

The SwissCovid Digital Proximity Tracing App after one year: Were expectations fulfilled?

Paola Daniore^{a,c}, Tala Ballouz^b, Dominik Menges^b, Viktor von Wyl^{a,b}^a Institute for Implementation Science in Health Care, University of Zurich, Switzerland^b Epidemiology, Biostatistics and Prevention Institute, University of Zurich, Switzerland^c Digital Society Initiative, University of Zurich, Switzerland

Summary

Digital proximity tracing has been promoted as a major technological innovation for its potential added benefits of greater speed, wider reach and better scalability compared with traditional manual contact tracing. First launched in Switzerland on 25 June 2020, the SwissCovid digital proximity tracing app has now been in use for more than one year. In light of this milestone, we raise the questions: What is currently known about the role of SwissCovid in mitigating the pandemic? Were the expectations fulfilled?

In this review, we will summarise the current state of the literature from empirical studies on the adoption, performance and effectiveness of SwissCovid. The review consists of three sections. The first section summarizes findings from effectiveness studies, which suggest that SwissCovid exposure notifications contributed to preventive actions in 76% of exposure notification recipients and were associated with a faster quarantine time in some SwissCovid user groups. The second describes the public perception and current state of adoption of SwissCovid in Switzerland in light of prevalent misconceptions and overemphasised expectations. The third places the evidence on SwissCovid in an international context. Specifically, we compare key performance indicators of SwissCovid, which are of similar magnitude as for digital proximity tracing apps from other European countries. Using findings from Switzerland, we subsequently derive a preliminary measure of the population-level effectiveness of digital proximity tracing apps. We estimate that exposure notifications may have contributed to the notification and identification of 500 to 1000 SARS-CoV-2-positive app users per month. We explore why this effectiveness estimation is somewhat lower when compared with Germany or the United Kingdom.

In light of the presented evidence, we conclude that digital proximity tracing works well in specific contexts, such as in mitigating non-household spread. However, future applications of digital proximity tracing should invest into stakeholder onboarding and increased process automatization

– without deviating from the principles of voluntariness and user privacy.

Introduction

One year after the public launch of SwissCovid on 25 June 2020, the app had 1.7 million users, and 83,000 positive test results have been entered into the app to trigger exposure notifications among close contacts. What can these numbers, as well as findings from other studies, tell us about the effectiveness of SwissCovid in preventing further transmissions? How do these data compare internationally? This review summarises how effectiveness of digital proximity tracing apps can be conceptually defined and presents the current state of empirical research on SwissCovid effectiveness by considering relevant data from other European countries.

The state of research about SwissCovid: What do we know after 12 months?

Around the time of the public launch of SwissCovid, a consortium of Swiss researchers developed a research agenda for a comprehensive evaluation of digital proximity tracing apps [1]. The proposed agenda rested on three postulated main advantages of digital proximity tracing apps over manual contact tracing: (1) digital proximity tracing should be able to warn exposed contacts faster than manual contact tracing, (2) digital proximity tracing should be able to reach exposed contacts who are not personally known to the infected index case, and (3) digital proximity tracing should still function properly in case manual contact tracing reaches capacity limits due to the automatic notification of exposed contacts. Concrete evaluation projects into the three postulated advantages started soon after the SwissCovid launch and were facilitated by sustained collaborations with other ongoing, nationwide research projects on the SARS-CoV-2 pandemic, such as the COVID-19 Social Monitor [2] and Corona Immunitas [3], which includes the Zurich SARS-CoV-2 Cohort [4].

Regarding the first potential advantage – the faster notification of exposed contacts – an analysis from the Zurich SARS-CoV-2 Cohort study [5] of 328 cases and 261 close contacts suggested that contacts notified by the Swiss-

Correspondence:
Prof. Viktor von Wyl, PhD
Institute for Implementation
Science in Health Care
University of Zurich
CH-8006 Zurich
viktor.vonwyl[at]uzh.ch

Covid app about their risk exposure in non-household settings entered quarantine on average 1 day earlier than contacts who did not receive an app notification. Although the underlying reasons for this time difference are still under investigation, the findings suggest that one in five persons who were notified by the digital proximity tracing app received the exposure notification before being reached by manual contact tracers. By contrast, notification of same-household contacts was comparatively faster than in non-household settings both for persons who received or did not receive an exposure notification, with no significant time difference being found. This analysis was conducted in the well-documented setting of a prospective cohort study and controlled for different confounders, including factors associated with app usage. Nevertheless, residual confounding could not be fully accounted for.

To investigate the second potential advantage – whether digital proximity tracing is able to reach and notify more persons than manual contact tracing – data from the Zurich SARS-CoV-2 Cohort study was less useful since it included only exposed contacts who were also identified by manual contact tracing. However, an analysis using data from the COVID-19 Social Monitor [2] from 2403 respondents (published as a pre-print [6], under peer review) provides further insights in this respect. In this study, 29 (1.2%) participants received a SwissCovid exposure notification. Among these, 22 (76%, 95% confidence interval [CI] 60–92%) took at least one mitigative action after receiving the exposure notification. Twenty respondents who received an exposure notification sought testing, among whom 6 (30%, 95% CI 12–54%) were tested positive for SARS-CoV-2 afterwards. This is over three times more than the proportion of SwissCovid app users who got tested without receipt of an exposure notification (8.0%, 95% CI 5.0–11.9%). A 30% test positivity rate upon receiving a SwissCovid exposure notification is likely an overestimation when applied to the wider population, but it can nevertheless be interpreted as an indication that persons who received an exposure notification could have had a relevant exposure risk.

The third possible advantage of digital proximity tracing – its potential for scalability in the face of rising SARS-CoV-2 case numbers – was also explored by further studies. A recent study [7] simulated the notification cascade using aggregated, publicly available data and research data to quantify the effect of SwissCovid on pandemic mitigation in the Canton of Zurich for the 537 app users who received a positive SARS-CoV-2 test result in the month of September 2020. The study found that SwissCovid could have led to an equivalent of 5% of all persons in manual contact tracing-mandated quarantine in Zurich to enter self-quarantine as a result of receiving a voluntary quarantine recommendation after an exposure notification. Moreover, the study also revealed that 30 persons tested positive for SARS-CoV-2 following an exposure notification.

However, this study also demonstrated challenges in adapting the app notification cascade to the steeply increasing case numbers in the second half of October 2020. Its findings revealed that the SwissCovid digital proximity tracing notification cascade did not scale as hoped with rising SARS-CoV-2 incidence. This was observed in the

ratio of entered CovidCodes (i.e., the codes entered by SARS-CoV-2-positive individuals to trigger exposure notifications for exposed contacts) over the number of SARS-CoV-2 cases, which dropped from 16.3% in September 2020 to 12.4% in the second half of October 2020 in Switzerland. Similarly, 6 in 10 digital proximity tracing app users who tested positive for SARS-CoV-2 entered a CovidCode in September 2020, but this ratio dropped closer to 4 in 10 app users in October 2020. During this time, manual contact tracing reached capacity limits, which may have affected the generation of CovidCodes and contributed to bottlenecks in enabling efficient functioning of the app. Similar trends were observed for further performance indicators evaluated in the study, such as the number of calls made to the infoline per entered CovidCode.

In the meantime, several measures have been taken to mitigate the bottlenecks related to the CovidCode generation process. Prior to October 2020, issuing of CovidCodes was linked to manual contact tracing. Specifically, it relied on contact tracers identifying whether a SARS-CoV-2 case required a CovidCode during the initial contact tracing call and if so, on them transferring that information to the person responsible for generating the codes. In October 2020, this process was separated from manual contact tracing in some cantonal health departments (among which was Zurich), where infected persons could directly request CovidCodes via text messages [8]. Additionally, the network of healthcare professionals who could generate and issue CovidCodes was widened, and the infoline was scaled up to handle higher call volumes. Additional reasons for delays in CovidCode generation were the processing and turn-around times of SARS-CoV-2 polymerase chain reaction (PCR) tests. The wider availability of SARS-CoV-2 rapid antigen tests starting from November 2020 could have also had a positive influence on the speed of the notification cascade, as evidenced by improvements in the time from symptom onset to CovidCode upload in persons who tested positive for SARS-CoV-2 [9].

Possible reasons for the prevalent scepticism about SwissCovid

Preceding the launch of the SwissCovid app, digital proximity tracing was discussed favourably in Swiss media, possibly the result of an inherent sense of trust in the technology enabled by the Swiss Federal Institutes of Technology in Zurich and Lausanne (ETHZ and EPFL) taking the lead in the development of the app [10]. The press, however, also expressed concerns over certain aspects, such as data governance or the possible involvement of major tech companies in the development and hosting of SwissCovid. Following the public roll-out of SwissCovid, challenges with its functionalities started to surface. In response, press coverage became more critical [11], and the initial enthusiasm about the app started to wane, as reflected by a stagnation of the number of active app users in autumn 2020 [12].

The rising doubts and challenges around SwissCovid were also mirrored in regular surveys from the COVID-19 Social Monitor. A detailed analysis based on data collected from 1511 Swiss residents since the app's release from June to October 2020 [13] reported that 45.5% of the re-

spondents were not currently using and had no intention to use the app, 3.5% were not using but had the intention to use it at a later point in time, 46.5% were already using it, and 4.4% had already uninstalled it. Among those who reported not using the app, lack of perceived benefits was expressed as a major reason for not using it (37% of all non-users), followed by the lack of a compatible phone (23%) and privacy concerns (22%). In addition, the study noted a stark increase in the number of active app users following a surge in daily case numbers, as well as with the release of a new SwissCovid version that enabled compatibility with older iOS versions in December 2020 [14]. The study concluded that removing technical hurdles and addressing citizens' concerns about app usefulness and privacy might further increase app uptake.

Another Swiss study [15], conducted in July 2020, applied a typology-based approach to group 1535 survey respondents into refusers, ditherers (preference to wait to install the app), adopters and de-adopters (uninstalled the app). Of note, this study found a similar proportion of app users ("adopters", 51.2%) and de-adopters ("uninstallers", 3.9%) as in the COVID-19 Social Monitor cohort. The study authors also emphasised the importance of specific approaches to communicating with app (non-)users to address concerns and information gaps, with a specific focus on ditherers, in order to persuade them to install the app.

As revealed by the different media analyses and surveys covering SwissCovid, there were and likely still are misconceptions about the role of and basic requirements for the app to help mitigate the pandemic. In an early modelling study led by the University of Oxford [16], the minimum app coverage required to contain pandemic spread in the absence of other mitigation measures was estimated at 60% of the United Kingdom population. Unfortunately, this value was interpreted by many as an absolute threshold. Therefore, the comparatively lower proportion of SwissCovid app users in Switzerland (see section below), as well as emerging procedural challenges [17] (e.g., problems in receiving CovidCodes), were met with disappointment by the public and the media. Yet, other studies [18] suggested that, in conjunction with other pandemic mitigation measures, an app coverage of 20% should already lead to noticeable mitigative effects on the pandemic.

In hindsight, the lingering doubts regarding the usefulness and privacy of the SwissCovid app should have been approached by more targeted communication efforts that elucidate the benefits and provide assurance regarding privacy measures taken within the app. Meanwhile, the privacy-preserving nature of the app also makes the evaluation of its effectiveness rather complex, as SwissCovid does not reveal any individual-level information about the user, exposure risks or how the app is utilised. In the future, the intended role of and realistic expectations around digital proximity tracing, as well as privacy measures and accumulating evidence of digital proximity tracing effectiveness from peer-reviewed studies, should be emphasised more clearly in lay communications to the public, in order to create a more positive perception of digital proximity tracing and increase their adoption.

SwissCovid from an international perspective

Downloads and utilisation of digital proximity tracing apps across different countries

As of 15 June 2021 – almost 1 year after its launch – the SwissCovid app has been downloaded more than 3.1 million times (corresponding to 36% of 8.6 million Swiss inhabitants, assuming a single download per person) and had approximately 1.7 million active users. Furthermore, 83,000 users have entered a CovidCode in the app, and the infoline has been contacted 69,000 times either by telephone or through web forms ("Leitfaden SwissCovid") following the receipt of a SwissCovid exposure notification [12]. By comparison, the German "Corona-Warn-App" was downloaded 28.3 million times (34% of the population of total 83 million) and sent exposure notifications following 478,000 positive test results [19]. In the Netherlands, there were 4.96 million app downloads (28.7% of the total population of 17.3 million) and 178,000 issued exposure notifications [20]. In the United Kingdom, 25.3 million app downloads have been registered as per June 2021 in a population of 59.5 million inhabitants, corresponding to 42.5% of the population [21].

When the number of triggered exposure notifications for cases who tested positive for SARS-CoV-2 on a per capita basis is assessed, Switzerland had 965 exposure notification triggers per 100,000 inhabitants, Germany had 900 exposure notification triggers per 100,000 inhabitants, and the Netherlands had 1029 exposure notification triggers per 100,000 inhabitants. However, the Netherlands launched their app only in October 2020, whereas the Swiss and the German apps were launched in June 2020 [22]. Information on per capita exposure notifications in the United Kingdom is available in the publication by Wymant and colleagues [18] for the period from September to December 2020. The authors reported 560,000 exposure notification triggers in this time, which is equivalent to 941 exposure notifications per 100,000 inhabitants (in a population of 59.4 million inhabitants) for the assessed time frame. This data suggest that the current cumulative per capita number of exposure notifications is likely substantially higher in the United Kingdom.

These preliminary international comparisons demonstrate that SwissCovid has reached an adoption rate and frequency of sending exposure notifications upon positive SARS-CoV-2 test results that is comparable to those of other countries that are operating well-established digital proximity tracing apps as part of their pandemic response.

International effectiveness studies

Monitoring data is, however, not fully informative with respect to the main question regarding the real-world contribution of digital proximity tracing apps to pandemic mitigation. A recent study from the United Kingdom investigated the impact of the National Health Services (NHS) COVID-19 app on mitigating pandemic spread between September and December 2020 [18]. In that time, the app sent out 1.7 million exposure notifications, corresponding to 4.2 exposure notifications per SARS-CoV-2-positive case. In their analysis, the researchers made use of residential postal code data that users entered to book SARS-CoV-2 test appointments through the app.

This allowed them to conduct regionally stratified investigations to assess the relationship between app usage and SARS-CoV-2 incidence. The authors concluded that the app prevented several hundreds of thousands of cases, ranging from 284,000 cases (range of sensitivity analyses 108,000–450,000) to 594,000 (95% CI 317,000–914,000), estimated by mathematical modelling and statistical comparison of matched neighbouring local authorities, respectively.

The Robert Koch Institute also recently stated in a press release that the German Corona-Warn-App has been able to avert around 100,000 cases [23]. Unfortunately, no details on the analysis were provided. This study was also informed by app monitoring and incidence data, as well as post-notification surveys. With this data, it assumes that through 4000 persons triggering an exposure notification on a given day during the third pandemic wave, between 20,000 and 40,000 app users were warned. Among these, 80% (16,000 to 32,000) got tested afterwards, leading to an additional daily detection of 1000 to 2000 infected individuals, when a secondary attack rate of 6% is assumed.

An attempt to measure population-level effectiveness for Switzerland

The emergence of international effectiveness studies prompts the question as to whether similar assessments can be performed for Switzerland. Of note, in the time between the first and the second pandemic waves (July to October 2020), there were two studies that attempted to assess the population-wide impact of SwissCovid before the second wave (i.e., up to October 2020) for Switzerland [17] and the Canton of Zurich [7]. Both studies indicated that at least some exposed contacts seek SARS-CoV-2 testing after receiving an exposure notification and subsequently test positive.

However, additional challenges arise when an estimation of the population-level effectiveness of the SwissCovid digital proximity tracing app is attempted for later phases of the pandemic. For example, routinely collected data used in earlier analyses are currently no longer being recorded. The mandatory reporting by treating physicians of testing reasons (including SwissCovid exposure notifications) for persons with a positive SARS-CoV-2 test was put on hold in November 2020 and has not been resumed since. Furthermore, testing reasons for persons who tested negative were never centrally recorded. Therefore, the lack of consistent data reporting severely affected the possibilities to assess the population impact of SwissCovid during and after the second pandemic wave.

Despite these difficulties, we attempt to provide a simplified population impact analysis using survey-based data, which have been continuously available throughout all pandemic waves. The following calculations are intended to provide a rough projection of the population-wide impact of SwissCovid in pandemic mitigation and should thus be interpreted with caution. Specifically, we aimed to estimate the number of persons who tested positive after receiving an exposure notification. We focused on the time frame from 1 January to 30 April 2021. During this time, around 21,700 exposure notifications were triggered, leading to the completion of 22,600 web forms (“Leitfaden SwissCovid”) or calls to the infoline (that is, measurable

actions by notified contacts; $n_{\text{leitfaden}}$ in formula below), and 1600 quarantine recommendations [12]. Overall, there were 206,000 positive SARS-CoV-2 tests recorded and average test positivity over the four months was 7.5% (varying from almost 20% in January to 5% in April 2021; $\%_{\text{test.positivity}}$ in the formula below).

Two essential additional parameters were extracted from ongoing research studies, namely the proportion of all exposure-notified contacts who stated that they had completed the web form or called the infoline ($\%_{\text{completer}}$; used to back-calculate the number of individuals receiving an exposure notification), as well as the percentage of exposure-notified persons who sought testing ($\%_{\text{tested}}$). Given these data, we were able to estimate the number of positive cases that were detected after receiving exposure notifications (EN) as follows:

$$n_{\text{pos.cases.after.EN}} = [N_{\text{leitfaden}} / \%_{\text{completer}}] * \%_{\text{tested}} * \%_{\text{test.positivity}}$$

The Corona Immunitas [3] and COVID-19 Social Monitor [6] studies provide varying estimates for the percentage of completers (50% and 25%, respectively) and the percentage of those who sought testing (around 60% in both studies). Therefore, by applying the $\%_{\text{completer}}$ estimates from both studies in the formula above we arrive at an estimated range of 2034 to 4068 of SARS-CoV-2-positive individuals detected after exposure notifications from January to April 2021 in Switzerland. Compared with the overall number of positive tests during the same period, this amounts to a contribution of 1–2% of all identified positive cases, which is of similar magnitude to the one reported for Switzerland in a previous analysis for the time-frame September to October 2020 [7].

An alternative approach for estimating the effectiveness of digital proximity tracing apps relies on calculating a “multiplier” of the number of exposure notifications sent per trigger (i.e., per uploaded CovidCode for SwissCovid). A Swiss study [7] estimated this multiplier to be between 2.5 (all of Switzerland) and 4.2 (Canton of Zurich) exposure notifications per trigger. Meanwhile, a study from the United Kingdom [18] estimated the magnitude of the multiplying effect at 4.2 exposure notifications per trigger, and German approximations [23] imply a multiplier ranging between 5 and 10. Given these estimates, the number of individuals who tested SARS-CoV-2-positive after exposure notification (EN) can be estimated as follows:

$$n_{\text{pos.cases.after.EN}} = [N_{\text{triggers}} * N_{\text{warnings.per.trigger}}] * \%_{\text{tested}} * \%_{\text{test.positivity}}$$

Applying this alternative approach, we estimated the number of positive tests after exposure notifications in Switzerland to be in the range of 2441 (Swiss national multiplier) to 4101 (Canton of Zurich multiplier) from January to April 2021, which is almost identical to the estimates calculated with the first approach. By comparison, the German analysis claims that between 110,000 and 230,000 positive tests were detected after exposure notifications, amounting to between 3.8% and 7.9% of all 2.9 million positive tests between 1 June 2020 and June 15, 2021. Of note, the German study assumes a significantly higher number of notified contacts per exposure notification trigger than other countries (5 to 10, compared with 4.2 exposure notifications in the United Kingdom and in Switzer-

land). In addition, applying data from the United Kingdom study yields an approximation of 141,000 positive tests after exposure notifications between September and December 2020, or 7.5% of 1,892,000 overall positive cases, based on 560,000 reported exposure notification triggers, 4.2 warned contacts, 6% test positivity and assuming that all notified contacts got tested.

Although covering different time periods, these results suggest that the number of averted cases as a result of exposure notifications are lower in Switzerland than in other European countries, despite having similar estimates of test positivity and number of contacts informed per triggered exposure notification as the United Kingdom. However, notable differences between countries emerge when the number of exposure notification triggers per infected cases is considered. In the United Kingdom, 560,000 exposure notifications were triggered by SARS-CoV-2-positive individuals, corresponding to 29.6% out of 1,892,000 persons tested positive between September and December 2020. In contrast, only 21,700 exposure notifications (10.5%) were triggered in a total population of 206,000 persons testing positive in Switzerland between January and April 2021 (or 11% for the period between June 2020 and June 2021). In Germany, 474,500 exposure notifications were triggered out of 2.9 million positive cases (16.4%) between June 2020 and June 2021. In other words, Switzerland had a lower proportion of positive tests, which led to a lower exposure notification trigger than its European counterparts.

In turn, the number of exposure notification triggers is a function of the percentage of app users in the population, as well as the percentage of users receiving and entering the upload authorisation codes. As previously discussed, among the European countries assessed, the percentage of app downloads in comparison with the population size is highest in the United Kingdom (42.5%), followed by Switzerland (36%) and Germany (34%). In addition, data from the SwissCovid monitoring website [12] suggest that only 64% of all generated upload authorisation codes were entered. That is, one in three codes were never used. For the United Kingdom and Germany, the respective percentages of entered codes were 72% and 61%.

Therefore, the lower per capita and per SARS-CoV-2 case-adjusted *effectiveness*, when defined as the identification of secondary positive cases after exposure notifications, in Switzerland seems to have explanations different from its European counterparts. Effectiveness in the United Kingdom was likely higher as a result of better nationwide app adoption and fewer lost exposure notifications, whereas effectiveness estimates in Germany may be linked to the assumption that more than twice as many contacts are notified per exposure notification trigger. The latter likely also reflects less conservative settings in Bluetooth signal-based exposure determination [24].

Limitations of current effectiveness studies

By design, decentralised digital proximity tracing (as implemented in the Netherlands, United Kingdom, Germany and Switzerland) provides no individual-level information on the number of informed contacts or actions taken after receiving an exposure notification. As revealed by our detailed analysis of the Zurich SARS-CoV-2 Cohort study

data [5] and the Covid-19 Social Monitor [6], not all exposure notifications directly lead to preventive actions among exposure notification recipients. For example, the Zurich SARS-CoV-2 Cohort analysis found that the potential speed advantage in alerting exposed contacts, relative to manual contact tracing, only became apparent in non-household settings. Moreover, numerous notified contacts reported not having responded to the warning because they were already in quarantine or had already been warned by other means. The Zurich SARS-CoV-2 Cohort analyses clearly describe temporality (e.g., relative to manual contact tracing) within different infection risk contexts (e.g., household, non-household); however, a direct inference of transmission prevention from exposure notifications requires strong assumptions to be made. Estimations of population-level effectiveness in transmission prevention are also made difficult owing to the inconsistent availability of data from cases in Switzerland on the testing reason, including receipt of an exposure notification from the SwissCovid app, as well as large sample size requirements.

The same applies to the available effectiveness studies from the United Kingdom and Germany, which do not provide any insights as to whether the exposure notification was truly the first and/or only warning source – even for persons who tested positive after receiving exposure notifications. Although the United Kingdom study attempts to adjust for some of these factors, the effectiveness estimates, including those from the German study, likely represent an upper bound of effectiveness.

Conclusion and outlook

Despite limitations in current studies and remaining knowledge gaps, the conclusion that digital proximity tracing apps have had a measurable impact on pandemic transmission prevention appears robust. This notion is also highlighted by our individual-level analyses of the notification cascade, which suggest a causality between exposure notifications and preventive actions taken by exposed contacts for some (but not all) persons who received an exposure notification [5, 6]. It is worthwhile to remember that the removal of potentially infectious cases from transmission chains through isolation and quarantine likely prevents further infections downstream. Our estimations indicate that SwissCovid led to the nationwide identification of approximately 500 to 1000 persons per month who tested SARS-CoV-2-positive after receiving an exposure notification (between January and April 2021). Furthermore, other Swiss studies suggest that 69% of all persons with an exposure notification sought testing for COVID-19 [6], and that exposure notifications triggered voluntary quarantine recommendations for the equivalent of 5% of all persons in manual contact tracing-mandated quarantine in the Canton of Zurich [7]. Based on this evidence, the contribution of SwissCovid to pandemic mitigation can clearly be deemed relevant.

Other less explored aspects of digital proximity tracing and manual contact tracing are the costs and cost-effectiveness of the measures. Compared with digital proximity tracing, manual contact tracing requires far more human involvement, leading to a lower potential for scalability. That is, reducing or increasing the size of the manual contact tracing workforce is attached to additional capacity

requirements (e.g., recruitment efforts, need for training, etc.). Therefore, it is plausible that the costs per identified SARS-CoV-2 case through digital proximity tracing-enabled exposure notifications may be lower than the costs of manual contact tracing. Furthermore, it should be re-emphasised that digital proximity tracing is complementary to manual contact tracing. That is, they should not be considered to be in competition with each other but should ideally complement the other's respective weaknesses (e.g., better scalability and wider reach – but fewer insights into transmission patterns and dynamics – in digital proximity tracing compared with manual contact tracing). In addition, manual contact tracing and digital proximity tracing may have a mutually reinforcing effect on compliance with quarantine measures.

The observed lacklustre perception among the public and healthcare professionals regarding digital proximity tracing app effectiveness, however, serves as a strong reminder that the ability of digital proximity tracing to achieve the goal of mitigating pandemic spread is not just a matter of technological capabilities and processes, but also of appropriate information, implementation and adoption. Exaggerated expectations, lack of understanding of the interplay of SwissCovid with other actors and parts of the healthcare system, or unclear responsibilities are examples of some of the problems that have affected the effectiveness of and undermined public trust in SwissCovid. Especially the processes for issuing CovidCodes and their timely transmission to infected individuals were identified as an important bottleneck that may have impeded SwissCovid from achieving its full potential. Improving app adoption is especially important as population effectiveness has been shown to scale with the number of active app users. For example, Wymant and colleagues estimate that a 1 percentage-point increase in app adoption could lead to a case reduction of 0.8% to 2.3% [18].

Throughout the the pandemic, responsible authorities have continuously adapted the technology and processes to optimise the performance of the (technical and non-technical) SwissCovid features. Past experiences in Switzerland, as well as those from other countries, strongly suggest that an increasing degree of digitalisation in the ordering of SARS-CoV-2 tests and communication of the results, the reporting of critical supplementary information on circumstances of positive SARS-CoV-2 tests by healthcare providers and testing laboratories, as well as automated processes for issuing CovidCodes may positively influence the speed of the digital proximity tracing notification cascade. Such technical optimisations have already been implemented through initiatives by health authorities and healthcare providers. It remains to be hoped that a continued push for digitalisation of the Swiss healthcare system will facilitate future applications of digital proximity tracing and reporting of critical infectious disease events (e.g., new cases or hospitalisations), thus requiring less human involvement from front-line clinical and public health personnel.

Further adjustments to the SwissCovid app and its health system implementation will be needed in the coming months to adapt the system to the ever-changing nature of the pandemic. Developments, such as the occurrence of new variants of concern, as well as the broad availability

and administration of SARS-CoV-2 vaccines, may require ongoing revisions regarding the future role of the SwissCovid app in pandemic response. Depending on the future course of the SARS-CoV-2 pandemic, it may be wise to promote the use of SwissCovid, especially during periods where SARS-CoV-2 cases are expected to rise. As vaccination rates increase in the coming months, lower attack rates are to be expected. Nevertheless, although current vaccines offer strong protection against the known SARS-CoV-2 variants, infections (and viral shedding) are still a possibility [25]. It is also to be assumed that non-vaccinated populations will remain prevalent in the coming months until more long-term clinical evidence on the risks and benefits of SARS-CoV-2 vaccines are available. Therefore, the SwissCovid app could exercise a useful role – even in a largely vaccinated population – to warn proximity contacts about a possible exposure to SARS-CoV-2 and to trigger actions in order to prevent community transmission. Recommendations for such preventive measures could include seeking PCR testing, wearing masks and avoiding personal contacts, but they should be defined and updated in accordance with the latest scientific evidence, while taking transmission- and immune-invasive characteristics of circulating SARS-CoV-2 variants into account.

To conclude, there is solid evidence that digital proximity tracing in Switzerland and elsewhere has successfully notified persons at risk and contributed to pandemic mitigation. However, it is important to set the right expectations regarding the effectiveness of digital proximity tracing apps. Such technologies are not a magic bullet and may not exert an impact in all settings and contexts. However, we have convincing evidence that digital proximity tracing apps work well in specific contexts, such as in mitigating non-household spread. Future applications of digital proximity tracing should invest more resources into the onboarding and education of relevant stakeholder groups, including public and health system actors, clearly define their role within pandemic management, and strive to automate procedures to the highest possible degree – without deviating from the principles of voluntariness and user privacy.

Disclosure statement

VvW had a mandate from the Federal Office of Public Health (FOPH) to evaluate the SwissCovid app. This review was written on our own initiative, and the views are those of the authors.

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