016	101
Total		3,313,249	16,003	800
Positivity rates as of Septemb 'HW, community health work	per 2021, when the ker.	phase one commenced.		
Positivity rates as of Septeml CHW, community health worl	per 2021, when the ker.	phase one commenced.		

BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de I Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

Characteristics		Number of respondents	%
Ease of using e-ASCov		•	
5	Easy	291	83.4
	Slightly easy	49	14
	Difficult	9	2.6
Training package			
81	Satisfied	315	90.2
	Somehow		
	satisfied	31	8.9
	Not satisfied	2	0.6
Simplicity of e-ASCov application	1.000000000000	-	0.0
	Easy	297	85 1
	Slightly easy	47	13 4
	Difficult	5	1 4
Duration of the training		5	1.4
	Sufficient	107	55 (
	Somehow	172	55.0
	sufficient	100	20 -
	Not sufficient	57	20.1 16 3
Equipmont/oursling	Not sufficient	57	10.3
Equipment/supplies	Setisfied	215	00 1
	Sansher	515	90.2
	Somenow	29	0.0
	satisfied	28	8.0
	Not satisfied	6	1.8
Access to internet		171	10 (
	Good	1/1	49.0
	Somehow good	190	48.7
	Poor	8	2.3
Time used to enter client's data	<b>C1</b>		
	Short	161	46.1
	Somehow short	116	33.3
~	Long	72	20.6
Getting support	~		
	Satisfied	295	84.5
	Somehow		
	satisfied	42	12.0
	Not satisfied	12	3.5
Service delivery through e-ASCov			
	Satisfied	325	93.1
	Somehow		
	satisfied	22	6.3
	Not satisfied	2	0.6
Need for future use of e-ASCov			
	Yes	349	100.
Scale-up of e-ASCov to other diseases	5		
-	Yes	348	99.7

Characteristics		Frequency	%
Overall perception			
	Easy	313	89.6
	Slightly easy	33	9.5
	Difficult	3	0.9
Training package			
	Satisfied	303	86.8
	Somehow satisfied	40	11 4
	Not satisfied	6	17
Juration of the training	The substee	0	1.7
Duration of the training	Sufficient	202	57
	Somehow sufficient	202	27.0
	Somenow sufficient	99	28.
	Not sufficient	48	13.
Equipment/Supplies			~-
	Satisfied	305	87.
	Somehow satisfied	36	10.
	Not satisfied	8	2.3
<b>Reading results of Ag-RDT</b>			
	Easy	326	93.
	Slightly easy	17	4.9
	Difficult	4	1.2
Entering results using e-ASCo	ov app		
	Easy	296	84.8
	Slightly easy	45	12.
	Difficult	8	2.3
Getting support			
8 . II .	Satisfied	298	85.4
	Somehow satisfied	40	11
	Not satisfied	11	3 1
	Not satisfied	11	5.1



# Reporting checklist for quality improvement in health care.

Based on the SQUIRE guidelines.

#### Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the SQUIREreporting guidelines, and cite them as:

Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for

QUality Improvement Reporting Excellence): revised publication guidelines from a detailed

consensus process

Reporting Item

Title

#1 Indicate that the manuscript concerns an initiative to improve 1
 healthcare (broadly defined to include the quality, safety, effectiveness, patientcenteredness, timeliness, cost, efficiency,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

1 2			and equity of healthcare)	
2 3 4 5	Abstract			
6 7 8		<u>#02a</u>	Provide adequate information to aid in searching and indexing	3
9 10 11		<u>#02b</u>	Summarize all key information from various sections of the text	3
12 13			using the abstract format of the intended publication or a	
14 15			structured summary such as: background, local problem,	
16 17 18			methods, interventions, results, conclusions	
19 20 21	Introduction			
22 23	Problem	<u>#3</u>	Nature and significance of the local problem	4
24 25 26 27	description			
28 29	Available	<u>#4</u>	Summary of what is currently known about the problem,	4-5
30 31 32	knowledge		including relevant previous studies	
33 34	Rationale	<u>#5</u>	Informal or formal frameworks, models, concepts, and / or	4-5
35 36 37			theories used to explain the problem, any reasons or	
38 39			assumptions that were used to develop the intervention(s), and	
40 41 42			reasons why the intervention(s) was expected to work	
43 44 45	Specific aims	<u>#6</u>	Purpose of the project and of this report	5
46 47 48	Methods			
49 50	Context	<u>#7</u>	Contextual elements considered important at the outset of	6
51 52 53			introducing the intervention(s)	
54 55 56	Intervention(s)	<u>#08a</u>	Description of the intervention(s) in sufficient detail that others	6-8
57 58			could reproduce it	
59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	
Page 35 of	36			
------------	----	--		
------------	----	--		

1 2 3	Intervention(s)	<u>#08b</u>	Specifics of the team involved in the work	6, 9
4 5	Study of the	<u>#09a</u>	Approach chosen for assessing the impact of the	6, 8, 9
7 8	Intervention(s)		intervention(s)	
9 10 11	Study of the	<u>#09b</u>	Approach used to establish whether the observed outcomes	6, 8, 9
12 13 14	Intervention(s)		were due to the intervention(s)	
15 16	Measures	<u>#10a</u>	Measures chosen for studying processes and outcomes of the	8-9
17 18			intervention(s), including rationale for choosing them, their	
19 20 21			operational definitions, and their validity and reliability	
22 23 24	Measures	<u>#10b</u>	Description of the approach to the ongoing assessment of	8-9
25 26			contextual elements that contributed to the success, failure,	
27 28 29			efficiency, and cost	
30 31	Measures	<u>#10c</u>	Methods employed for assessing completeness and accuracy	10
32 33 34			of data	
35 36 27	Analysis	<u>#11a</u>	Qualitative and quantitative methods used to draw inferences	8-9
38 39 40			from the data	
41 42	Analysis	<u>#11b</u>	Methods for understanding variation within the data, including	8-9
43 44 45			the effects of time as a variable	
46 47	Ethical	<u>#12</u>	Ethical aspects of implementing and studying the	9
48 49 50	considerations		intervention(s) and how they were addressed, including, but not	
50 51 52			limited to, formal ethics review and potential conflict(s) of	
53 54 55			interest	
56 57	Results			
58 59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

					BM
1 2		<u>#13a</u>	Initial steps of the intervention(s) and their evolution over time	Figures	J Open
3 4 5			(e.g., time-line diagram, flow chart, or table), including	and 2	: first
5 6 7			modifications made to the intervention during the project		publish
8 9 10		<u>#13b</u>	Details of the process measures and outcome	10-13	ed as 10. Pr
11 12 13		<u>#13c</u>	Contextual elements that interacted with the intervention(s)	12-13	.1136/bm otected k
14 15 16		<u>#13d</u>	Observed associations between outcomes, interventions, and	10-13	jopen-20 by copyri
17 18 19			relevant contextual elements		)23-0834 ight, incl
20 21		<u>#13e</u>	Unintended consequences such as unexpected benefits,	12-13	10 on Iuding
22 23 24			problems, failures, or costs associated with the intervention(s).		1 Octobe Ens for uses
25 26 27		<u>#13f</u>	Details about missing data	11	eigneme related
28 29 30	Discussion				Download ent Super to text ar
31 32 33	Summary	<u>#14a</u>	Key findings, including relevance to the rationale and specific	14	ded fro rieur ( <i>F</i> nd data
34 35 36			aims		m http:// \BES) . I mining,
37 38 39	Summary	<u>#14b</u>	Particular strengths of the project	14-15	bmjopen Al traini
40 41 42	Interpretation	<u>#15a</u>	Nature of the association between the intervention(s) and the	13	ng, and
43 44			outcomes		n/ on 、 similar
45 46 47	Interpretation	<u>#15b</u>	Comparison of results with findings from other publications	13, 15	June 11, 2 <sup>.</sup> technolc
48 49 50	Interpretation	<u>#15c</u>	Impact of the project on people and systems	15-16	025 at A <sub>0</sub> ogies.
51 52 53	Interpretation	<u>#15d</u>	Reasons for any differences between observed and anticipated	15-16	gence Bi
54 55 56			outcomes, including the influence of context		bliogra
50 57 58	Interpretation	<u>#15e</u>	Costs and strategic trade-offs, including opportunity costs	15	aphique
60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml		de I

Page 37 of 36

BMJ Open

1 2 3	Limitations	<u>#16a</u>	Limits to the generalizability of the work	15
4 5	Limitations	<u>#16b</u>	Factors that might have limited internal validity such as	15
6 7			confounding, bias, or imprecision in the design, methods,	
8 9 10			measurement, or analysis	
11 12 13 14	Limitations	<u>#16c</u>	Efforts made to minimize and adjust for limitations	15
15 16 17	Conclusion	<u>#17a</u>	Usefulness of the work	15-16
18 19 20	Conclusion	<u>#17b</u>	Sustainability	15-16
21 22 23	Conclusion	<u>#17c</u>	Potential for spread to other contexts	15-16
24 25 26	Conclusion	<u>#17d</u>	Implications for practice and for further study in the field	15-16
27 28 29	Conclusion	<u>#17e</u>	Suggested next steps	15-16
30 31	Other			
32 33 34	information			
35 36 37	Funding	<u>#18</u>	Sources of funding that supported this work. Role, if any, of the	17
38 39			funding organization in the design, implementation,	
40 41 42			interpretation, and reporting	
43 44	None The SQUIR	E 2.0 cł	necklist is distributed under the terms of the Creative Commons At	tribution
45 46 47	License CC BY-N	C 4.0. T	This checklist can be completed online using https://www.goodrepo	o <mark>rts.org/</mark> , a
48 49 50	tool made by the E	EQUAT	OR Network in collaboration with Penelope.ai	
51 52 53				
54 55 56				
57 58				
59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

# Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study

Journal:	BMJ Open
Manuscript ID	bmjopen-2023-083410.R1
Article Type:	Original research
Date Submitted by the Author:	15-Jul-2024
Complete List of Authors:	Nshimiyimana, Ladislas; Rwanda Biomedical Center, Bigirimana, Noella; Rwanda Biomedical Center Ngabonziza, JCS; Rwanda Biomedical Center; University of Rwanda RUKUNDO, Gilbert ; Rwanda Biomedical Center Rwabihama, Jean-Paul ; Republic of Rwanda Ministry of Health Rutayisire, Robert; Rwanda Biomedical Center Semakula, Muhammed; Republic of Rwanda Ministry of Health Mugabo, Hassan; Rwanda Biomedical Center, Research Innovation and Data science Mutabazi, Josue; Independent consultant Mukamana, Beatrice; Rwanda Biomedical Center Mazarati, Jean-Baptiste ; FIND Kadam, Rigveda; FIND Akinwusi, Olukunle; FIND Suleiman, Khairunisa; FIND Muvunyi, Claude; Rwanda Biomedical Center; University of Rwanda Akugizibwe, Paula; FIND
<b>Primary Subject Heading</b> :	Diagnostics
Secondary Subject Heading:	Diagnostics, Infectious diseases, Public health
Keywords:	COVID-19, Public health < INFECTIOUS DISEASES, Health Services





I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

terez oni

Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de I Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

2 3 4 5 6 7 8		Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study
9 10	1	Ladislas Nshimiyimana <sup>1</sup> , Noella Bigirimana <sup>1</sup> , Jean-Claude S. Ngabonziza <sup>1,2</sup> , Jean-Paul
11 12	2	Rwabihama <sup>3</sup> , Robert Rutayisire <sup>1</sup> , Muhammed Semakula <sup>3</sup> , Gilbert Rukundo <sup>1</sup> , Hassan Mugabo <sup>1</sup> ,
12 13 14 15	3 4	Josue Mutabazi <sup>4</sup> , Beatrice Mukamana <sup>1</sup> , Jean-Baptiste Mazarati <sup>5</sup> , Rigveda Kadam <sup>5</sup> , Olukunle Akinwusi <sup>5</sup> , Khairunisa Suleiman <sup>5</sup> , Claude Mambo Muvunyi <sup>1,2</sup> , Paula Akugizibwe <sup>5</sup>
16 17	5	<sup>1</sup> Rwanda Biomedical Centre, Kigali, Rwanda
18 19 20	6	<sup>2</sup> University of Rwanda, Kigali, Rwanda
20 21 22	7	<sup>3</sup> Ministry of Health, Kigali, Rwanda
23 24 25	8	<sup>4</sup> Independent consultant, Kigali, Rwanda
26 27	9	<sup>5</sup> FIND, Geneva, Switzerland
28	10	* Correspondence:
29 30	11	Corresponding author
31 32 33	12	ladislas.nsnimiyimana@rbc.gov.rw
34 35 36	14	Word Count: 4951/5000
37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 50	15	Keywords: COVID-19, diagnostics and tools, public health
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# 16 ABSTRACT

### 5 17 **Introduction**

18 Antigen-based rapid diagnostic tests (Ag-RDTs) can improve the diagnosis, management and control

of COVID-19, by bringing testing closer to patients. However, testing in decentralized settings
 presents challenges in terms of data reporting, linkage to care, and decision-making. In line with

- presents challenges in terms of data reporting, linkage to care, and decision-making. In line with
   Rwanda's ambition to decentralize COVID-19 testing, this study evaluated the use of Ag-RDTs
- <sup>11</sup> 22 alongside a digital tool to deliver household-level COVID-19 testing by community health workers
- <sup>12</sup> 13 (CHWs).

### <sup>14</sup> 15 24 **Methods**

This was an operational pilot study to evaluate the impact and operational characteristics of using the digital tool e-ASCov combined with Ag-RDTs to support COVID-19 symptom screening and rapid testing by CHWs across eight districts in Rwanda. A total of 800 CHWs selected from both rural and urban areas were trained in delivering Ag-RDTs for COVID-19 testing and using the e-ASCOV application for data capture on a smartphone. Laboratory technicians repeated a subset of Ag-RDTs to assess the concordance of results obtained by CHWs. The study also assessed CHWs experience of the intervention using a mixed methods approach. 

### 26 32 **Results**

From February to May 2022, CHWs screened 19,544 participants, of whom 4575 (23.4%) had COVID-19 related symptoms or history of exposure to the infection. Among them, 86 (1.9%) were positive on Ag-RDTs. Concordance of Ag-RDT results between CHWs and laboratory technicians was 100%. Of the 800 trained CHWs, 746 (93.3%) were independently able to conduct household-based COVID-19 screening, perform the Ag-RDTs and send data to the central server. Most CHWs (>80%) found Ag-RDTs and e-ASCOV easy to use. 

# 3536 39 Conclusion

This study demonstrated the feasibility of deploying a digital tool and Ag-RDTs for household-level
 SARS-CoV-2 detection in Rwanda. The findings support broader roll-out of digitally supported rapid

 $40_{41}$  42 testing by CHWs to broaden access to testing for priority diseases.

# <sup>42</sup><sub>43</sub> 43 Word count: 299/300

### 45 44 Strengths and limitations of the study

- The study built on a well-established community health worker network, leveraging existing personnel and operational structures to introduce a new intervention with minimal disruption to the health system.
- Digitization of the study process helped to ensure that standardized procedures were followed for screening and data management despite the dispersed settings in which study activities took place in the communities.
- The study used only Android smartphones; challenges related to different phones were not assessed. However, the application met the requirement for installation and use in all smartphone versions.

• The study did not include control districts or other comparators, as this was not feasible during the emergency response to the pandemic.

For perteries only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# 58 INTRODUCTION

As of 9 February 2022, Rwanda had reported 129,210 cases of COVID-19, over 4.5 million tests conducted, and 1449 deaths.<sup>1</sup> Of the 4.5 million tests, 73.3% were antigen-based rapid diagnostic tests (Ag-RDTs), while 26.7% were polymerase chain reaction (PCR) tests. Most COVID-19 cases were reported during three major waves in which rapid surges of infection took place in a short period of time. Error! Bookmark not defined. underscoring the importance of widespread testing to enable the rapid detection of SARS-CoV-2 and contain its transmission. 

While the epidemic was initially concentrated in urban settings, with the capital city, Kigali, accounting for 29.1% (28,267 of 97,190) of cumulative cases,<sup>2</sup> over time an increasing number of cases were detected in more rural areas of the country. Lower access to health facilities in less urbanized settings highlighted the need to expand community-based testing. Even outside of an emergency, the opportunity costs associated with travel to health facilities present significant barriers to care-seeking in many settings,<sup>3</sup> which were further heightened by movement restrictions and economic constraints during the COVID-19 pandemic.<sup>4</sup> 

The increased availability of point-of-care testing for COVID-19, specifically Ag-RDTs, created new opportunities to bring testing closer to patients given the limited laboratory infrastructure available to deliver the gold standard testing using PCR, especially in rural areas. COVID-19 testing with Ag-RDTs in Rwanda was initially delivered by trained clinicians or laboratory professionals and had not been formally offered by CHWs at the household level. However, the country's extensive network of CHWs were already involved in the diagnosis of other diseases, including symptom screening and referral for tuberculosis (TB). For example, between 2020 and 2021, 26.3% of the 5435 TB cases in Rwanda were referred by CHWs.<sup>5</sup> Consequently, there was a basis on which to review the COVID-19 testing process and consider expanding Ag-RDT testing at the community level through trained CHWs. Extending diagnostic ability using CHWs promises tremendous potential for expanded access, but also presents challenges in terms of accurate and timely data reporting. 

Accurate testing and timely data reporting are critical for the effective management of the COVID-19 response, particularly during periods of rapid transmission when such data provide early alerts of impending waves and hotspots to which intensified resources should be directed. CHWs could thus play a role not only in expanding access to diagnosis, but in supporting the development of community health surveillance approaches, which the World Health Organization has highlighted as a core pillar of pandemic preparedness.<sup>6</sup> 

Digital tools play an important role in enabling the rapid transmission of data to support real-time monitoring and epidemiological surveillance, and ease CHWs' path to making decisions with clinical implications. Digital solutions provide real-time guidance and standardization of processes at the point of care and at the management level and enable visibility into procedures being implemented at decentralized sites.7 

Leveraging Rwanda's widespread CHW network, the "e-ASCov project" was initiated and piloted by
 the Rwanda Biomedical Centre (RBC) and partners to evaluate the use of digital tools and Ag-RDT

**BMJ** Open Page 6 of 37 BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies. testing by CHWs in 2020. The pilot project was rolled out in two urban and two rural districts in Rwanda, whereby CHWs were trained and equipped with innovative digital technology to support community-based screening and referral of people with COVID-19 symptoms. The RBC-developed e-ASCov mobile application was installed on the phones of participating CHWs to support them with COVID-19 symptom screening and referral, and ensure that related data are systematically captured and rapidly transmitted to national data servers to guide national surveillance and response efforts. This study sought to build on the original e-ASCov pilot, and the opportunities offered by the expansion of Ag-RDT testing, by expanding e-ASCov to include instructions and data capture for administration of Ag-RDTs, and mechanisms for real-time reporting. At the time it was designed, to the authors' knowledge this was the first study that evaluated the ability of CHWs to perform SARS-CoV-2 Ag-RDT testing, capture and transmit results in Rwanda and the broader African region. Thus, the study would provide grounds to review and update COVID-19 laboratory testing guiding principles in Rwanda vis-a-vis the possibility to decentralize RDT-based diagnosis at community level by trained

### **METHODS**

CHWs.

This was an operational pilot study to evaluate the impact and operational characteristics of using the digital tool e-ASCov combined with Ag-RDTs to support symptom screening and delivery of rapid testing by CHWs at the household level. 

Study setting and population 

The study took place in eight districts in four provinces in Rwanda, including the four districts selected in the e-ASCov pilot. Four additional districts were selected based on infection rates (those with the highest infection rates at the time the study began) and geographic location. In terms of geographic location, a spread of rural, urban and semi-urban districts were included, with prioritization of rural districts as residents had restricted access to health facilities in these areas compared to the rest of the population. Districts with land borders were also prioritized due to a greater risk of COVID19 transmission because of higher levels of movement between countries. 

A total of 800 CHWs were selected for this study across 34 health centres (100 per district), representing around 5% of the total CHW workforce in the studied districts. Villages were selected randomly depending on the number of CHWs required per health centre, with all active CHWs included from selected villages. Supplementary Table 1 provides an overview of the study districts and CHWs included in the project by district. Within these districts, the intervention was fully integrated into the 

1 2	120	CHWs' routine nackage of care, which is accessible to all residents. As a result, the eligible population
2 3 4	129	for this project was any person resident in the study districts.
- 5 6 7	131	Digitally enabled screening and rapid testing
8	132	This study built on the e-ASCov pilot described previously <sup>8</sup> in which CHWs identified individuals
9	133	suspected to have COVID-19 and referred them for testing The e-ASCov tool was an existing field-
10 11	134	tested mobile application for symptom screening to identify possible COVID-19 cases. CHWs verbally
12	135	administered a screening questionnaire to individuals in their communities, which focused on signs
13	136	and symptoms suggesting a risk of COVID-19 recording individual's response in the e-ASCov
14 15	137	application Based on the responses an algorithm built into the application assigned participants to one
16	138	of three risk levels (low risk suspected case and urgent case)—with the latter two categories being
17	139	referred for Ag-RDT testing
18 10	107	
20	140	The algorithm used for screening was updated to align with the latest guidance from Rwanda's
21	141	Ministry of Health (Figure 1), with inbuilt skip logic determining which of the case categories an
22 23	142	individual fell into.
23 24		
25	143	
26 27	144	
28	144	
29	145	
30 31		
32	146	
33		
34 35	147	Figure 1. e-ASCov algorithm used in pilot study
36	148	
37 20	110	
30 39	149	RDT, rapid diagnostic test.
40	150	For this study, the PDT toollit (developed by Dimeni Ire) <sup>9</sup> <sup>10</sup> was interested into a ASC to
41 47	150	rou ins study, the KD1 toolkit (developed by Dimagi inc) <sup>2, w</sup> was integrated into e-ASCOV, to
43	151	2) Originally developed to support rapid diagnostic testing for malaria, the teally it is readily
44	152	2). Originally developed to support rapid diagnostic testing for infatalia, the toolkit is readily extension and the support approximation of the support of the superior of the support of the support of the support of the superior of
45 46	155	delivery of the SAPS CoV 2 Ag PDTs and translated to make instructions available in
47	154	uchvery of the SANS-COV-2 Ag-ND IS and translated to make instructions available in Vinverwanda
48	155	Kinyai wanua.
49 50	156	When a CHW was prompted to conduct a test after the e-ASCov questionnaire, the workflow
51	157	automatically transitioned into the RDT toolkit without the CHW having to change applications. This
52	158	presented a set of instructions in Kinyarwanda. The CHW collected nasal samples for the Ag-RDT
53 54	159	using nasopharyngeal swabs, and were thereafter instructed to start the timer after initiating the test.
55		
56	160	Rapid testing by the CHWs was conducted according to manufacturer's instructions using a validated
57 58	161	Ag-RDT (Panbio COVID-19 Ag Rapid Test Device, Abbott), which was already recommended by
59		6
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

ω

Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.	Enseignement Superieur (ABES)	J Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de
--	-------------------------------	---

162	Rwanda's COVID-19 Laboratory Testing Guiding Principles and routinely used. <sup>11</sup> Using the timer on
163	the application, CHWs read the Ag-RDT result after the processing time and recorded the result in the

a 163 the application, CHW stead the Ag RDT result after the processing time and recorded the result in 4
 b 164 e-ASCov tool. There was also an option to capture and transmit images of the test result to enable

6 165 validation of the result by the central team at RBC. As e-ASCov was fully integrated within the

broader Ministry of Health digital system for reporting on COVID-19, data were subsequently

167 transmitted to RBC servers in real time.

11 168

169 Figure 2. Study workflow

172 HMIS, health management information system; RBC, Rwanda Biomedical Centre; RDT, rapid diagnostic test.

Patients who tested positive on the Ag-RDTs were referred to a nearby facility if their risk was classified as "urgent" (Case 3 in Figure 1), or would otherwise be referred to the existing home-based care programme, which includes guidance on isolation and self-monitoring of symptoms. In addition, their contacts were registered and tested using the same procedure.

# Evaluation of the concordance and performance of ag-RDT

To assess the concordance of Ag-RDT results between CHWs and the laboratory technician, 499 CHWs were randomly selected and shadowed by a laboratory technician for a period of time. During that time, the CHWs administered Ag-RDTs and read the result independently, then re-read by the field trainer (observer). The result interpreted by the CHW was blinded to the laboratory technician as an operator. The laboratory technician then repeated the Ag-RDT and reported their result independently. The results from the tests performed by the laboratory technician were considered final and communicated to clients. 

# 37186Assessment of the experience

The study assessed CHWs' experience of the intervention using a mixed methods approach. Firstly, a self-administered questionnaire with close-ended questions was provided to CHWs. Secondly, qualitative data were collected using focus group discussions with CHWs in four districts (Rubavu, Huye, Nyagatare and Gasabo). The questions focused on e-ASCov and the administration of Ag-RDTs, in terms of usability, satisfaction, enablers and barriers, and the perceived continuity of the intervention. Interviews were conducted in Kinyarwanda and recorded with the aid of smartphones and tablet devices, then later transcribed and translated in English. Copies of questions asked as part of the focus group discussions are available in the Supplementary methods. 

# <sup>51</sup> 195 **Training and mentorship**

196 CHWs and supervising staff at participating facilities underwent 1–2 days of theory and practical
 197 training at the district level. A refresher training was conducted on general COVID-19 information
 198 including the use of personal protective equipment (PPE), detecting symptoms of COVID-19, and
 199 follow-up of COVID-19 cases. CHWs were then further trained on screening and data capture using

e-ASCov. Finally, qualified staff from the NRL provided training on how to conduct Ag-RDTs. This
included a demonstration with the aid of a practical video, following which the CHWs conducted

- Ag-RDT testing under the supervision of facilitators. The community health supervisor and the training facilitators at the respective health centres were responsible for ensuring distribution of
- $\frac{7}{8}$  204 materials to the CHWs and accountability in the use of these materials.

Pre- and post-training tests were conducted to confirm participants' level of knowledge. Trainees' feedback on the digital tool also informed further refinement of the application during the training process. During implementation, ongoing mentorship was provided through existing supervisors at facilities, with additional support from RBC, particularly for resolving any operational and technological issues that arose during the study. Refresher training and technical support around using the digital tool were provided as needed, and the proportion of CHWs who needed such support was monitored. 

20 212 Data management and analysis
 21

# <sup>22</sup><sub>23</sub> 213 Sample size and sampling techniques

The target sample size for Ag-RDT testing was determined by feasibility considerations, with a target of delivering up to 6816 tests to symptomatic individuals plus direct contacts of confirmed cases. Based on data from the first pilot phase of e-ASCov, in which 30% of all individuals screened were eligible for testing based on symptoms, it was estimated that close to 20,000 individuals would need to be screened to achieve the testing target. Each CHW therefore aimed to screen 20-25 individuals during the study period. 

<sup>33</sup><sup>34</sup> 220 Data collection and sharing

Participants were given a unique number, which was used to identify the collected data. Demographic and clinical data, test results and images linked to these data were stored in e-ASCov and transmitted to the local RBC servers for integration into the national COVID-19 data system. The e-ASCov app included validation rules that prevented skipping of mandatory questions and therefore prevented missing data. 

All the information obtained in this study was kept and handled in accordance with applicable laws and/or regulations. Data were stored and archived to the RBC server in compliance with national data security guidelines per the Rwanda Information Security Authority,<sup>12</sup> with only authorized personnel processing the information. Data encryption and anonymization principles were applied to safeguard confidentiality. Any access to and use of the data was subjected to the approved data sharing agreements between different institutions that formed the study team. 

# Regulatory and ethical considerations Regulatory and ethical considerations

Ethical clearance to conduct this study was obtained from the Rwanda National Ethics Committee
 (RNEC) No.920/RNEC/2021. As this intervention was integrated into routine Ministry of Health

programming included in the CHWs' package of services, RBC secured a formal waiver of informed consent for community members to take part in the household-level COVID-19 testing through the RBC's CHWs. Thus, no additional informed consent forms were required from individuals. However, the CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation.

This study was conducted in accordance with the protocol and with consensus ethical principles derived from international guidelines, particularly the Declaration of Helsinki and Good Clinical Practice Guidelines: ICH GCP E6 (R2). Several measures were taken to minimize the risk of infection for CHWs or other members of the household during community-based testing, including previously described training and provision of PPE to CHWs. In addition, CHWs were trained on how to assess the households of individuals who were eligible for testing, to determine whether an appropriate space was available (in terms of size, distance from other household members, and adequate ventilation). If the household did not contain such a space, testing was conducted outside of the house, in the household compound. 

An author reflexivity statement is provided in the supplementary methods.

# **Patient and public involvement**

Patients and the community were involved in the pilot, with the experience and findings used to inform the design of this study.

# **RESULTS**

# 259 Number tested and screened

A total of 19,544 individuals were enrolled in the study and screened for signs and symptoms of COVID-19 (Table 1). Of these, 4575 (23.4%) had signs and symptoms suggestive of COVID-19 infection and were thus eligible for testing with Ag-RDTs (Table 1).

# 265 Table 1. Number of participants screened and tested

District	All screened	Number with symptoms (eligible for testing)	h Percentage screened eligible for testing	Negative	Positive	Invalid	Positivity rate (%)
Gasabo	1,708	598	35.0	558	14	26	2.3
Huye	1,625	435	26.8	414	4	17	0.9
Kirehe	3,009	787	26.2	717	8	62	1
Musanze	2,549	563	22.1	513	13	37	2.3

Page	1	l of	37
------	---	------	----

Total	19,544	4,575	23.4	4,245	86	244	1.9
Rubavu	2,675	674	25.2	634	24	16	3.6
Rusizi	3,254	359	11.0	345	1	13	0.3
Nyarugenge	2,226	694	31.2	621	21	52	3
Nyagatare	2,498	465	18.6	443	1	21	0.2

> The proportion of those screened who reported symptoms of COVID-19 was highest in urban areas, with the highest rates observed around the capital city, Kigali, in Gasabo (35.0%) and Nyarugenge (31.2%) (Table 1).

> The overall positivity rate in the study was 1.9%, and by district, was highest in the border district of Rubavu (3.6%) and Nyarungenge district (3.0%), which forms part of the capital city. A total of 244 tests, representing 5.3% of all tests conducted, were automatically flagged by e-ASCov as "Invalid: Control Failed", as over 20 minutes elapsed with no result being entered in the application. The test was repeated for individuals with invalid results. There were no missing data (Table1).

### **Contribution to case-finding in districts**

During the study period, a total of 378 COVID-19 cases were diagnosed in the eight districts. Of these, 86 were diagnosed through the study intervention, with CHWs thus accounting for 22.8% of all diagnosed COVID-19 cases during the study period (Supplementary Table). 

### **Concordance of results between CHW and laboratory technician**

A total of 499 participants were tested for COVID-19 using Ag-RDT by CHWs and laboratory professionals for the concordance evaluation. Of these, three positive cases and 496 negative cases were identified by both CHWs and laboratory professionals. All the Ag-RDT results obtained by CHWs were confirmed by professional laboratory technicians, with a perfect agreement of 100% between results from the CHWs and the laboratory technicians (Cohen's kappa of 1.0) (Table 2).

### Table 2. Concordance of COVID-19 testing between community health workers and laboratory technicians

	Re-testing by laboratory technicians		
Testing by community health worker	Positive	Negative	
Positive	3	0	
Negative*	0	496	
Invalid	0	0	

Total	3	496
Observed agreement (%)	100%	
Expected agreement (%)	98.78%	
Cohen's kappa	1.0	
NRL, National Reference Laboratory.		
Feasibility		
Overall, 746 out of 800 CHWs (93.3%) we without support from supervisors. This administering nasal swabs for the Ag-RDTs at to the national RBC server. The remaining put to implement one or more of the above steps.	re able to independe included screening nd conducting the test roportion (6.7%) of C	ntly conduct all study procedures using the e-ASCov application , reporting results and sending data HWs required substantive suppor
Qualitative assessment: Satisfaction,	usability and acc	eptability
Respondent profiles		
A total of 349 CHWs participated in qualitation of these participants was 44 years with a range education and 44.1% had completed secon education, while 9.5% had undergone vocation	ve assessments of the of 20–72 years. Of the dary education. Only nal training.	e testing experience. The mean age bese, 42.1% had completed primary 4.3% had received a university
CHW perceptions of e-ASCov		
Respondents were asked a number of question with findings summarized in Supplementary experience, with main areas identified for imp	ns related to their exp Table 2. The majority provement including:	eriences with using the digital tool reported positive feedback of the
<ul> <li>Duration of training: 28.7% of participants while 16.3% believed that it was not suffi</li> <li>Access to internet: close to half (48.7% internet access during the study.</li> <li>Time taken to enter data: one in five resplong, while 1 in 3 did not believe that it w</li> </ul>	believed the length of cient to cover all the s ) of participants repo- ondents stated that th as short enough.	Etraining was only partly sufficient kills they needed to learn. rted only partial satisfaction with e time required for data entry was
Despite these challenges, all respondents exp recommending that it should be scaled up to c	ressed the need for for the	uture use of e-ASCov, with 99.7%
CHW perceptions of CHW-led Ag-RD	T testing	

BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de l Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies

A small proportion of respondents (0.9%) expressed challenges with administering tests, although the majority (89.6%) still believed this was easy and 9.5% indicated it was slightly easy. While only 57.8%

- a signify case. While only signify case.
   b and signify case.
   c and signify case.
   <li
- 6 319 84.8% found it easy to report results through e-ASCov (Supplementary Table 3).
- <sup>8</sup><sub>9</sub> 320

# 10 321 DISCUSSION

11 322 

This study successfully leveraged previous investments in a screen-and-refer model to enable CHWs to deliver near-patient, high-quality screening and testing for COVID-19 in Rwanda using Ag-RDTs and a mobile application. Although implementation took place during a period of low COVID-19 transmission in Rwanda, nearly a quarter of the 19,544 participants screened had signs and symptoms of COVID-19. Rates of COVID-19 were particularly high in the Kigali metropolis, where over 30% of screened individuals were identified as potential COVID-19 cases. This indicated a higher frequency of respiratory and other symptoms in urban areas, highlighting a need for expanded and more targeted COVID-19 case finding in communities. Overall, 1.9% of tested individuals were positive for SARS-CoV-2—a significant decline from the earlier screen-and-refer e-ASCov pilot where the positivity rate was 7.5% preceding scale-up of Rwanda's COVID-19 vaccination programme. 

The CHWs demonstrated an excellent capacity to perform the COVID-19 Ag-RDT. There was full concordance (100%) between the Ag-RDTs run by CHWs and those performed by laboratory professionals, which demonstrates that trained CHWs are capable of delivering Ag-RDTs with comparable quality to laboratory personnel, making the case for task-shifting of rapid diagnostic testing to the lowest levels of care providers. While PCR testing is known to be more sensitive than antigen-based rapid testing, Ag-RDTs still have a valuable role to play in detecting cases especially in resource-limited settings.13 

Wide variations were observed in the Ag-RDT positivity rate in the study, with the highest rate found in Rubavu, a district at the border with the Democratic Republic of Congo. Across multiple disease areas, cross-border mobility has often been associated with increased spread of disease.<sup>14, 15</sup> While this prompted widespread restrictions on international movement, especially in the earlier stages of the pandemic response, there is a lack of conclusive evidence on the effect of these restrictions on the incidence of COVID-19.<sup>16</sup> Nevertheless, our study highlights the role of enhanced testing to better identify high transmission areas and evaluate what measures can most effectively reduce disease transmission. Expanding access to testing through CHW-led diagnosis, as was conducted in this study, is one such way to intensify testing, particularly in environments where there is a higher risk of transmission such as densely populated urban settings and border districts. 

The urban districts, Nyarugenge and Gasabo, also reported high COVID-19 positivity rates of 3.0% and 2.3%, respectively, at the time when the national positivity rate was below 1%. Community-based testing methods supported by digital tools, as deployed in this study, could be a useful approach for earlier identification of high-transmission areas such as these, by facilitating near-patient access to testing. Disaggregated data on vaccination status and previous infection per district were not collected 

BMJ Open: first published as 10.1136/bmjopen-2023-083410 on 1 October 2024. Downloaded from http://bmjopen.bmj.com/ on June 11, 2025 at Agence Bibliographique de Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

# BMJ Open

- by this study; these would be useful in interpreting the symptoms and positivity rates seen in the
   different districts. Towards the and of the study, there was a reduction in COVID 10 insidence and
- different districts. Towards the end of the study, there was a reduction in COVID-19 incidence and
   people with COVID-19 symptoms, which was also observed nationwide in both urban and rural areas.

During the study, the testing conducted by CHWs accounted for 22.8% of all cases identified in the study districts, although only 5% of the overall CHWs in the study districts were involved in the study. The disproportionately high contribution of CHWs to identifying COVID-19 cases illustrates the significant potential of this cadre of health workers to expand case finding for COVID-19 and other diseases if engaged at a larger scale. 

- The use of a digital tool played an important role enabling CHWs to carry out COVID-19 testing in
   the community, by providing decision support and facilitating data entry. The FGDs with CHWs
   provided insights into this experience.
- <sup>19</sup> 366 *"Was understandable and didn't take much time, the way that tools were made makes everything easy,*<sup>21</sup> 367 *so we were 100% confident." A* FGD participant.

While some CHWs interviewed in the FGDs acknowledged that they initially faced difficulties with using the digital tool and indicated the need for a longer period of training, most were comfortable with the tool by the end of the study. The training was delivered in most study sites within two days, but the speed of learning differed across the sites and between participants. Across CHWs, training first-time users of smartphones on how to navigate the telephone took the longest time. 

- It was observed that younger CHWs were the fastest learners due to strong digital literacy, while CHWs
   With more advanced age (60 years and above) faced more challenges and required closer support from
   the facilitators and supervisors.<sup>17</sup>
- 35
   36 376 "At first time the phones were going to be hard for us. Saving the information obtained from the people
   37 377 failed to work completely. They helped us and showed it to us how to proceed. We continued to try and
   38 378 end up by becoming familiar with the system. I am 90% confident." An FGD respondent.

In addition to expanding access to testing, the process used in this study – Ag-RDTs combined with a digital tool – strengthened surveillance systems, and decongested health facilities and laboratories in study areas. The ability of CHWs to report directly to the national database, using unique patient codes, which were part of Rwanda's testing architecture since the start of the pandemic, greatly enhanced the benefit of this intervention. Together the findings demonstrate the value of investing in strong digital health systems that can easily be built on to improve services. 

General Stress St

55
 56 389 "This method of COVID testing I found is not a difficult thing, because otherwise we as CHW usually
 57 390 do malaria treatment...although performing malaria test and COVID-19 tests seems to be different, it

### **BMJ** Open

- is not difficult...If you know that you're going to help a patient who comes to you to get better life,
   that's something I found possible and we do, it's not too difficult." A FGD CHW respondent.
- <sup>5</sup>
  <sup>6</sup> 393 "I suggest to introduce the diseases that we are normally treating in the [e-ASCov] system...it will be
  <sup>7</sup> 394 helpful and delivering information will be so quick." A FGD CHW respondent.

In other settings, the use of digital tools in community-based testing has demonstrated several benefits, including improving the assessment of disease risk based on embedded algorithms to guide appropriate triage of patients<sup>18</sup> and improve diagnostic accuracy.<sup>19</sup> The COVID-19 pandemic response also led to an unprecedented surge in the use of digital solutions to support healthcare delivery and decision-making.<sup>7, 20</sup> However, the proliferation of different tools can increase fragmentation of the digital health architecture and contribute to misalignment between data systems,<sup>21</sup> limiting full visibility into patient data across different disease areas.<sup>22</sup> Hence, it is important to consider the fit and interoperability of digital tools within the existing digital health architecture before implementing new approaches. 

Inclusion of other diseases into e-ASCov to accelerate community-based testing would help to avoid the fragmentation of the digital health architecture and enable more efficient use of resources by facilitating the diagnosis of other diseases. Increasing the ease of differential diagnosis is particularly important, given that over one in five patients in this study had illness-related symptoms that were not diagnosed as COVID-19. Such people could benefit from point-of-care testing for other diseases that may be causing symptoms similar to COVID-19, particularly febrile and respiratory illnesses. Based on the findings of this study, and the national plan to digitize the CHWs services, we are jointly developing a robust integrated community health information system that will also incorporate the contents of e-ASCov. We intend to evaluate the effectiveness and impact of the planned integrated system once developed, particularly on conditions with overlapping clinical presentations such as TB, pneumonia, COVID-19 and malaria. Demonstrating the value of an integrated community health system in Rwanda can set a precedent for other nations in Africa and in other regions to implement similar systems. 

Limitations of the study include that it did not evaluate the cost-effectiveness of the evaluation, as its primary objective was to investigate if non-conventional medical staff can perform Ag-RDT testing for COVID-19, to bring testing closer to the community. Future studies would be valuable to assess the cost-effectiveness of the intervention. Although the study provides a general demonstration of the value of using CHWs to deliver community-based testing, the specifics of the intervention (e.g. the number of CHWs, training required) would need to be tailored to the specific setting if rolled out more broadly. 

Point-of-care diagnostics, such as Ag-RDTs, are also critical to expand access to testing and have been successfully applied as part of testing approaches for other diseases, including HIV. Evidence from systematic reviews of HIV point-of-care testing by non-laboratory workers and lay workers have demonstrated the value of point-of-care diagnostics in expanding access to health services,<sup>23, 24</sup> reducing diagnosis delays, allowing timely treatment initiation, and facilitating linkage to care.<sup>25</sup> 

429 Beyond its immediate benefits for detecting diseases like COVID-19, improved community
 430 surveillance could also be used to predict and potentially swart enidemic outbreaks in the future

- $\frac{3}{4}$  430 surveillance could also be used to predict and potentially avert epidemic outbreaks in the future. For
- 431 example, in India's early COVID-19 response, regular analysis of syndromic data deepened the
   432 precision of hotspot predictions.<sup>26</sup> Establishing systems for routine collection of such data could thus
- <sup>7</sup> 433 be beneficial for overall pandemic preparedness.

In summary, this study demonstrated the value of a digital tool combined with Ag-RDT testing to support household-level SARS-CoV-2 detection and contact tracing by CHWs in Rwanda. The study fed into Rwanda's vision for decentralizing COVID-19 services and healthcare more broadly. It also provides evidence to support the inclusion of COVID-19 rapid testing within the portfolio of diagnostic services that are already provided by CHWs in the country. The operational model – namely, point-of-care tests by CHWs, supported by digital tools for real-time clinical guidance, process management and data capture and transmission - could be scaled up nationally to enable greater access to decentralized testing for COVID-19 and other diseases across the rest of the country. Together, the findings indicate an opportunity to roll out digitally supported rapid testing for COVID-19 and other diseases to support healthcare service delivery closer to the community and evidence-based decision-making. Although this study was conducted during the COVID-19 pandemic, when Rwanda needed urgent solutions to maximize early detection and control of the disease and COVID-19 is currently endemic,<sup>27</sup> the lessons from this study can also be adapted for early warning of outbreaks and surveillance of other diseases. As an example, the digital approaches used in this study have subsequently been applied in the development of a national community health information system, by designing digital symptom screening and decision support integrated across the full package of services by delivered CHWs. This system has been piloted in Rwanda since 2023. 

1 2 3	451	
4 5	452	ACKNOWLEDGEMENTS
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	453 454 455 456 457 458 459 460 461 462	The authors would like to thank the community health workers who participated in the intervention as well as the district teams, Rwanda National Referral Laboratory, community health workers who supported the field data collection, local leaders, community members, and heads of health facilities. RBC, Ministry of Health and FIND for their support. The authors would also like to thank Dimagi for the support with the technical documentation and integration of the Ag-RDT-Toolkit, and the e- ASCov project group who conducted the preceding pilot in four districts with financial support from the French National Agency for Research on AIDS and Emerging Infectious Diseases (ANRS COV17). Medical writing support was provided by Talya Underwood, Principal Writer, of Anthos Communications Ltd, according to Good Publication Practice guidelines.
21 22	463	DATA AVAILABILITY STATEMENT
23 24 25	464	Data are available on reasonable request addressed to Rwanda Ministry of Health.
25 26 27	465	
28 29 30	466	ETHICS STATEMENTS
31 32	467	Patient consent for publication
33 34	468	Not applicable.
35 36	469	
37 38 39	470	COMPETING INTERESTS
40 41 42	471 472	The authors J.B.M, O.A, K.S, P.A and R.K disclose that they are employed by FIND. The other authors declare that no conflicts of interest exist.
43 44	473	
45 46 47	474	FUNDING
48 49 50 51 52 53 54 55 56 57 58	475 476 477 478 479 480 481	The study was funded by FIND, United Kingdom (FCDO 40105983), Switzerland (81066910), Netherlands (SDD 4000004160), Canada (DFATD 7429348), The Kingdom of Saudi Arabia (FIND – ACT-A DX PARTNERSHIP 20.08.2020), The Rockefeller Foundation (2020 HTH 059), Germany (BMZ Covid-19 Diagnostic and Surveillance Response 27.07.2021), Australia (DFAT 76442), Kuwait (M239/2020), and The Government of Portugal and Partners (ANF, BCP, CGF, APIFARMA). Medical writing support was funded by FIND, according to Good Publication Practice guidelines.
59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 16

### 

### **AUTHOR CONTRIBUTIONS**

The guarantor, Ladislas Nshimiyimana, accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. 

Conceptualization: LN, NB, PA, RK, OA, JB, JPR, MS; Data curation: NB, HM, JM, PA, OA, MS; 

Formal Analysis: NB, PA, HM, GR; Funding Acquisition: RK; Investigation: LN, JB, PA, JCSN, 

RR, HM, GR, BM; Methodology: PA, LN, MS; Project Administration: LN; Resources: LN, JB, PA,

JCSN, CMM, NB; Software: JM, OA, GR, HM, MS; Supervision: LN, JB, PA, KS; Validation: PA; Visualization: LN; Writing – Original Draft Preparation: LN, PA; Writing – Review & Editing: All 

authors.

# **BMJ** Open

ES	
Biomedical Centre. Coronavirus Disease COVID-19 [Available from:	9
<u>c.gov.rw/index.php?id=727</u> accessed 25 May 2022.	
Biomedical Centre. COVID-19 updates, 25 May 2022 2022 [14 November 2023]	3].
from: https://rbc.gov.rw/index.php?id=727).	2
alth Organization. National surveys of costs faced by tuberculosis patients and	their -
ls 2015-2021 2023 [Available from:	rot
www.ho_int/publications/i/item/9789240065536 accessed 17 October 2023	ecte
AKS Aijsola M Azeem K et al Impact of the societal response to COVID-19	on 5
healthcare for non COVID 10 health issues in slum communities of Banglades	
incartine and Paleiston; results of pro COVID and COVID 10 lookdown stakehold	
igeria and Pakistan: results of pre-COVID and COVID-19 lockdown stakehold	er rig
mts. <i>BMJ Global Health</i> 2020;5(8):e003042. doi: 10.1136/bmjgh-2020-003042	, ,t, , ii
of Rwanda Ministry of Health. National tuberculosis and other respiratory	าดไม
cable diseases program: Annual report 2020-2021 2023 [Available from:	Idin
w.ccm.rw/fileadmin/user_upload/Annual%20report%20TB%20%20ORD%20	<u>)2020</u> <sup>g</sup> f
.pdf accessed 17 October 2023.	r بر ۳
u C. WHO Hub for Pandemic and Epidemic Intelligence [Available from:	Ses
n.who.int/media/docs/default-source/blue-print/07_chikwe-ihekwazu_day-	rela
tif_24-25feb2022.pdf?sfvrsn=5aacbcdf_7 accessed 8 June 2023.	ited
, Msolomba V, Venter F, et al. Monitored Implementation of COVID-19 Rapid	i to t
creening at Taxi Ranks in Johannesburg, South Africa. Diagnostics (Basel)	ext
2) doi: 10.3390/diagnostics12020402 [published Online First: 2022/02/26]	and
Biomedical Centre. Use of digital tools by community health workers in the	l da
ent of Covid-19 pandemic in Rwanda: Action Research (eASCov Project)	(AB r
e from: https://rbc.gov.rw/rnhrr/article?code=103]/accessed 20 June 2024.	linir
TIND – Digital Solution for COVID-19 RDTs 2021 [Available from:	
ww.dimagi.com/blog/find-covid-19-rdt-solution/ accessed 17 October 2023	A tr'
re COVID-19 Template App: COVID-19 RDT Tracking [Available from:	aini
afluence dimagi com/display/commearenublic/COVID-	ng,
late+App%3A+COVID-	anc
-Tracking? ga=2 242044000 300057840 1607005310 828340103 1607005300	l sir
17 October 2022	nila
17 October 2025. A Haalth Byyanda, COVID 10 Clinical Management Chidalings, 2rd Edition	r tec
n 2021 - d. 2021	chn
1 2021  cu, 2021.	οΙοί
ent of Kwanda. Law N° 058/2021 OF $13/10/2021$ Relating to the Protection of	yies
Data and Privacy_[Available from:	·
per.gov.rw/index.php?eID=dumpFile&t=f&t=229&token=742569646abebc43c	<u>11ad8</u>
<u>2f4f11f9639</u> accessed 22 June 2024.	
user I, Knies K, Hofmann D, Rauschenberger V, et al. Virus variant-specific cli	inical
nce of SARS coronavirus two rapid antigen tests in point-of-care use, from	,
	-
	-
	18
For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

▥

1 2 3	494	REFERENCES
4 5	495	1. Rwanda Biomedical Centre. Coronavirus Disease COVID-19 [Available from:
6	496	https://rbc.gov.rw/index.php?id=727 accessed 25 May 2022.
7	497	2. Rwanda Biomedical Centre. COVID-19 updates, 25 May 2022 2022 [14 November 2
8 0	498	Available from: https://rbc.gov.rw/index.php?id=727).
10	499	3. World Health Organization. National surveys of costs faced by tuberculosis patients a
11	500	households 2015-2021 2023 [Available from:
12	501	https://www.who.int/publications/i/item/9789240065536 accessed 17 October 2023
13 14	502	4. Ahmed SAKS, Ajisola M, Azeem K, et al. Impact of the societal response to COVID-
15	503	access to healthcare for non-COVID-19 health issues in slum communities of Banglad
16	504	Kenya, Nigeria and Pakistan: results of pre-COVID and COVID-19 lockdown stakeho
17	505	engagements. BMJ Global Health 2020;5(8):e003042. doi: 10.1136/bmjgh-2020-0030
19	506	5. Republic of Rwanda Ministry of Health. National tuberculosis and other respiratory
20	507	communicable diseases program: Annual report 2020-2021 2023 [Available from:
21	508	https://www.ccm.rw/fileadmin/user_upload/Annual%20report%20TB%20%20ORD%
23	509	%202021.pdf accessed 17 October 2023.
24	510	6. Ihekweazu C. WHO Hub for Pandemic and Epidemic Intelligence [Available from:
25 26	511	https://cdn.who.int/media/docs/default-source/blue-print/07 chikwe-ihekwazu day-
27	512	1 who grif 24-25feb2022.pdf?sfvrsn=5aacbcdf 7 accessed 8 June 2023.
28	513	7. Majam M, Msolomba V, Venter F, et al. Monitored Implementation of COVID-19 Ra
29 30	514	Antigen Screening at Taxi Ranks in Johannesburg, South Africa. <i>Diagnostics (Basel)</i>
31	515	2022;12(2) doi: 10.3390/diagnostics12020402 [published Online First: 2022/02/26]
32	516	8. Rwanda Biomedical Centre. Use of digital tools by community health workers in the
33 34	517	management of Covid-19 pandemic in Rwanda: Action Research (eASCov Project)
35	518	[Available from: https://rbc.gov.rw/rnhrr/article?code=103]/accessed 20 June 2024.
36	519	9. Dimagi. FIND – Digital Solution for COVID-19 RDTs 2021 [Available from:
37 38	520	https://www.dimagi.com/blog/find-covid-19-rdt-solution/ accessed 17 October 2023.
39	521	10. CommCare. COVID-19 Template App: COVID-19 RDT Tracking [Available from:
40	522	https://confluence.dimagi.com/display/commcarepublic/COVID-
41 42	523	19+Template+App%3A+COVID-
43	524	19+RDT+Tracking? ga=2.242944000.300957840.1697095310-828340193.16970953
44	525	accessed 17 October 2023.
45 46	526	11. Ministry of Health Rwanda. COVID-19 Clinical Management Guidelines. 3rd Edition
40 47	527	September 2021 ed, 2021.
48	528	12. Government of Rwanda. Law Nº 058/2021 OF 13/10/2021 Relating to the Protection
49 50	529	Personal Data and Privacy [Available from:
50	530	https://cyber.gov.rw/index.php?eID=dumpFile&t=f&f=229&token=742569646abebc
52	531	1e3d3bee2f4f11f9639 accessed 22 June 2024.
53 54	532	13. Wagenhäuser I, Knies K, Hofmann D, Rauschenberger V, et al. Virus variant-specific
54 55	533	performance of SARS coronavirus two rapid antigen tests in point-of-care use, from
56		
57		
SQ		

1			
2	534		November 2020 to January 2022. Clin Microbiol Infect 2022;29(2)
3 ⊿	535		doi:10.1016/j.cmi.2022.08.006 [published Oline First: 2022/08/24]
4 5	536	14.	. Suk JE, Van Cangh T, Beauté J, et al. The interconnected and cross-border nature of risks
6	537		posed by infectious diseases. Glob Health Action. 2014;7:25287. doi: 10.3402/gha.v7.25287.
7	538	15.	Ehrlich R, Montgomery A, Akugizibwe P, et al. Public health implications of changing
8	539		patterns of recruitment into the South African mining industry, 1973-2012; a database
9 10	540		analysis <i>BMC Public Health</i> 2017;18(1):93 doi: 10.1186/s12889-017-4640-x [published
11	541		Online First: 2017/08/05]
12	542	16	Emeto TL Alele FO Ilesanmi OS Evaluation of the effect of border closure on COVID-19
13 14	5/3	10.	incidence rates across nine A frican countries: an interrupted time series study. Transactions of
15	544		The Poyal Society of Tropical Medicine and Hygiane 2021:115(10):1174-82 doi:
16	544		10 1002/trotmb/trob022
17	545	17	10.1095/usunil/uado55
18 10	546	1/.	van Deursen AJ. Digital Inequality During a Pandemic: Quantitative Study of Differences in
20	547		COVID-19-Related Internet Uses and Outcomes Among the General Population. J Med
21	548		Internet Res. 22(8):e20073. doi: 10.2196/20073. [published Online First: 2020/08/20]
22	549	18.	. Roy T, Marcil L, Chowdhury RH, et al. The BRAC Manoshi Approach 2011 [Available
23 24	550		from: https://brac.net/sites/default/files/portals/Manoshi-book-v3-1.pdf accessed 8 June 2023.
24	551	19.	. Laktabai J, Platt A, Menya D, et al. A mobile health technology platform for quality
26	552		assurance and quality improvement of malaria diagnosis by community health workers. PLoS
27	553		One 2018;13(2):e0191968. doi: 10.1371/journal.pone.0191968 [published Online First:
28 29	554		2018/02/02]
30	555	20.	Karanja S, Aduda J, Thuo R, et al. Utilization of digital tools to enhance COVID-19 and
31	556		tuberculosis testing and linkage to care: A cross-sectional evaluation study among Bodaboda
32	557		motorbike riders in the Nairobi Metropolis Kenya PLOS ONE 2023:18(9):e0290575 doi:
33 34	558		10 1371/journal pone 0290575
35	559	21	Atun R de Jongh T Secci F et al Integration of targeted health interventions into health
36	560	<u> </u>	systems: a concentual framework for analysis <i>Health Policy Plan</i> 2010:25(2):104-11 doi:
37	561		10 1003/heanol/czn055 [nubliched Online First: 2000/11/18]
30 39	562	$\mathbf{r}$	Muinga N. Magara S. Monda L et al. Digital health Systems in Kanyan Dublia Hagnitals: a
40	502	LL.	. Multiga N, Magare S, Monda J, et al. Digital fleatin Systems in Kenyan Public Hospitals. a
41	303 5(4		mixed-methods survey. BMC Mea Inform Decis Mak 2020;20(1):2. doi: 10.1180/s12911-019-
42 43	564	<b>a</b> a	1005-7 [published Online First: 2020/01/08]
44	565	23.	. Vojnov L, Taegtmeyer M, Boeke C, et al. Performance of non-laboratory staff for diagnostic
45	566		testing and specimen collection in HIV programs: A systematic review and meta-analysis.
46	567		<i>PLOS ONE</i> 2019;14(5):e0216277. doi: 10.1371/journal.pone.0216277
47 48	568	24.	Kennedy CE, Yeh PT, Johnson C, et al. Should trained lay providers perform HIV testing? A
49	569		systematic review to inform World Health Organization guidelines. AIDS Care
50	570		2017;29(12):1473-79. doi: 10.1080/09540121.2017.1317710 [published Online First:
51	571		2017/04/25]
52 53	572	25.	Pham MD, Agius PA, Romero L, et al. Acceptability and feasibility of point-of-care CD4
54	573		testing on HIV continuum of care in low and middle income countries: a systematic review.
55	574		BMC Health Services Research 2016;16(1):343. doi: 10.1186/s12913-016-1588-y
56			
57 58			
59			10
60			For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

1 2 3	575 576	26. FIND. Use of digital tools and data science to strengthen COVID-19 management: India case study 2021 [Available from: <u>https://www.finddx.org/wp-</u>
5	577	content/uploads/2023/05/20210501_digital_health_report_india_FV_EN.pdf accessed 18
6 7	578 570	October 2023.
8	579 580	2022; 6. doi: 10.29328/journal.ijcv.1001049 [published Online First: 2022/11/07]
10		
11 12		
13 14		
15 16		
17		
10		
20 21		
22 23		
24 25		
26 27		
28		
29 30		
31 32		
33 34		
35 36		
37		
39		
40 41		
42 43		
44 45		
46 47		
48		
49 50		
51 52		
53 54		
55 56		
57		
58 59		For poor roviow only http://bmionon.hmi.com/sita/about/swidelines.yhtml 20
60		For peer review only - http://binjopen.binj.com/site/about/guidelines.xhtml









# 1 SUPPLEMENTAL MATERIAL

# 2 Supplementary methods

4 Focus group discussions (FGDs) at the study site: community health workers (CHWs)

5 N=64; 2 FGDs per each of the four selected districts, 8 participants per each FGD.

# Experiences on the use of the e-ASCov application for screening and testing COVID-19 using RDTs by CHWs (perception and satisfaction of CHWs on their role).

8 English: Thank you for agreeing to participate today and give your informed consent. I would like to 9 ask you about your experiences on the use of the e-ASCov application and testing COVID-19 by 10 Community Health Workers using RDTs. All your answers will remain confidential and you do not 11 have to answer to questions that you do not want. There is no right or wrong answer to these questions. 12 Please feel free to ask questions anytime during the interview and we can stop at any time. Thank you 13 again for your participation

Kinyarwanda : Murakoze kwemera kwitabira iki kiganiro uyu munsi no kwemera kugira uruhare muri ubu bushakashatsi nyuma yo gusobanurirwa. Nifuzaga kubabaza kubijyanye n ' u b u **mufite** y i kw'i ko**r**ye's **i**h kwoar a muagutfana hamakuurg nao gupima COVID-19 bikozwen' a b a j y a n a m a b' u b u z i **Ibisubizo** rbyanyu bigirwa ibanga kandi mufite uburenganzira bwo guhitamo kudasubiza bimwe mu bibazo mubazwa igihe mwumva bibabangamiye. Nta gisubizo kiri cyo cyangwa se gipfuye. Mwisanzure mubaze ikibazo cyose mwagira mugihe turi kuganira, kandi dushobora guhagarika iki kiganiro igihe icyo aricyo cyose mubyifuje. Murakoze cyane nanone kwitabira iki kiganiro. 

**Note:** *Record the District of residence, age, sex, level of education, and occupation for each participant* 

**SECTION A: USE OF E-ASCOV** 

Knowledge of the e-ASCOV application /Ubumenyi rusange ku ikoranabunga rya e-ASCOV mu gufata amakuru no guhangana n'icyorezo cya COVID-19

**1.** What do you think in general on the use of digital tool (e-ASCOV application) by CHWs for COVID-19 response?

Muri rusange mwadusngiza icyo mutekekereza ku ikoreshwas ryikoranabuhanga n'abaj yanama bubuzi ma mu g-19 Rangana n'i

2. What expectations do you or did you have regarding e-ASCOV app?

	Ni iki mwari mwiteze cyangwa se nubu mucyiteze ku ikoreshwa ry'u bu b <b>e-A</b> ts?
3.	How confident are you with the use of e-ASCOV app by CHWs?
	Mwumva mwifitiye icyizere kingana iki (Ku ruhe rugero) kw'i ko meza shiwa r koranabunga e ASCOV?
Pe	rceived benefits, barriers and facilitators e-ASCOV
Ing	yungu , inzitizi n'ibishyigikira
4. N	Can you describe the positive (perceived benefits) of e-ASCOV app? (Probe: contribution of ASCOV app in COVID-19 prevention and control) Autorikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mwabonye mu gukoreshu bu buryo bwa e-ASCOV? (Aba ndashaka kuyuga icyo ubu buryo bwaba bwarafashije mu
k	wirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19 ?
5. •	What do you think are the negative experiences with e-ASCOV app? Ni iki mwumva cyangwa se mubona kitagenze neza mugihe mwakoreshaga ubu bury bwa e-ASCOV?
<b>6.</b>	What are the factors hindering (barriers) the use of e-ASCOV app? Mukurikije uko mubyumva, ni izihe mbogamizi mubona ku ikoreshwa r y ' <b>b</b> u <b>b</b> yubwa ASCOV ?
7. N r	Wat are the factors facilitating (enablers) the use of e-ASCOV app? Iukurikije uko mubyumva, ni iki mubona cyaba gifasha cyane cyangwa cyoroshya ikoreshy y'ubu buryo bwa e ASCOV ?
Sa	tisfaction vis-à-vis the use of e-ASCOV app
Ku	inyurwa n'imikoreshereze y'ikoranabuhanga e-ASCOV
8.	What do you think about the use e-ASCOV app in the future? Do you have any suggestion improvement?
•	Mu t e k e r e z a i k i k u i k -oAfSGOV huugihe kiri iymbene bhari ichyou mutekereza cyakogerwaho cyangwa cyakurwaho kuri ubu buryo bwa e-ASCOV kugirango burusheho gukora neza?
SE	CTION B: TESTING COVID-19 DONE BY CHWS
Ge n':	neral perception on COVID-19 testing by CHWs /Gusuzuma COVID-19 bikozwe abajyanama b'ubuzima
9.	How do you see in general the testing of COVID-19 done by CHWs?
9.	How do you see in general the testing of COVID-19 done by CHWs?

	Muri rusange mubona mute uburyo bwo gusuzuma COVID-19 bikozwe n 'a b a j y b 'u b u z i m a ?
10	• What expectations do you or did you have regarding testing COVID-19 by CHWs?
	Ni iki mwari mwiteze cyangwa se nubu mucyiteze ku gusuzuma COVID-19 bikozwe n'abaj yanama b'ubuzi ma?
11	• How confident are you with COVID-19 testing done by CHWs?
	Mwumva mwifitiye icyizere kingana iki (kuruhe rugero) ku gupima COVID-19 bikozwe n'abaj yanama b'ubuzi ma?
Pe	rceived benefits, barriers and facilitators e-ASCOV
1.	Inyungu , inzitizi n'ibishyigikira
12	Can you describe the positive (perceived benefits) of testing COVID-19 by CHWs? (Pr contribution of COVID-19 testing by CHWs to COVID-19 prevention, control, and management)
•	Mukurikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mubona mu gusuzum COVID-19 bikozwe n' a b a j by 'a un la um (alianmadashaka kuvuga icyo ubu buryo bwa bwarafashije mu kwirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19 n' a k a m a r o b i f i t i y e a b a t u r a R w a n d a )
13. •	What do you think are the negative experiences with testing COVID-19 by CHWs? Mukurikije uko mubyumva ni iki mubona kitagenze neza mu gusuzuma COVID-19 bikozv n ' a b a j y a n a m a b ' u b u z i m a ?
14	• What are the factors hindering (barriers) the testing COVID-19 by CHWs?
•	Mukurikije uko mubyumva, ni izihe mbogamizi mubona mu gusuzuma COVID-19 bikozw n'abaj yanama b'ubuzi ma?
15	• Wat are the factors facilitating (enablers) the testing COVID-19 by CHWs?
•	Mukurikije uko mubyumva, ni iki mubona cyaba gifasha cyane cyangwa cyoroshya gusuzu COVID-19 bi kozwe n'abajyanama b'ubuzima
16	• What do you think about the testing of COVID-19 by CHWs in the future? Do you have a suggestions for improvement?
•	Mutekereza iki ku gupima COVID-19 bi kozwe n'abajyana l hari icyo mutekereza cyakogerwaho cyangwa cyakurwaho mu buryo bwo gupima COVID- bi kozwe n'abalgugir <b>a</b> nggo burushehoug bkoraz niezan? a
	END OF THE
IN	TERVIEW

# 25 Author reflexivity statement

This study was conceptualized, designed and led in collaboration with Rwanda Biomedical Centre and R w a n dManistry of Health. Members of Rwanda Biomedical Centre and the Ministry of Health who led this work are included as authors. The position of first author reflects the contribution of Ladislas Nshimiyimana, NTD Research Senior Officer at Rwanda Biomedical Centre, to the work.

The study addresses local research and policy priorities in Rwanda. R w a n dhealth system has a
 vision for decentralized COVID-19 testing and there was interest in utilizing the c o u n strong CHW
 capacity to increase access to testing. This study aimed to realize these ambitions and the team designed
 an intervention that utilized the c o u n CHWyworkforce to deliver decentralized COVID-19 testing.

The study has contributed to improvements in local infrastructure, through the development and updating of a mobile application ( "AeS C o to enable community-based screening and testing for COVID-19. The project also trained CHWs on using the digital tool and rapid tests to detect COVID-19 at the household-level.

Safeguarding procedures were implemented to protect local study participants and researchers. Firstly, the screening and testing intervention was conducted as part of routine Ministry of Health programming included in the CHW package of services. Several measures were taken to minimize the risk of infection for CHWs and other members of the household during community-based testing, as described in the manuscript. All CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation. 

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# **Supplementary Tables and Figures**

### Supplementary Table 1. Overview of study districts

District	COVID-19 positivity rate (%)*	District population	Number of CHWs in district	Number of CHWs selected for the project (%)
Gasabo (urban)	2.0	530,907	1731	102 (6)
Nyarugenge (urban)	1.2	284,561	1135	100 (9)
Kirehe (Rural)	1.6	382,932	2587	99 (4)
Rusizi (Rural)	2.5	483,615	2298	99 (4)
Rubavu (Rural)	1.3	403,662	1990	100 (5)
Musanze (Rural)	5.9	368,267	1715	99 (6)
Nyagatare (Rural)	4.4	530,907	2531	100 (4)
Huye (Semi-urban)	8.3	328,398	2016	101 (5)
Total		3,313,249	16,003	800 (5)

\*Positivity rates as of September 2021, when the phase one commenced. 1, when the phase one commenced.

CHW, community health worker.

Characteristics		Number of respondents	%
Ease of using e-ASCov		respondentes	
	Easy	291	83.4
	Slightly easy	49	14
	Difficult	9	2.6
Training nackage	Difficult		2.0
Панны раскаде	Satisfied	315	90.2
	Satisfieu	515	90.2
	somenow	21	80
	Satisfied	2	0.9
	Not satisfied	2	0.6
Simplicity of e-ASCov application	F	207	05.1
	Easy	297	85.1
	Slightly easy	47	13.5
	Difficult	5	1.4
Duration of the training			
	Sufficient	192	55.0
	Somehow		
	sufficient	100	28.7
	Not sufficient	57	16.3
Equipment/supplies			
	Satisfied	315	90.2
	Somehow		
	satisfied	28	8.0
	Not satisfied	6	1.8
A googs to internet	Not satisfied	0	1.0
Access to internet	Good	171	40.0
	Courses and	1/1	49.0
	Somenow good	190	48.7
	Poor	8	2.3
Time used to enter client's data	<b>C1</b>		
	Short	161	46.1
	Somehow short	116	33.3
	Long	72	20.6
Getting support			
	Satisfied	295	84.5
	Somehow		
	satisfied	42	12.0
	Not satisfied	12	3.5
Service delivery through e-ASCov			
v G	Satisfied	325	93.1
	Somehow	-	
	satisfied	22	63
	Not satisfied	2	0.5
Need for future use of e-ASCov	1 of building	-	0.0
	Ves	340	100
Scale-up of a-ASCov to other disagges	100	JT7	100.
Scale-up of e-ASCOV to other useases	Voc	210	00.7
	I CS	34ð 1	99.7
	INO	1	0.3

# 50 Supplementary Table 2. Respondent perceptions of e-ASCov

Character istics		Frequency	%
Overall perception			
	Easy	313	89.
	Slightly easy	33	9.5
	Difficult	3	0.9
Training package			
	Satisfied	303	86.
	Somehow satisfied	40	11.
	Not satisfied	6	1.7
Duration of the training			
	Sufficient	202	57.
	Somehow sufficient	99	28.
	Not sufficient	48	13.
Equipment/Supplies			
	Satisfied	305	87.
	Somehow satisfied	36	10.
	Not satisfied	8	2.3
Reading results of Ag-RDT			
	Easy	326	93.
	Slightly easy	17	4.9
	Difficult	4	1.2
Entering results using e-ASCo	v app		
	Easy	296	84.
	Slightly easy	45	12.
	Difficult	8	2.3
Getting support			
	Satisfied	298	85.
	Somehow satisfied	40	11.

# 52 Supplementary Table 3. Respondent perceptions of CHW-led Ag-RDT testing

DISTRICT	All screened	Positive	Positivity rate (%)	Ag-RDT per district (%)	All reported positive cases	Contribution of CHWS (%) to confirmed cases
Gasabo	1,708	14	2.3	35.0	126	11.1
Huye	1,625	4	0.9	26.8	7	57.1
Kirehe	3,009	8	1	26.2	21	38.1
Musanze	2,549	13	2.3	22.1	18	72.2
Nyagatare	2,498	1	0.2	18.6	27	3.7
Nyarugenge	2,226	21	3	31.2	135	15.6
Rusizi	3,254		0.3	11.0	1	100
Rubavu	2,675	24	3.6	25.2	43	55.8
TOTAL	19,544	86	1.9	23.4	378	22.8



1

### Supplementary Figure 1. Interface of the e-ASCov application

Umujyanama w'ubuzima	Tangiza Ikizamini			
	SD STANDARD" Q COVID-19 Ag Test			
-ASC W	Ubwoko bw'isuzuma burakoreshwa SD STANDARD <sup>™</sup> Q COVID-19 Ag			
	i est Igihe cyo gubona ibisubizo			
no KODE vawe	15 Iminota Kasete			
	States 1			
	Erekana amabwiriza kuri iri suzuma rya RDT			
Injira	Gukomeza			
	0 0 0			


# Reporting checklist for quality improvement in health care.

Based on the SQUIRE guidelines.

# Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the SQUIREreporting guidelines, and cite them as:

Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for

QUality Improvement Reporting Excellence): revised publication guidelines from a detailed

consensus process

Reporting Item

Page

Number

Title

 #1
 Indicate that the manuscript concerns an initiative to improve
 1

 healthcare (broadly defined to include the quality, safety,
 1

 effectiveness, patientcenteredness, timeliness, cost, efficiency,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

		and equity of healthcare)	
Abstract			
	<u>#02a</u>	Provide adequate information to aid in searching and indexing	3
	<u>#02b</u>	Summarize all key information from various sections of the text	3
		using the abstract format of the intended publication or a	
		structured summary such as: background, local problem,	
		methods, interventions, results, conclusions	
Introduction			
Problem	<u>#3</u>	Nature and significance of the local problem	4
description			
Available	<u>#4</u>	Summary of what is currently known about the problem,	4-5
knowledge		including relevant previous studies	
Rationale	<u>#5</u>	Informal or formal frameworks, models, concepts, and / or	4-5
		theories used to explain the problem, any reasons or	
		assumptions that were used to develop the intervention(s), and	
		reasons why the intervention(s) was expected to work	
Specific aims	<u>#6</u>	Purpose of the project and of this report	5
Methods			
Context	<u>#7</u>	Contextual elements considered important at the outset of	6
		introducing the intervention(s)	
Intervention(s)	<u>#08a</u>	Description of the intervention(s) in sufficient detail that others	6-8
		could reproduce it	
	For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

1 2 3	Intervention(s)	<u>#08b</u>	Specifics of the team involved in the work	6, 9
4 5	Study of the	<u>#09a</u>	Approach chosen for assessing the impact of the	6, 8, 9
6 7 8	Intervention(s)		intervention(s)	
9 10 11	Study of the	<u>#09b</u>	Approach used to establish whether the observed outcomes	6, 8, 9
12 13 14	Intervention(s)		were due to the intervention(s)	
15 16	Measures	<u>#10a</u>	Measures chosen for studying processes and outcomes of the	8-9
17 18			intervention(s), including rationale for choosing them, their	
19 20 21 22			operational definitions, and their validity and reliability	
22 23 24	Measures	<u>#10b</u>	Description of the approach to the ongoing assessment of	8-9
25 26			contextual elements that contributed to the success, failure,	
27 28 29			efficiency, and cost	
30 31	Measures	<u>#10c</u>	Methods employed for assessing completeness and accuracy	10
32 33 34			of data	
35 36 37	Analysis	<u>#11a</u>	Qualitative and quantitative methods used to draw inferences	8-9
38 39 40			from the data	
41 42	Analysis	<u>#11b</u>	Methods for understanding variation within the data, including	8-9
43 44 45			the effects of time as a variable	
46 47	Ethical	<u>#12</u>	Ethical aspects of implementing and studying the	9
48 49 50	considerations		intervention(s) and how they were addressed, including, but not	
50 51 52			limited to, formal ethics review and potential conflict(s) of	
53 54			interest	
55 56 57	Results			
58 59		Forp	eer review only - http://hmionen.hmi.com/cite/about/guidelines.yhtml	
60		iuip	eer review only - http://binjopen.binj.com/site/about/guidelines.xittini	

1 2		<u>#13a</u>	Initial steps of the intervention(s) and their evolution over time	Figures 1
3 4			(e.g., time-line diagram, flow chart, or table), including	and 2
5 6 7			modifications made to the intervention during the project	
8 9 10		<u>#13b</u>	Details of the process measures and outcome	10-13
11 12 13		<u>#13c</u>	Contextual elements that interacted with the intervention(s)	12-13
14 15 16		<u>#13d</u>	Observed associations between outcomes, interventions, and	10-13
17 18 19			relevant contextual elements	
20 21		<u>#13e</u>	Unintended consequences such as unexpected benefits,	12-13
22 23 24			problems, failures, or costs associated with the intervention(s).	
25 26 27		<u>#13f</u>	Details about missing data	11
28 29 30	Discussion			
31 32 33	Summary	<u>#14a</u>	Key findings, including relevance to the rationale and specific	14
34 35 26			aims	
37 38 39	Summary	<u>#14b</u>	Particular strengths of the project	14-15
40 41 42	Interpretation	<u>#15a</u>	Nature of the association between the intervention(s) and the	13
43 44			outcomes	
45 46 47	Interpretation	<u>#15b</u>	Comparison of results with findings from other publications	13, 15
48 49 50	Interpretation	<u>#15c</u>	Impact of the project on people and systems	15-16
51 52 53	Interpretation	<u>#15d</u>	Reasons for any differences between observed and anticipated	15-16
54 55 56			outcomes, including the influence of context	
57 58	Interpretation	<u>#15e</u>	Costs and strategic trade-offs, including opportunity costs	15
59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

1 2 3	Limitations	<u>#16a</u>	Limits to the generalizability of the work	15
4 5	Limitations	<u>#16b</u>	Factors that might have limited internal validity such as	15
6 7 0			confounding, bias, or imprecision in the design, methods,	
8 9 10			measurement, or analysis	
11 12 13	Limitations	<u>#16c</u>	Efforts made to minimize and adjust for limitations	15
14 15 16	Conclusion	<u>#17a</u>	Usefulness of the work	15-16
17 18 19 20	Conclusion	<u>#17b</u>	Sustainability	15-16
20 21 22 23	Conclusion	<u>#17c</u>	Potential for spread to other contexts	15-16
24 25 26	Conclusion	<u>#17d</u>	Implications for practice and for further study in the field	15-16
27 28 29	Conclusion	<u>#17e</u>	Suggested next steps	15-16
30 31	Other			
32 33 34	information			
35 36 37	Funding	<u>#18</u>	Sources of funding that supported this work. Role, if any, of the	17
38 39			funding organization in the design, implementation,	
40 41 42			interpretation, and reporting	
43 44	None The SQUIR	E 2.0 cl	necklist is distributed under the terms of the Creative Commons At	tribution
45 46 47	License CC BY-N	C 4.0. 1	This checklist can be completed online using <u>https://www.goodrepo</u>	<u>orts.org/</u> , a
48 49 50	tool made by the <u>I</u>	EQUAT	OR Network in collaboration with Penelope.ai	
51 52 53				
54 55 56				
57 58				
59		Гаки	oor roviow only http://bmionon.hmi.com/cite/about/guidelines.yhtml	

# **BMJ Open**

### Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study

Journal:	BMJ Open
Manuscript ID	bmjopen-2023-083410.R2
Article Type:	Original research
Date Submitted by the Author:	26-Aug-2024
Complete List of Authors:	Nshimiyimana, Ladislas; Rwanda Biomedical Center, Bigirimana, Noella; Rwanda Biomedical Center Ngabonziza, JCS; Rwanda Biomedical Center; University of Rwanda Rwabihama, Jean-Paul ; Republic of Rwanda Ministry of Health Rutayisire, Robert; Rwanda Biomedical Center Semakula, Muhammed; Republic of Rwanda Ministry of Health RUKUNDO, Gilbert ; Rwanda Biomedical Center Mugabo, Hassan; Rwanda Biomedical Center, Research Innovation and Data science Mutabazi, Josue; Independent consultant Mukamana, Beatrice; Rwanda Biomedical Center Mazarati, Jean-Baptiste ; FIND Kadam, Rigveda; FIND Akinwusi, Olukunle; FIND Suleiman, Khairunisa; FIND Muvunyi, Claude; Rwanda Biomedical Center; University of Rwanda Akugizibwe, Paula; FIND
<b>Primary Subject Heading</b> :	Diagnostics
Secondary Subject Heading:	Diagnostics, Infectious diseases, Public health
Keywords:	COVID-19, Public health < INFECTIOUS DISEASES, Health Services





I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

reliez oni

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# Using digital tools and antigen rapid testing to support household-level SARS-CoV-2 detection by community health workers in Rwanda: an operational pilot study

- Ladislas Nshimiyimana<sup>1</sup>, Noella Bigirimana<sup>1</sup>, Jean-Claude S. Ngabonziza<sup>1,2</sup>, Jean-Paul
- Rwabihama<sup>3</sup>, Robert Rutayisire<sup>1</sup>, Muhammed Semakula<sup>3</sup>, Gilbert Rukundo<sup>1</sup>, Hassan Mugabo<sup>1</sup>,
- Josue Mutabazi<sup>4</sup>, Beatrice Mukamana<sup>1</sup>, Jean-Baptiste Mazarati<sup>5</sup>, Rigveda Kadam<sup>5</sup>, Olukunle

Akinwusi<sup>5</sup>, Khairunisa Suleiman<sup>5</sup>, Claude Mambo Muvunyi<sup>1,2</sup>, Paula Akugizibwe<sup>5</sup> 

- <sup>1</sup>Rwanda Biomedical Centre, Kigali, Rwanda
- <sup>2</sup>University of Rwanda, Kigali, Rwanda
- <sup>3</sup>Ministry of Health, Kigali, Rwanda
- <sup>4</sup>Independent consultant, Kigali, Rwanda
- <sup>5</sup> FIND, Geneva, Switzerland
- \* Correspondence:
- Corresponding author
- ladislas.nshimiyimana@rbc.gov.rw

- Word Count: 4951/5000
- c health Keywords: COVID-19, diagnostics and tools, public health

# $\frac{2}{3}$ 16 **ABSTRACT**

- <sup>4</sup><sub>5</sub> 17 **Objective**: To evaluate the use of antigen-based rapid diagnostic tests (Ag-RDTs) alongside a digital
  - 18 tool to deliver household-level COVID-19 testing by community health workers (CHWs), in line
- 7 19 with Rwanda's ambition to decentralize COVID-19 testing.
  - Design: This was an operational pilot study to evaluate the impact and operational characteristics of using the digital e-ASCov tool combined with Ag-RDTs to support COVID-19 symptom screening and rapid testing by CHWs across eight districts in Rwanda. A total of 800 CHWs selected from both rural and urban areas were trained in delivering Ag-RDTs for COVID-19 testing and using the e-ASCOV application for data capture on a smartphone. Laboratory technicians repeated a subset of Ag-RDTs to assess the concordance of results obtained by CHWs. The study also assessed CHWs experience of the intervention using a mixed methods approach.
- Setting: Eight rural, urban and semi-urban districts in Rwanda.
- 28 Participants: A total of 19,544 individuals were enrolled and screened for signs and symptoms of COVID-19.
- Interventions: Community-based screening for COVID-19 by CHWs using the digital tool e-ASCov
   combined with rapid testing using Ag-RDTs.
- 32 Main outcome measures: Number of participants screened and tested; concordance of Ag-RDT
   33 results between CHWs and laboratory technicians; feasibility of study procedures by CHWs; and CHWs perceptions of the digital tool and Ag-RDT testing.
- **Results:** From February to May 2022, CHWs screened 19,544 participants, of whom 4575 (23.4%) had COVID-19 related symptoms or history of exposure to the infection. Among them, 86 (1.9%) were positive on Ag-RDTs. Concordance of Ag-RDT results between CHWs and laboratory technicians was 100%. Of the 800 trained CHWs, 746 (93.3%) were independently able to conduct household-based COVID-19 screening, perform the Ag-RDTs and send data to the central server. Most CHWs (>80%) found Ag-RDTs and e-ASCOV easy to use.
- 41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   40
   41
   42
   43
   43
   44
   44
   45
   46
   47
   48
   49
   49
   49
   40
   41
   42
   43
   43
   44
   44
   45
   46
   47
   48
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   47
   48
   49
   49
   40
   41
   42
   43
   44
   44
   45
   46
   47
   48
   49
   49
   49
   40
   41
   42
   43
   44
   44
   44
   44
   44
   45
   46
   47
   48
   48
   4
- 44 44

- 46 45 **Strengths and limitations of the study** 
  - The study built on a well-established community health worker network, leveraging existing personnel and operational structures to introduce a new intervention with minimal disruption to the health system.
  - Digitization of the study process helped to ensure that standardized procedures were followed for screening and data management despite the dispersed settings in which study activities took place in the communities.

• The study used only Android smartphones; challenges related to different phones were not assessed. However, the application met the requirement for installation and use in all smartphone versions.

• The study did not include control districts or other comparators, as this was not feasible during the emergency response to the pandemic.

tor beer terien only

### BMJ Open

## **INTRODUCTION**

As of 9 February 2022, Rwanda had reported 129,210 cases of COVID-19, over 4.5 million tests conducted, and 1449 deaths.<sup>1</sup> Of the 4.5 million tests, 73.3% were antigen-based rapid diagnostic tests (Ag-RDTs), while 26.7% were polymerase chain reaction (PCR) tests. Most COVID-19 cases were reported during three major waves in which rapid surges of infection took place in a short period of time,1 underscoring the importance of widespread testing to enable the rapid detection of SARS-CoV-2 and contain its transmission.<sup>2</sup> 

While the epidemic was initially concentrated in urban settings, with the capital city, Kigali, accounting for 29.1% (28,267 of 97,190) of cumulative cases,<sup>3</sup> over time an increasing number of cases were detected in more rural areas of the country. Lower access to health facilities in less urbanized settings highlighted the need to expand community-based testing. Even outside of an emergency, the opportunity costs associated with travel to health facilities present significant barriers to care-seeking in many settings,<sup>4</sup> which were further heightened by movement restrictions and economic constraints during the COVID-19 pandemic.<sup>5</sup> 

The increased availability of point-of-care testing for COVID-19, specifically Ag-RDTs, created new opportunities to bring testing closer to patients given the limited laboratory infrastructure available to deliver the gold standard testing using PCR, especially in rural areas. COVID-19 testing with Ag-RDTs in Rwanda was initially delivered by trained clinicians or laboratory professionals and had not been formally offered by CHWs at the household level. However, the country's extensive network of CHWs were already involved in the diagnosis of other diseases, including symptom screening and referral for tuberculosis (TB). For example, between 2020 and 2021, 26.3% of the 5435 TB cases in Rwanda were referred by CHWs.<sup>6</sup> Consequently, there was a basis on which to review the COVID-19 testing process and consider expanding Ag-RDT testing at the community level through trained CHWs. Extending diagnostic ability using CHWs promises tremendous potential for expanded access, but also presents challenges in terms of accurate and timely data reporting. 

Accurate testing and timely data reporting are critical for the effective management of the COVID-19 response, particularly during periods of rapid transmission when such data provide early alerts of impending waves and hotspots to which intensified resources should be directed. CHWs could thus play a role not only in expanding access to diagnosis, but in supporting the development of community health surveillance approaches, which the World Health Organization has highlighted as a core pillar of pandemic preparedness.<sup>7</sup> 

Digital tools play an important role in enabling the rapid transmission of data to support real-time monitoring and epidemiological surveillance, and ease CHWs' path to making decisions with clinical implications. Digital solutions provide real-time guidance and standardization of processes at the point of care and at the management level and enable visibility into procedures being implemented at decentralized sites.8 

Leveraging Rwanda's widespread CHW network, the "e-ASCov project" was initiated and piloted by
 the Rwanda Biomedical Centre (RBC) and partners to evaluate the use of digital tools and Ag-RDT

testing by CHWs in 2020. The pilot project was rolled out in two urban and two rural districts in Rwanda, whereby CHWs were trained and equipped with innovative digital technology to support community-based screening and referral of people with COVID-19 symptoms. The RBC-developed e-ASCov mobile application was installed on the phones of participating CHWs to support them with COVID-19 symptom screening and referral, and ensure that related data are systematically captured

and rapidly transmitted to national data servers to guide national surveillance and response efforts. 

This study sought to build on the original e-ASCov pilot, and the opportunities offered by the expansion of Ag-RDT testing, by expanding e-ASCov to include instructions and data capture for administration of Ag-RDTs, and mechanisms for real-time reporting. At the time it was designed, to the authors' knowledge this was the first study that evaluated the ability of CHWs to perform SARS-CoV-2 Ag-RDT testing, capture and transmit results in Rwanda and the broader African region. Thus, the study would provide grounds to review and update COVID-19 laboratory testing guiding principles in Rwanda vis-a-vis the possibility to decentralize RDT-based diagnosis at community level by trained OPP-CHWs. 

#### **METHODS**

This was an operational pilot study to evaluate the impact and operational characteristics of using the digital tool e-ASCov combined with Ag-RDTs to support symptom screening and delivery of rapid testing by CHWs at the household level. 

#### Study setting and population

The study took place in eight districts in four provinces in Rwanda, including the four districts selected in the e-ASCov pilot. Four additional districts were selected based on infection rates (those with the highest infection rates at the time the study began) and geographic location. In terms of geographic location, a spread of rural, urban and semi-urban districts were included, with prioritization of rural districts as residents had restricted access to health facilities in these areas compared to the rest of the population. Districts with land borders were also prioritized due to a greater risk of COVID19 transmission because of higher levels of movement between countries. 

A total of 800 CHWs were selected for this study across 34 health centres (100 per district), representing around 5% of the total CHW workforce in the studied districts. Villages were selected randomly depending on the number of CHWs required per health centre, with all active CHWs included from selected villages. Supplementary Table 1 provides an overview of the study districts and CHWs included in the project by district. Within these districts, the intervention was fully integrated into the 

1 2 3 4	130 131	CHWs' routine package of care, which is accessible to all residents. As a result, the eligible population for this project was any person resident in the study districts.
5 6 7	132	Digitally enabled screening and rapid testing
<ul> <li>7</li> <li>8</li> <li>9</li> <li>10</li> <li>11</li> <li>12</li> <li>13</li> <li>14</li> <li>15</li> <li>16</li> </ul>	133 134 135 136 137 138 139	This study built on the e-ASCov pilot, described previously, <sup>9</sup> in which CHWs identified individuals suspected to have COVID-19 and referred them for testing. The e-ASCov tool was an existing, field-tested mobile application for symptom screening to identify possible COVID-19 cases. CHWs verbally administered a screening questionnaire to individuals in their communities, which focused on signs and symptoms suggesting a risk of COVID-19, recording individual's response in the e-ASCov application. Based on the responses, an algorithm built into the application assigned participants to one of three risk levels (low risk, suspected case, and urgent case)—with the latter two categories being
17 18	140	referred for Ag-RDT testing.
19 20 21 22 23	141 142 143	The algorithm used for screening was updated to align with the latest guidance from Rwanda's Ministry of Health (Figure 1), with inbuilt skip logic determining which of the case categories an individual fell into.
24 25	144	
26 27 28	145	
29 30	146	
31 32	147	
33 34 35	148	Figure 1. e-ASCov algorithm used in pilot study
36 37	149	
38 39	150	RDT, rapid diagnostic test.
40 41	151	For this study, the RDT toolkit (developed by Dimagi Inc) <sup>1011</sup> was integrated into e-ASCov, to
42	152	provide instructions for administering RDTs, a timer, and data capture for the test and result (Figure
43	153	2). Originally developed to support rapid diagnostic testing for malaria, the toolkit is readily
44 15	154	customizable for different conditions for which RDTs are used. It was thus adapted to support
46	155	delivery of the SARS CoV 2 Ag RDTs and translated to make instructions available in
47 48	155	Kinyarwanda.
49		
50	157	When a CHW was prompted to conduct a test after the e-ASCov questionnaire, the workflow
51	158	automatically transitioned into the RDT toolkit without the CHW having to change applications. This
52	159	presented a set of instructions in Kinyarwanda. The CHW collected nasal samples for the Ag-RDT
53 54 57	160	using nasopharyngeal swabs, and were thereafter instructed to start the timer after initiating the test.
55 56	161	Rapid testing by the CHWs was conducted according to manufacturer's instructions using a validated
57 58	162	Ag-RDT (Panbio COVID-19 Ag Rapid Test Device, Abbott), which was already recommended by
59		For poor rovious only, http://honion.org/prices/site/shares/anis/shares/
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xntml

1		
2	163	Rwanda's COVID-19 Laboratory Testing Guiding Principles and routinely used. <sup>12</sup> Using the timer on
3 4	164	the application, CHWs read the Ag-RDT result after the processing time and recorded the result in the
5	165	e-ASCov tool. There was also an option to capture and transmit images of the test result to enable
6	166	validation of the result by the central team at RBC. As e-ASCov was fully integrated within the
7 0	167	broader Ministry of Health digital system for reporting on COVID-19, data were subsequently
9	168	transmitted to RBC servers in real time.
10		
11	169	
12	170	Figure 2. Study workflow
14	171	
15	172	
16 17	173	HMIS, health management information system; RBC, Rwanda Biomedical Centre; RDT, rapid diagnostic test.
18	174	Patients who tested positive on the Ag-RDTs were referred to a nearby facility if their risk was
19	175	classified as "urgent" (Case 3 in Figure 1), or would otherwise be referred to the existing home-based
20	176	care programme, which includes guidance on isolation and self-monitoring of symptoms. In addition,
22	177	their contacts were registered and tested using the same procedure.
23		
24 25	178	Evaluation of the concordance and performance of Ag-RDT
25 26		
27	179	To assess the concordance of Ag-RDT results between CHWs and the laboratory technician, 499
28 20	180	CHWs were randomly selected and shadowed by a laboratory technician for a period of time. During
29 30	181	that time, the CHWs administered Ag-RDTs and read the result independently, then re-read by the field
31	182	trainer (observer). The result interpreted by the CHW was blinded to the laboratory technician as an
32	183	operator. The laboratory technician then repeated the Ag-RDT and reported their result independently.
33 34	184	The results from the tests performed by the laboratory technician were considered final and
35	185	communicated to clients.
36	186	
37 38	187	Assessment of the experience
39	188	The study assessed CHWs' experience of the intervention using a mixed methods approach. Firstly, a
40 41	189	self-administered questionnaire with close-ended questions was provided to CHWs. Secondly,
42	190	qualitative data were collected using focus group discussions with CHWs in four districts (Rubavu,
43	191	Huve, Nyagatare and Gasabo). The questions focused on e-ASCov and the administration of Ag-RDTs.
44 45	192	in terms of usability, satisfaction, enablers and barriers, and the perceived continuity of the
45 46	193	intervention. Interviews were conducted in Kinvarwanda and recorded with the aid of smartphones and
47	194	tablet devices, then later transcribed and translated in English. Copies of questions asked as part of the
48	195	focus group discussions are available in the Supplementary methods.
49 50	-	
51	196	Training and mentorship
52		- •

CHWs and supervising staff at participating facilities underwent 1–2 days of theory and practical
 training at the district level. A refresher training was conducted on general COVID-19 information
 including the use of personal protective equipment (PPE), detecting symptoms of COVID-19, and
 follow-up of COVID-19 cases. CHWs were then further trained on screening and data capture using

58 59

**BMJ** Open

<sup>2</sup> 201 e-ASCov. Finally, qualified staff from the NRL provided training on how to conduct Ag-RDTs. This

- included a demonstration with the aid of a practical video, following which the CHWs conducted
   Ag-RDT testing under the supervision of facilitators. The community health supervisor and the
- 5 203 Ag-RDT testing under the supervision of facilitators. The community health supervisor and the 6 204 training facilitators at the respective health centres were responsible for ensuring distribution of
- $\frac{7}{8}$  205 materials to the CHWs and accountability in the use of these materials.

Pre- and post-training tests were conducted to confirm participants' level of knowledge. Trainees' feedback on the digital tool also informed further refinement of the application during the training process. During implementation, ongoing mentorship was provided through existing supervisors at facilities, with additional support from RBC, particularly for resolving any operational and technological issues that arose during the study. Refresher training and technical support around using the digital tool were provided as needed, and the proportion of CHWs who needed such support was monitored. 

20 213 **Data management and analysis** 

# <sup>22</sup><sub>23</sub> 214 Sample size and sampling techniques

The target sample size for Ag-RDT testing was determined by feasibility considerations, with a target of delivering up to 6816 tests to symptomatic individuals plus direct contacts of confirmed cases. Based on data from the first pilot phase of e-ASCov, in which 30% of all individuals screened were eligible for testing based on symptoms, it was estimated that close to 20,000 individuals would need to be screened to achieve the testing target. Each CHW therefore aimed to screen 20-25 individuals during the study period. 

<sup>33</sup><sup>34</sup> 221 Data collection and sharing

Participants were given a unique number, which was used to identify the collected data. Demographic and clinical data, test results and images linked to these data were stored in e-ASCov and transmitted to the local RBC servers for integration into the national COVID-19 data system. The e-ASCov app included validation rules that prevented skipping of mandatory questions and therefore prevented missing data. 

All the information obtained in this study was kept and handled in accordance with applicable laws and/or regulations. Data were stored and archived to the RBC server in compliance with national data security guidelines per the Rwanda Information Security Authority,<sup>13</sup> with only authorized personnel processing the information. Data encryption and anonymization principles were applied to safeguard confidentiality. Any access to and use of the data was subjected to the approved data sharing agreements between different institutions that formed the study team. 

Regulatory and ethical considerations
Regulatory and ethical considerations

Ethical clearance to conduct this study was obtained from the Rwanda National Ethics Committee
 (RNEC) No.920/RNEC/2021. As this intervention was integrated into routine Ministry of Health

programming included in the CHWs' package of services, RBC secured a formal waiver of informed consent for community members to take part in the household-level COVID-19 testing through the RBC's CHWs. Thus, no additional informed consent forms were required from individuals. However, the CHWs taking part in the interviews or focus group discussions signed an informed consent form 

before participation. 

This study was conducted in accordance with the protocol and with consensus ethical principles derived from international guidelines, particularly the Declaration of Helsinki and Good Clinical Practice Guidelines: ICH GCP E6 (R2). Several measures were taken to minimize the risk of infection for CHWs or other members of the household during community-based testing, including previously described training and provision of PPE to CHWs. In addition, CHWs were trained on how to assess the households of individuals who were eligible for testing, to determine whether an appropriate space was available (in terms of size, distance from other household members, and adequate ventilation). If the household did not contain such a space, testing was conducted outside of the house, in the household compound. 

An author reflexivity statement is provided in the supplementary methods.

#### Patient and public involvement

Patients and the community were involved in the pilot, with the experience and findings used to inform the design of this study. Jie4

#### RESULTS

#### Number tested and screened

A total of 19,544 individuals were enrolled in the study and screened for signs and symptoms of COVID-19 (Table 1). Of these, 4575 (23.4%) had signs and symptoms suggestive of COVID-19 infection and were thus eligible for testing with Ag-RDTs (Table 1).

#### Table 1. Number of participants screened and tested

District	All screened	Number with symptoms (eligible for testing)	n Percentage screened eligible for testing	Negative	Positive	Invalid	Positivity rate (%)
Gasabo	1,708	598	35.0	558	14	26	2.3
Huye	1,625	435	26.8	414	4	17	0.9
Kirehe	3,009	787	26.2	717	8	62	1
Musanze	2,549	563	22.1	513	13	37	2.3

Page	11	of 38
------	----	-------

Total	19,544	4,575	23.4	4,245	86	244	1.9
Rubavu	2,675	674	25.2	634	24	16	3.6
Rusizi	3,254	359	11.0	345	1	13	0.3
Nyarugenge	2,226	694	31.2	621	21	52	3
Nyagatare	2,498	465	18.6	443	1	21	0.2

> The proportion of those screened who reported symptoms of COVID-19 was highest in urban areas, with the highest rates observed around the capital city, Kigali, in Gasabo (35.0%) and Nyarugenge (31.2%) (Table 1).

> The overall positivity rate in the study was 1.9%, and by district, was highest in the border district of Rubavu (3.6%) and Nyarungenge district (3.0%), which forms part of the capital city. A total of 244 tests, representing 5.3% of all tests conducted, were automatically flagged by e-ASCov as "Invalid: Control Failed", as over 20 minutes elapsed with no result being entered in the application. The test was repeated for individuals with invalid results. There were no missing data (Table1).

#### **Contribution to case-finding in districts**

During the study period, a total of 378 COVID-19 cases were diagnosed in the eight districts. Of these, 86 were diagnosed through the study intervention, with CHWs thus accounting for 22.8% of all diagnosed COVID-19 cases during the study period (Supplementary Table). 

#### **Concordance of results between CHW and laboratory technician**

A total of 499 participants were tested for COVID-19 using Ag-RDT by CHWs and laboratory professionals for the concordance evaluation. Of these, three positive cases and 496 negative cases were identified by both CHWs and laboratory professionals. All the Ag-RDT results obtained by CHWs were confirmed by professional laboratory technicians, with a perfect agreement of 100% between results from the CHWs and the laboratory technicians (Cohen's kappa of 1.0) (Table 2).

#### Table 2. Concordance of COVID-19 testing between community health workers and laboratory technicians

	Re-testing by laboratory technicians			
Testing by community health worker	Positive	Negative		
Positive	3	0		
Negative*	0	496		
Invalid	0	0		

1			Ι	1
2 3		Total	3	496
4 5		Observed agreement (%)	100%	
6 7		Expected agreement (%)	98.78%	
8 9 10		Cohen's kappa	1.0	
10 11 12	291	NRL, National Reference Laboratory.		
13 14	292	Feasibility		
15 16	293	Overall 746 out of 800 CHWs (93.3%) were	e able to independently co	nduct all study procedures
17	294	without support from supervisors. This in	cluded screening using t	he e-ASCov application.
18	295	administering nasal swabs for the Ag-RDTs and	d conducting the test, reporti	ng results and sending data
20	296	to the national RBC server. The remaining pro	portion (6.7%) of CHWs re	equired substantive support
21	297	to implement one or more of the above steps.	F (0)	-1
22 23				
23 24 25	298	Qualitative assessment: Satisfaction, u	isability and acceptabi	lity
26 27	299	Respondent profiles		
28 29	300	A total of 349 CHWs participated in qualitative	e assessments of the testing	experience. The mean age
30	301	of these participants was 44 years with a range of	of 20–72 years. Of these, 42.	1% had completed primary
31	302	education and 44.1% had completed seconda	ary education. Only 4.3%	had received a university
32 33	303	education, while 9.5% had undergone vocation	al training.	
35 36	304	CHW perceptions of e-ASCov		
37	305	Respondents were asked a number of questions	related to their experiences	with using the digital tool,
38 30	306	with findings summarized in Supplementary T	able 2. The majority report	ed positive feedback of the
40 41	307	experience, with main areas identified for impre-	ovement including:	
42	308	- Duration of training: 28.7% of participants b	believed the length of training	g was only partly sufficient,
43 44	309	while 16.3% believed that it was not suffici	ent to cover all the skills the	ey needed to learn.
45	310	- Access to internet: close to half (48.7%)	of participants reported on	ly partial satisfaction with
46	311	internet access during the study.		
47 49	312	- Time taken to enter data: one in five respo	ndents stated that the time	required for data entry was
49 50	313	long, while 1 in 3 did not believe that it was	s short enough.	1 5
51	314	Despite these challenges, all respondents expre	essed the need for future us	e of e-ASCov, with 99.7%
52 53	315	recommending that it should be scaled up to oth	her disease areas.	,
54 55 56	316	CHW perceptions of CHW-led Ag-RDT	testing	
57 58 59				
60		For peer review only - http://bmjop	pen.bmj.com/site/about/guideli	nes.xhtml 11

- responded that the training was sufficient, 93.9% still found it easy to read Ag-RDT results, while
  - 320 84.8% found it easy to report results through e-ASCov (Supplementary Table 3).
- 8 321

## 10 322 DISCUSSION

11 323 

This study successfully leveraged previous investments in a screen-and-refer model to enable CHWs to deliver near-patient, high-quality screening and testing for COVID-19 in Rwanda using Ag-RDTs and a mobile application. Although implementation took place during a period of low COVID-19 transmission in Rwanda, nearly a quarter of the 19,544 participants screened had signs and symptoms of COVID-19. Rates of COVID-19 were particularly high in the Kigali metropolis, where over 30% of screened individuals were identified as potential COVID-19 cases. This indicated a higher frequency of respiratory and other symptoms in urban areas, highlighting a need for expanded and more targeted COVID-19 case finding in communities. Overall, 1.9% of tested individuals were positive for SARS-CoV-2—a significant decline from the earlier screen-and-refer e-ASCov pilot where the positivity rate was 7.5% preceding scale-up of Rwanda's COVID-19 vaccination programme. 

The CHWs demonstrated an excellent capacity to perform the COVID-19 Ag-RDT. There was full concordance (100%) between the Ag-RDTs run by CHWs and those performed by laboratory professionals, which demonstrates that trained CHWs are capable of delivering Ag-RDTs with comparable quality to laboratory personnel, making the case for task-shifting of rapid diagnostic testing to the lowest levels of care providers. While PCR testing is known to be more sensitive than antigen-based rapid testing, Ag-RDTs still have a valuable role to play in detecting cases especially in resource-limited settings.14 

Wide variations were observed in the Ag-RDT positivity rate in the study, with the highest rate found in Rubavu, a district at the border with the Democratic Republic of Congo. Across multiple disease areas, cross-border mobility has often been associated with increased spread of disease.<sup>15 16</sup> While this prompted widespread restrictions on international movement, especially in the earlier stages of the pandemic response, there is a lack of conclusive evidence on the effect of these restrictions on the incidence of COVID-19.<sup>17</sup> Nevertheless, our study highlights the role of enhanced testing to better identify high transmission areas and evaluate what measures can most effectively reduce disease transmission. Expanding access to testing through CHW-led diagnosis, as was conducted in this study, is one such way to intensify testing, particularly in environments where there is a higher risk of transmission such as densely populated urban settings and border districts. 

The urban districts, Nyarugenge and Gasabo, also reported high COVID-19 positivity rates of 3.0% and 2.3%, respectively, at the time when the national positivity rate was below 1%. Community-based testing methods supported by digital tools, as deployed in this study, could be a useful approach for earlier identification of high-transmission areas such as these, by facilitating near-patient access to testing. Disaggregated data on vaccination status and previous infection per district were not collected 

<sup>2</sup> 356 by this study; these would be useful in interpreting the symptoms and positivity rates seen in the

 $\frac{3}{4}$  357 different districts. Towards the end of the study, there was a reduction in COVID-19 incidence and

5 358 people with COVID-19 symptoms, which was also observed nationwide in both urban and rural areas.

During the study, the testing conducted by CHWs accounted for 22.8% of all cases identified in the study districts, although only 5% of the overall CHWs in the study districts were involved in the study. The disproportionately high contribution of CHWs to identifying COVID-19 cases illustrates the significant potential of this cadre of health workers to expand case finding for COVID-19 and other diseases if engaged at a larger scale. 

The use of a digital tool played an important role enabling CHWs to carry out COVID-19 testing in
 the community, by providing decision support and facilitating data entry. The FGDs with CHWs
 provided insights into this experience.

<sup>19</sup> 367 *"Was understandable and didn't take much time, the way that tools were made makes everything easy,*<sup>21</sup> 368 *so we were 100% confident." A* FGD participant.

While some CHWs interviewed in the FGDs acknowledged that they initially faced difficulties with using the digital tool and indicated the need for a longer period of training, most were comfortable with the tool by the end of the study. The training was delivered in most study sites within two days, but the speed of learning differed across the sites and between participants. Across CHWs, training first-time users of smartphones on how to navigate the telephone took the longest time. 

It was observed that younger CHWs were the fastest learners due to strong digital literacy, while CHWs
 With more advanced age (60 years and above) faced more challenges and required closer support from
 the facilitators and supervisors.<sup>18</sup>

35
 36 377 "At first time the phones were going to be hard for us. Saving the information obtained from the people
 37 378 failed to work completely. They helped us and showed it to us how to proceed. We continued to try and
 379 end up by becoming familiar with the system. I am 90% confident." – An FGD respondent.

In addition to expanding access to testing, the process used in this study – Ag-RDTs combined with a digital tool – strengthened surveillance systems, and decongested health facilities and laboratories in study areas. The ability of CHWs to report directly to the national database, using unique patient codes, which were part of Rwanda's testing architecture since the start of the pandemic, greatly enhanced the benefit of this intervention. Together the findings demonstrate the value of investing in strong digital health systems that can easily be built on to improve services. 

General Stress St

55
 56 390 "This method of COVID testing I found is not a difficult thing, because otherwise we as CHW usually
 57 391 do malaria treatment...although performing malaria test and COVID-19 tests seems to be different, it

### **BMJ** Open

- 392 is not difficult...If you know that you're going to help a patient who comes to you to get better life,
   393 that's something I found possible and we do, it's not too difficult." A FGD CHW respondent.
- <sup>5</sup>
  <sup>6</sup> 394 "I suggest to introduce the diseases that we are normally treating in the [e-ASCov] system...it will be
  <sup>7</sup> 395 helpful and delivering information will be so quick." A FGD CHW respondent.

In other settings, the use of digital tools in community-based testing has demonstrated several benefits, including improving the assessment of disease risk based on embedded algorithms to guide appropriate triage of patients<sup>19</sup> and improve diagnostic accuracy.<sup>20</sup> The COVID-19 pandemic response also led to an unprecedented surge in the use of digital solutions to support healthcare delivery and decision-making.<sup>8 21</sup> However, the proliferation of different tools can increase fragmentation of the digital health architecture and contribute to misalignment between data systems,<sup>22</sup> limiting full visibility into patient data across different disease areas.<sup>23</sup> Hence, it is important to consider the fit and interoperability of digital tools within the existing digital health architecture before implementing new approaches. 

Inclusion of other diseases into e-ASCov to accelerate community-based testing would help to avoid the fragmentation of the digital health architecture and enable more efficient use of resources by facilitating the diagnosis of other diseases. Increasing the ease of differential diagnosis is particularly important, given that over one in five patients in this study had illness-related symptoms that were not diagnosed as COVID-19. Such people could benefit from point-of-care testing for other diseases that may be causing symptoms similar to COVID-19, particularly febrile and respiratory illnesses. Based on the findings of this study, and the national plan to digitize the CHWs services, we are jointly developing a robust integrated community health information system that will also incorporate the contents of e-ASCov. We intend to evaluate the effectiveness and impact of the planned integrated system once developed, particularly on conditions with overlapping clinical presentations such as TB, pneumonia, COVID-19 and malaria. Demonstrating the value of an integrated community health system in Rwanda can set a precedent for other nations in Africa and in other regions to implement similar systems. 

Limitations of the study include that it did not evaluate the cost-effectiveness of the evaluation, as its primary objective was to investigate if non-conventional medical staff can perform Ag-RDT testing for COVID-19, to bring testing closer to the community. Future studies would be valuable to assess the cost-effectiveness of the intervention. Although the study provides a general demonstration of the value of using CHWs to deliver community-based testing, the specifics of the intervention (e.g. the number of CHWs, training required) would need to be tailored to the specific setting if rolled out more broadly. 

Point-of-care diagnostics, such as Ag-RDTs, are also critical to expand access to testing and have been successfully applied as part of testing approaches for other diseases, including HIV. Evidence from systematic reviews of HIV point-of-care testing by non-laboratory workers and lay workers have demonstrated the value of point-of-care diagnostics in expanding access to health services, 2425 reducing diagnosis delays, allowing timely treatment initiation, and facilitating linkage to care.<sup>26</sup> 

430 Beyond its immediate benefits for detecting diseases like COVID-19, improved community
 431 surveillance could also be used to predict and potentially avert anidemic outbreaks in the fut

- $\frac{3}{4}$  431 surveillance could also be used to predict and potentially avert epidemic outbreaks in the future. For
- 432 example, in India's early COVID-19 response, regular analysis of syndromic data deepened the
- $\frac{6}{7}$  433 precision of hotspot predictions.<sup>27</sup> Establishing systems for routine collection of such data could thus
- $\frac{7}{8}$  434 be beneficial for overall pandemic preparedness.

In summary, this study demonstrated the value of a digital tool combined with Ag-RDT testing to support household-level SARS-CoV-2 detection and contact tracing by CHWs in Rwanda. The study fed into Rwanda's vision for decentralizing COVID-19 services and healthcare more broadly. It also provides evidence to support the inclusion of COVID-19 rapid testing within the portfolio of diagnostic services that are already provided by CHWs in the country. The operational model – namely, point-of-care tests by CHWs, supported by digital tools for real-time clinical guidance, process management and data capture and transmission - could be scaled up nationally to enable greater access to decentralized testing for COVID-19 and other diseases across the rest of the country. Together, the findings indicate an opportunity to roll out digitally supported rapid testing for COVID-19 and other diseases to support healthcare service delivery closer to the community and evidence-based decision-making. Although this study was conducted during the COVID-19 pandemic, when Rwanda needed urgent solutions to maximize early detection and control of the disease and COVID-19 is currently endemic,<sup>28</sup> the lessons from this study can also be adapted for early warning of outbreaks and surveillance of other diseases. As an example, the digital approaches used in this study have subsequently been applied in the development of a national community health information system, by designing digital symptom screening and decision support integrated across the full package of services delivered bv CHWs. This system has been piloted in Rwanda since 2023. 

1 2 3	452	
4 5	453	ACKNOWLEDGEMENTS
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	454 455 456 457 458 459 460 461 462 463	The authors would like to thank the community health workers who participated in the intervention as well as the district teams, Rwanda National Referral Laboratory, community health workers who supported the field data collection, local leaders, community members, and heads of health facilities. RBC, Ministry of Health and FIND for their support. The authors would also like to thank Dimagi for the support with the technical documentation and integration of the Ag-RDT-Toolkit, and the e- ASCov project group who conducted the preceding pilot in four districts with financial support from the French National Agency for Research on AIDS and Emerging Infectious Diseases (ANRS COV17). Medical writing support was provided by Talya Underwood, Principal Writer, of Anthos Communications Ltd, according to Good Publication Practice guidelines.
21 22	464	DATA AVAILABILITY STATEMENT
23 24 25	465	Data are available on reasonable request addressed to Rwanda Ministry of Health.
26 27	466	
28 29 30	467	ETHICS STATEMENTS
30 31 32	468	Patient consent for publication
33 34	469	Not applicable.
35 36 37	470	
38 39	471	COMPETING INTERESTS
40 41 42	472 473	The authors J.B.M, O.A, K.S, P.A and R.K disclose that they are employed by FIND. The other authors declare that no conflicts of interest exist.
43 44 45	474	
46 47	475	FUNDING
48 49 50 51 52 53 54 55 56 57 58	476 477 478 479 480 481 482	The study was funded by FIND, United Kingdom (FCDO 40105983), Switzerland (81066910), Netherlands (SDD 4000004160), Canada (DFATD 7429348), The Kingdom of Saudi Arabia (FIND – ACT-A DX PARTNERSHIP 20.08.2020), The Rockefeller Foundation (2020 HTH 059), Germany (BMZ Covid-19 Diagnostic and Surveillance Response 27.07.2021), Australia (DFAT 76442), Kuwait (M239/2020), and The Government of Portugal and Partners (ANF, BCP, CGF, APIFARMA). Medical writing support was funded by FIND, according to Good Publication Practice guidelines.
59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 16

#### **AUTHOR CONTRIBUTIONS**

The guarantor, Ladislas Nshimiyimana, accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. 

Conceptualization: LN, NB, PA, RK, OA, JB, JPR, MS; Data curation: NB, HM, JM, PA, OA, MS; 

Formal Analysis: NB, PA, HM, GR; Funding Acquisition: RK; Investigation: LN, JB, PA, JCSN, 

RR, HM, GR, BM; Methodology: PA, LN, MS; Project Administration: LN; Resources: LN, JB, PA,

JCSN, CMM, NB; Software: JM, OA, GR, HM, MS; Supervision: LN, JB, PA, KS; Validation: PA; 

ing – Orig. Visualization: LN; Writing – Original Draft Preparation: LN, PA; Writing – Review & Editing: All authors.

1 2 3	495	REFERENCES
4 5 6 7	496 497	1. Rwanda Biomedical Centre. Coronavirus Disease COVID-19 [Available from: https://rbc.gov.rw/index.php?id=727 accessed 25 May 2022.
, 8 9 10 11	498 499	2. World Health Organization. Why testing is important? 2022 [Available from: https://www.who.int/multi-media/details/why-testing-is-important accessed 14 August 2024.
12 13 14	500 501	3. Rwanda Biomedical Centre. COVID-19 updates, 25 May 2022 2022 [14 November 2023]. Available from: https://rbc.gov.rw/index.php?id=727).
15 16 17 18 19	502 503 504	<ol> <li>World Health Organization. National surveys of costs faced by tuberculosis patients and their households 2015-2021 2023 [Available from: https://www.who.int/publications/i/item/9789240065536 accessed 17 October 2023.</li> </ol>
20 21 22 23 24 25 26	505 506 507 508	5. Ahmed SAKS, Ajisola M, Azeem K, et al. Impact of the societal response to COVID-19 on access to healthcare for non-COVID-19 health issues in slum communities of Bangladesh, Kenya, Nigeria and Pakistan: results of pre-COVID and COVID-19 lockdown stakeholder engagements. <i>BMJ Global Health</i> 2020;5(8):e003042. doi: 10.1136/bmjgh-2020-003042
20 27 28 29 30 31	509 510 511 512	<ol> <li>Republic of Rwanda Ministry of Health. National tuberculosis and other respiratory communicable diseases program: Annual report 2020-2021 2023 [Available from: https://www.ccm.rw/fileadmin/user_upload/Annual%20report%20TB%20%20ORD%202020 %202021.pdf accessed 17 October 2023.</li> </ol>
32 33 34 35 36	513 514 515	7. Ihekweazu C. WHO Hub for Pandemic and Epidemic Intelligence [Available from: https://cdn.who.int/media/docs/default-source/blue-print/07_chikwe-ihekwazu_day- 1_who_grif_24-25feb2022.pdf?sfvrsn=5aacbcdf_7 accessed 8 June 2023.
37 38 39 40 41	516 517 518	<ol> <li>Majam M, Msolomba V, Venter F, et al. Monitored Implementation of COVID-19 Rapid Antigen Screening at Taxi Ranks in Johannesburg, South Africa. <i>Diagnostics (Basel)</i> 2022;12(2) doi: 10.3390/diagnostics12020402 [published Online First: 2022/02/26]</li> </ol>
42 43 44 45 46	519 520 521	9. Rwanda Biomedical Centre. Use of digital tools by community health workers in the management of Covid-19 pandemic in Rwanda: Action Research (eASCov Project ) [Available from: https://rbc.gov.rw/rnhrr/article?code=103 accessed 14 August 2024.
47 48 49 50	522 523	<ol> <li>Dimagi. FIND – Digital Solution for COVID-19 RDTs 2021 [Available from: https://www.dimagi.com/blog/find-covid-19-rdt-solution/ accessed 17 October 2023.</li> </ol>
51 52 53 54 55 56 57	524 525 526 527 528	<ul> <li>11. CommCare. COVID-19 Template App: COVID-19 RDT Tracking [Available from: https://confluence.dimagi.com/display/commcarepublic/COVID- 19+Template+App%3A+COVID- 19+RDT+Tracking?_ga=2.242944000.300957840.1697095310-828340193.1697095309 accessed 17 October 2023.</li> </ul>
58 59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

2 3 4	529 530	<ol> <li>Ministry of Health Rwanda. COVID-19 Clinical Management Guidelines. 3rd Edition September 2021 ed, 2021.</li> </ol>
5 6 7 8 9 10	531 532 533 534	<ul> <li>13. Government of Rwanda. Law N° 058/2021 OF 13/10/2021 Relating to the Protection of Personal Data and Privacy [Available from: https://cyber.gov.rw/index.php?eID=dumpFile&amp;t=f&amp;f=229&amp;token=742569646abebc43d1ad8 1e3d3bee2f4f11f9639 accessed 14 August 2024.</li> </ul>
11 12 13 14 15 16 17	535 536 537 538	<ol> <li>Wagenhäuser I, Knies K, Hofmann D, et al. Virus variant-specific clinical performance of SARS coronavirus two rapid antigen tests in point-of-care use, from November 2020 to January 2022. <i>Clin Microbiol Infect</i> 2023;29(2):225-32. doi: 10.1016/j.cmi.2022.08.006 [published Online First: 2022/08/27]</li> </ol>
18 19 20	539 540	15. Suk JE, Van Cangh T, Beauté J, et al. The interconnected and cross-border nature of risks posed by infectious diseases, 2015.
21 22 23 24 25 26 27	541 542 543 544	<ol> <li>Ehrlich R, Montgomery A, Akugizibwe P, et al. Public health implications of changing patterns of recruitment into the South African mining industry, 1973-2012: a database analysis. <i>BMC</i> <i>Public Health</i> 2017;18(1):93. doi: 10.1186/s12889-017-4640-x [published Online First: 2017/08/05]</li> </ol>
27 28 29 30 31 32 22	545 546 547 548	<ol> <li>Emeto TI, Alele FO, Ilesanmi OS. Evaluation of the effect of border closure on COVID-19 incidence rates across nine African countries: an interrupted time series study. <i>Transactions of</i> <i>The Royal Society of Tropical Medicine and Hygiene</i> 2021;115(10):1174-83. doi: 10.1093/trstmh/trab033</li> </ol>
33 34 35 36 37 38	549 550 551	<ol> <li>van Deursen AJ. Digital Inequality During a Pandemic: Quantitative Study of Differences in COVID-19-Related Internet Uses and Outcomes Among the General Population. J Med Internet Res 2020;22(8):e20073. doi: 10.2196/20073 [published Online First: 2020/08/05]</li> </ol>
39 40 41	552 553	19. Roy T, Marcil L, Chowdhury RH, et al. The BRAC Manoshi Approach 2011 [Available from: https://brac.net/sites/default/files/portals/Manoshi-book-v3-1.pdf accessed 8 June 2023.
42 43 44 45 46 47 48	554 555 556 557	<ol> <li>20. Laktabai J, Platt A, Menya D, et al. A mobile health technology platform for quality assurance and quality improvement of malaria diagnosis by community health workers. <i>PLoS One</i> 2018;13(2):e0191968. doi: 10.1371/journal.pone.0191968 [published Online First: 2018/02/02]</li> </ol>
48 49 50 51 52 53 54	558 559 560 561	21. Karanja S, Aduda J, Thuo R, et al. Utilization of digital tools to enhance COVID-19 and tuberculosis testing and linkage to care: A cross-sectional evaluation study among Bodaboda motorbike riders in the Nairobi Metropolis, Kenya. <i>PLOS ONE</i> 2023;18(9):e0290575. doi: 10.1371/journal.pone.0290575
55 56 57 58	562 563 564	22. Atun R, de Jongh T, Secci F, et al. Integration of targeted health interventions into health systems: a conceptual framework for analysis. <i>Health Policy Plan</i> 2010;25(2):104-11. doi: 10.1093/heapol/czp055 [published Online First: 2009/11/18]
59 60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 19

1 2 3 4 5	565 566 567	<ol> <li>Muinga N, Magare S, Monda J, et al. Digital health Systems in Kenyan Public Hospitals: a mixed-methods survey. <i>BMC Med Inform Decis Mak</i> 2020;20(1):2. doi: 10.1186/s12911-019- 1005-7 [published Online First: 2020/01/08]</li> </ol>
6 7 8 9 10	568 569 570	24. Vojnov L, Taegtmeyer M, Boeke C, et al. Performance of non-laboratory staff for diagnostic testing and specimen collection in HIV programs: A systematic review and meta-analysis. <i>PLOS ONE</i> 2019;14(5):e0216277. doi: 10.1371/journal.pone.0216277
11 12 13 14 15 16	571 572 573 574	25. Kennedy CE, Yeh PT, Johnson C, et al. Should trained lay providers perform HIV testing? A systematic review to inform World Health Organization guidelines. <i>AIDS Care</i> 2017;29(12):1473-79. doi: 10.1080/09540121.2017.1317710 [published Online First: 2017/04/25]
17 18 19 20 21	575 576 577	26. Pham MD, Agius PA, Romero L, et al. Acceptability and feasibility of point-of-care CD4 testing on HIV continuum of care in low and middle income countries: a systematic review. <i>BMC</i> <i>Health Services Research</i> 2016;16(1):343. doi: 10.1186/s12913-016-1588-y
22 23 24 25 26 27	578 579 580 581	27. FIND. Use of digital tools and data science to strengthen COVID-19 management: India case study 2021 [Available from: https://www.finddx.org/wp- content/uploads/2023/05/20210501_digital_health_report_india_FV_EN.pdf accessed 18 October 2023.
28 29 30 31	582 583	<ol> <li>Razdan A, Arora R, Agarwal G, et al. COVID-19 pandemic to endemic. Int J Clin Virol 2022: 043-49. doi: 10.29328/journal.ijcv.1001049</li> </ol>
32 33 34 35	584	
36 37		
38 39 40		
41 42		
43 44		
45 46		
47 48		
49 50		
51 52		
53 54		
55		
57		
58 59		20
60		For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml







### 1 SUPPLEMENTAL MATERIAL

### 2 Supplementary methods

4 Focus group discussions (FGDs) at the study site: community health workers (CHWs)

5 N=64; 2 FGDs per each of the four selected districts, 8 participants per each FGD.

# 6 Experiences on the use of the e-ASCov application for screening and testing COVID-19 using 7 RDTs by CHWs (perception and satisfaction of CHWs on their role).

8 English: Thank you for agreeing to participate today and give your informed consent. I would like to 9 ask you about your experiences on the use of the e-ASCov application and testing COVID-19 by 10 Community Health Workers using RDTs. All your answers will remain confidential and you do not 11 have to answer to questions that you do not want. There is no right or wrong answer to these questions. 12 Please feel free to ask questions anytime during the interview and we can stop at any time. Thank you 13 again for your participation

Kinyarwanda : Murakoze kwemera kwitabira iki kiganiro uyu munsi no kwemera kugira uruhare muri ubu bushakashatsi nyuma yo gusobanurirwa. Nifuzaga kubabaza kubijyanye n'ubumenyi mufite kw'ikoreshwa ry'ikoranabuhanga mu gufata amakuru no gupima COVID-19 bikozwe n'abajyanama b'ubuzimamuri. Ibisubizo byanyu bigirwa ibanga kandi mufite uburenganzira bwo guhitamo kudasubiza bimwe mu bibazo mubazwa igihe mwumva bibabangamiye. Nta gisubizo kiri cyo cyangwa se gipfuye. Mwisanzure mubaze ikibazo cyose mwagira mugihe turi kuganira, kandi dushobora guhagarika iki kiganiro igihe icyo aricyo cyose mubyifuje. Murakoze cyane nanone kwitabira iki kiganiro. 

**Note:** *Record the District of residence, age, sex, level of education, and occupation for each participant* 

**SECTION A: USE OF E-ASCOV** 

Knowledge of the e-ASCOV application /Ubumenyi rusange ku ikoranabunga rya e-ASCOV mu gufata amakuru no guhangana n'icyorezo cya COVID-19

**1.** What do you think in general on the use of digital tool (e-ASCOV application) by CHWs for COVID-19 response?

Muri rusange mwadusngiza icyo mutekekereza ku ikoreshwas ry' ikoranabuhanga n'abajyanama bubuzima mu guhangana n'icyorezo cya COVID-19 ?

2. What expectations do you or did you have regarding e-ASCOV app?

3.	How confident are you with the use of e-ASCOV app by CHWs?
	Mwumva mwifitiye icyizere kingana iki (Ku ruhe rugero) kw'ikoreshwa neza ry'iri koranabunga e ASCOV?
Pe	rceived benefits, barriers and facilitators e-ASCOV
In	yungu , inzitizi n'ibishyigikira
4.	Can you describe the positive (perceived benefits) of e-ASCOV app? (Probe: contribution of ASCOV app in COVID-19 prevention and control)
ן ו ו	Aukurikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mwabonye mu gukoresh ibu buryo bwa e-ASCOV? ( Aha ndashaka kuvuga icyo ubu buryo bwaba bwarafashije mu cwirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19 ?
5.	What do you think are the negative experiences with e-ASCOV app?
•	Ni iki mwumva cyangwa se mubona kitagenze neza mugihe mwakoreshaga ubu buryo bwa e-ASCOV?
<b>6.</b>	What are the factors hindering (barriers) the use of e-ASCOV app? Mukurikije uko mubyumva, ni izihe mbogamizi mubona ku ikoreshwa ry'ubu buryo bwa e ASCOV ?
7. N r	Wat are the factors facilitating (enablers) the use of e-ASCOV app? Aukurikije uko mubyumva, ni iki mubona cyaba gifasha cyane cyangwa cyoroshya ikoreshwa y'ubu buryo bwa e ASCOV ?
Sa	tisfaction vis-à-vis the use of e-ASCOV app
Kı	unyurwa n'imikoreshereze y'ikoranabuhanga e-ASCOV
8.	What do you think about the use e-ASCOV app in the future? Do you have any suggestions improvement?
•	Mutekereza iki ku ikoreshwa ry'ubu buryo bwa e- ASCOV mugihe kiri imbere ? hari icyo mutekereza cyakogerwaho cyangwa cyakurwaho kuri ubu buryo bwa e-ASCOV kugirango burusheho gukora neza?
SE	ECTION B: TESTING COVID-19 DONE BY CHWS
Go n'	eneral perception on COVID-19 testing by CHWs /Gusuzuma COVID-19 bikozwe abajyanama b'ubuzima

IN	END OF THE
•	suggestions for improvement? Mutekereza iki ku gupima COVID-19 bikozwe n'abajyana b'ubuzima mugihe kiri imbere hari icyo mutekereza cyakogerwaho cyangwa cyakurwaho mu buryo bwo gupima COVID- bikozwe n'abajyana b'ubuzima kugirango burusheho gukora neza?
• 16	COVID-19 bikozwe n'abajyanama b'ubuzima . What do you think about the testing of COVID-19 by CHWs in the future? Do you have a
15	• Wat are the factors facilitating (enablers) the testing COVID-19 by CHWs?
14 •	• What are the factors hindering (barriers) the testing COVID-19 by CHWs? Mukurikije uko mubyumva, ni izihe mbogamizi mubona mu gusuzuma COVID-19 bikozy n'abajyanama b'ubuzima?
•	• what do you think are the negative experiences with testing COVID-19 by CHWs? Mukurikije uko mubyumva ni iki mubona kitagenze neza mu gusuzuma COVID-19 bikozy n'abajyanama b'ubuzima?
•	Mukurikije uko mubyumva, mwatubwira inyungu cyangwa se ibyiza mubona mu gusuzum COVID-19 bikozwe n'abajyanama b'ubuzima? (ahan ndashaka kuvuga icyo ubu buryo bwa bwarafashije mu kwirinda ndetse no gukurikirana abantu bafite iki cyorezo cya Covid-19 n'akamaro bifitiye abaturaRwanda)
12	• Can you describe the positive (perceived benefits) of testing COVID-19 by CHWs? (P contribution of COVID-19 testing by CHWs to COVID-19 prevention, control, and management)
Pe 1.	rceived benefits, barriers and facilitators e-ASCOV Inyungu , inzitizi n'ibishyigikira
	Mwumva mwifitiye icyizere kingana iki (kuruhe rugero) ku gupima COVID-19 bikozwe n'abajyanama b'ubuzima?
11	. How confident are you with COVID-19 testing done by CHWs?
	Ni iki mwari mwiteze cyangwa se nubu mucyiteze ku gusuzuma COVID-19 bikozwe n'abajyanama b'ubuzima?

# 25 Author reflexivity statement

This study was conceptualized, designed and led in collaboration with Rwanda Biomedical Centre and
Rwanda's Ministry of Health. Members of Rwanda Biomedical Centre and the Ministry of Health who
led this work are included as authors. The position of first author reflects the contribution of Ladislas
Nshimiyimana, NTD Research Senior Officer at Rwanda Biomedical Centre, to the work.

The study addresses local research and policy priorities in Rwanda. Rwanda's health system has a
 Vision for decentralized COVID-19 testing and there was interest in utilizing the country's strong CHW
 capacity to increase access to testing. This study aimed to realize these ambitions and the team designed
 an intervention that utilized the country's CHW workforce to deliver decentralized COVID-19 testing.

The study has contributed to improvements in local infrastructure, through the development and updating of a mobile application ("e-ASCov") to enable community-based screening and testing for COVID-19. The project also trained CHWs on using the digital tool and rapid tests to detect COVID-19 at the household-level.

Safeguarding procedures were implemented to protect local study participants and researchers. Firstly, the screening and testing intervention was conducted as part of routine Ministry of Health programming included in the CHW package of services. Several measures were taken to minimize the risk of infection for CHWs and other members of the household during community-based testing, as described in the manuscript. All CHWs taking part in the interviews or focus group discussions signed an informed consent form before participation. Liczoni 

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# **Supplementary Tables and Figures**

#### Supplementary Table 1. Overview of study districts

District	COVID-19 positivity rate (%)*	District population	Number of CHWs in district	Number of CHWs selected for the project (%)
Gasabo (urban)	2.0	530,907	1731	102 (6)
Nyarugenge (urban)	1.2	284,561	1135	100 (9)
Kirehe (Rural)	1.6	382,932	2587	99 (4)
Rusizi (Rural)	2.5	483,615	2298	99 (4)
Rubavu (Rural)	1.3	403,662	1990	100 (5)
Musanze (Rural)	5.9	368,267	1715	99 (6)
Nyagatare (Rural)	4.4	530,907	2531	100 (4)
Huye (Semi-urban)	8.3	328,398	2016	101 (5)
Total		3,313,249	16,003	800 (5)

\*Positivity rates as of September 2021, when the phase one commenced. a. Σ.

CHW, community health worker.

Characteristics		Number of respondents	%
Ease of using e-ASCov		•	
	Easy	291	83.4
	Slightly easy	49	14
	Difficult	9	2.6
Training package			
01 0	Satisfied	315	90.2
	Somehow		
	satisfied	31	8.9
	Not satisfied	2	0.6
Simplicity of e-ASCov application	Ttot Sullsiled	-	0.0
simplicity of c fibeot upplication	Fasy	297	85 1
	Slightly easy	277 47	13 5
	Difficult	5	1.5.5
Duration of the training	Difficult	5	1.4
Duration of the training	Sufficient	102	55 (
	Sumerelie	192	55.0
	Somenow	100	20 -
	sufficient	100	20.7
	Not sufficient	57	16.3
Equipment/supplies		215	00.0
	Satisfied	315	90.2
	Somehow	•	0.0
	satisfied	28	8.0
	Not satisfied	6	1.8
Access to internet			
	Good	171	49.0
	Somehow good	190	48.7
	Poor	8	2.3
Time used to enter client's data			
	Short	161	46.1
	Somehow short	116	33.3
	Long	72	20.6
Getting support			
	Satisfied	295	84.5
	Somehow		
	satisfied	42	12.0
	Not satisfied	12	3.5
Service delivery through e-ASCov			
v o o o o o o o o o o o o o o o o o o o	Satisfied	325	93.1
	Somehow		
	satisfied	22	6.3
	Not satisfied	2	0.6
Need for future use of e-ASCov	1 tot buildilleu	-	0.0
	Yes	349	100
Scale-up of e-ASCov to other disea	100	577	100.
Scale-up of e-ASCOV to other disea	Ves	2/18	00 -
	105	340	77.1

#### Supplementary Table 2. Respondent perceptions of e-ASCov
Characteristics		Frequency	%
Overall perception			
	Easy	313	89.
	Slightly easy	33	9.5
	Difficult	3	0.9
Training package			
	Satisfied	303	86.
	Somehow satisfied	40	11.
	Not satisfied	6	1.7
Duration of the training			
	Sufficient	202	57.
	Somehow sufficient	99	28.
	Not sufficient	48	13.
Equipment/Supplies			
	Satisfied	305	87.
	Somehow satisfied	36	10.
	Not satisfied	8	2.3
<b>Reading results of Ag-RDT</b>			
	Easy	326	93.
	Slightly easy	17	4.9
	Difficult	4	1.2
Entering results using e-AS	Cov app		
	Easy	296	84.
	Slightly easy	45	12.
	Difficult	8	2.3
Getting support			
	Satisfied	298	85.
	Somehow satisfied	40	11.
	Not satisfied	11	3.1
g-RDT, antigen-based rapid diagr	nostic tests.		

## 52 Supplementary Table 3. Respondent perceptions of CHW-led Ag-RDT testing

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

DISTRICT	All screened	Positive	Positivity rate (%)	Ag-RDT per district (%)	All reported positive cases	Contribution of CHWS (%) to confirmed cases
Gasabo	1,708	14	2.3	35.0	126	11.1
Huye	1,625	4	0.9	26.8	7	57.1
Kirehe	3,009	8	1	26.2	21	38.1
Musanze	2,549	13	2.3	22.1	18	72.2
Nyagatare	2,498	1	0.2	18.6	27	3.7
Nyarugenge	2,226	21	3	31.2	135	15.6
Rusizi	3,254		0.3	11.0	1	100
Rubavu	2,675	24	3.6	25.2	43	55.8
TOTAL	19,544	86	1.9	23.4	378	22.8



1 Umujyanama w'ubu	uzima Tangiza Ikizamini
	SD STANDARD" Q COVID-19 Ag Test
e ASC V	Ubwoko bw'isuzuma burakoreshwa SD STANDARD™ Q COVID-19 A Test
	Igihe cyo gubona ibisubizo 15 Iminota
uzamo KODE yawe	Kasete
li	Cowb-19
	Erekana amabwiriza kuri iri suzuma iya RDT
Injira	Gukomeza
	Sobanura Amobwieza Tarigin
	C 0 0

### **BMJ** Open



### **Supplementary References**

- 1. Wikimedia Commons. File:Rwanda Districts Map.jpg. Available from:
- https://commons.wikimedia.org/wiki/File:Rwanda\_Districts\_Map.jpg (accessed 16 August 2024).

Lorentering

# Reporting checklist for quality improvement in health care.

Based on the SQUIRE guidelines.

# Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the SQUIREreporting guidelines, and cite them as:

Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for

QUality Improvement Reporting Excellence): revised publication guidelines from a detailed

consensus process

Reporting Item

Page

Number

### Title

#1Indicate that the manuscript concerns an initiative to improve1healthcare (broadly defined to include the quality, safety,<br/>effectiveness, patientcenteredness, timeliness, cost, efficiency,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

### BMJ Open

1			and equity of healthcare)	
2 3 4	Abstract			
5 6 7 8		<u>#02a</u>	Provide adequate information to aid in searching and indexing	3
9 10		<u>#02b</u>	Summarize all key information from various sections of the text	3
12 13			using the abstract format of the intended publication or a	
14			structured summary such as: background, local problem,	
16 17			methods, interventions, results, conclusions	
18 19 20 21	Introduction			
22 23	Problem	<u>#3</u>	Nature and significance of the local problem	4
24 25 26 27	description			
27 28 29	Available	<u>#4</u>	Summary of what is currently known about the problem,	4-5
30 31 32	knowledge		including relevant previous studies	
33 34	Rationale	<u>#5</u>	Informal or formal frameworks, models, concepts, and / or	4-5
35 36 37			theories used to explain the problem, any reasons or	
38 39			assumptions that were used to develop the intervention(s), and	
40 41 42			reasons why the intervention(s) was expected to work	
43 44 45	Specific aims	<u>#6</u>	Purpose of the project and of this report	5
46 47 48	Methods			
49 50	Context	<u>#7</u>	Contextual elements considered important at the outset of	6
51 52 53			introducing the intervention(s)	
54 55 56	Intervention(s)	<u>#08a</u>	Description of the intervention(s) in sufficient detail that others	6-8
57 58			could reproduce it	
59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

Page 37 of 38

### BMJ Open

1 2 3	Intervention(s)	<u>#08b</u>	Specifics of the team involved in the work	6, 9
4 5	Study of the	<u>#09a</u>	Approach chosen for assessing the impact of the	6, 8, 9
6 7 8 0	Intervention(s)		intervention(s)	
9 10 11	Study of the	<u>#09b</u>	Approach used to establish whether the observed outcomes	6, 8, 9
12 13 14	Intervention(s)		were due to the intervention(s)	
15 16	Measures	<u>#10a</u>	Measures chosen for studying processes and outcomes of the	8-9
17 18			intervention(s), including rationale for choosing them, their	
19 20			operational definitions, and their validity and reliability	
21 22 22	Magguroo	#10b	Description of the approach to the approximation approximation	0 0
25 24 25	Measures	<u>#100</u>	Description of the approach to the origoing assessment of	0-9
25 26			contextual elements that contributed to the success, failure,	
27 28 20			efficiency, and cost	
29 30 31	Measures	<u>#10c</u>	Methods employed for assessing completeness and accuracy	10
32 33 34			of data	
35 36 27	Analysis	<u>#11a</u>	Qualitative and quantitative methods used to draw inferences	8-9
37 38 39			from the data	
40 41 42	Analysis	<u>#11b</u>	Methods for understanding variation within the data, including	8-9
43 44 45			the effects of time as a variable	
46 47	Ethical	<u>#12</u>	Ethical aspects of implementing and studying the	9
48 49 50	considerations		intervention(s) and how they were addressed, including, but not	
50 51 52			limited to, formal ethics review and potential conflict(s) of	
53 54			interest	
55 56 57	Results			
58 59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

1 2		<u>#13a</u>	Initial steps of the intervention(s) and their evolution over time	Figures
3 4			(e.g., time-line diagram, flow chart, or table), including	and 2
5 6 7			modifications made to the intervention during the project	
8 9 10		<u>#13b</u>	Details of the process measures and outcome	10-13
11 12 13		<u>#13c</u>	Contextual elements that interacted with the intervention(s)	12-13
14 15 16		<u>#13d</u>	Observed associations between outcomes, interventions, and	10-13
17 18 19			relevant contextual elements	
20 21		<u>#13e</u>	Unintended consequences such as unexpected benefits,	12-13
22 23 24			problems, failures, or costs associated with the intervention(s).	
25 26 27		<u>#13f</u>	Details about missing data	11
27 28 29 30	Discussion			
31 32 33	Summary	<u>#14a</u>	Key findings, including relevance to the rationale and specific	14
34 35 36			aims	
37 38 39	Summary	<u>#14b</u>	Particular strengths of the project	14-15
40 41 42	Interpretation	<u>#15a</u>	Nature of the association between the intervention(s) and the	13
42 43 44			outcomes	
45 46 47	Interpretation	<u>#15b</u>	Comparison of results with findings from other publications	13, 15
48 49 50	Interpretation	<u>#15c</u>	Impact of the project on people and systems	15-16
51 52 53	Interpretation	<u>#15d</u>	Reasons for any differences between observed and anticipated	15-16
54 55 56			outcomes, including the influence of context	
57 58	Interpretation	<u>#15e</u>	Costs and strategic trade-offs, including opportunity costs	15
59 60		For p	eer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	

Page 39 of 38

BMJ Open

1 2 3	Limitations	<u>#16a</u>	Limits to the generalizability of the work	15	
4 5	Limitations	<u>#16b</u>	Factors that might have limited internal validity such as	15	
6 7			confounding, bias, or imprecision in the design, methods,		
8 9 10			measurement, or analysis		
11 12 13 14	Limitations	<u>#16c</u>	Efforts made to minimize and adjust for limitations	15	
15 16 17	Conclusion	<u>#17a</u>	Usefulness of the work	15-16	
18 19 20	Conclusion	<u>#17b</u>	Sustainability	15-16	
21 22 23	Conclusion	<u>#17c</u>	Potential for spread to other contexts	15-16	
24 25 26	Conclusion	<u>#17d</u>	Implications for practice and for further study in the field	15-16	
27 28 29	Conclusion	<u>#17e</u>	Suggested next steps	15-16	
30 31	Other				
32 33 34	information				
35 36 37	Funding	<u>#18</u>	Sources of funding that supported this work. Role, if any, of the	17	
38 39			funding organization in the design, implementation,		
40 41 42			interpretation, and reporting		
43 44	None The SQUIR	E 2.0 cł	necklist is distributed under the terms of the Creative Commons At	tribution	
45 46 47	License CC BY-NC 4.0. This checklist can be completed online using https://www.goodreports.org/, a				
47 48 49 50 51 52 53 54	tool made by the E	EQUAT	OR Network in collaboration with Penelope.ai		
55 56 57 58 59 60		For p	eer review only - http://bmiopen.bmi.com/site/about/quidelines.xhtml		
		1			