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Social determinants of Covid-19 infection and death in a rural Indonesia

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Social determinants of Covid-19 infection and death in a rural Indonesia

Abstract

Objectives This study aims to examine social determinants of Covid-19 infection and death in the context of rural Indonesia.

Design A non-random cross-sectional study.

Setting Population in 390 villages in Malang District, East Java Province, Indonesia.

Participants We used Malang district government Covid-19 contact tracing data from 14,264 individuals, spanning from March 1, 2020 to July 29, 2020.

Primary outcome measures The outcome variables in this study are Covid-19 infections and Covid-19 deaths. The associations between individual and village-level determinants with Covid-19 infection and death were analysed using multilevel logistic regression.

Results Among the 14,264 samples, we found that 551 individuals were confirmed as being infected with Covid-19, and 62 individuals died of Covid-19. Older age was associated with higher Covid-19 risk infection. Non-health workers civil servants (OR=6.63, 95% CI 2.74 to 16.03), and those with close contact with confirmed cases (OR=18.39, 95% CI 11.94 to 28.33) had a higher likelihood of infection with Covid-19. Greater numbers of community-based healthcare interventions (OR=0.98, 95% CI 0.97 to 0.99) and a lesser distance to a pandemic epicentre (OR=0.92, 95% CI 0.91 to 0.94) reduced the likelihood of infection with the virus. In addition of age, being males (OR=8.19, 95% CI 1.41 to 47.47), diagnosed with hypertension, pneumonia, and respiratory failure were associated with higher likelihood of death due to Covid-19. Further distance to a Covid-19 referral hospital increases the risk of death among Covid-19 patients (OR=1.24, 95% CI 1.02 to 1.51).

Conclusions This study shows for the first time that the Covid-19 infection and death in rural Indonesia were not only related to individual characteristics but also the presence of community-based healthcare intervention and access to hospital care. Strategies in public health, including improving health care access, are required to reduce Covid-19 infections among the most susceptible groups in Indonesia.

Keywords: social medicine; public health; Covid-19

Strengths and limitations if this study:

- This study examines the association between sociodemographic characteristics, healthcare access and Covid-19 infection and died in a unique rural setting.
- Multilevel or hierarchical regression analyses were applied to take full advantage of the village clustering information available from the data.
- This is a rapid healthcare assessment which is based on four months of contact tracing data.
- Some of the variables in this study were based on retrospective data, especially regarding respondents' histories of heart disease and diabetes.

Introduction

Understanding social determinants of health and inequalities in Covid-19 infections and deaths is vital for the development of effective mitigation strategies [1, 2]. By identifying various social determinants of health such as age, sex, education, income, employment and living area as well as access to healthcare for infected individuals, we can determine conditions associated with infected individuals and those who die from Covid-19. Hence, we may be able to identify certain vulnerable groups in the community whose members are at high risk of infection and death due to the virus. Policymakers need this information to formulate early detection and mitigation strategies to protect the community from Covid-19 infection risks and, most importantly, to minimise the number of deaths caused by the virus.

Earlier studies in Wuhan, China have shown that certain types of jobs are related to Covid-19 infection. It has been reported that occupational groups at risk include workers (and visitors) at seafood and wet animal wholesale markets [3]. Health care workers have been recognised as another group at high risk of infection [3]. In Beijing, it was found that individuals who had close contact with people with confirmed cases, as well as those who had been to Wuhan, were at risk of infection [4-6]. Studies have also reported that male sex, older age, and comorbidities, especially cardiovascular metabolic diseases, confer a greater risk of death due to Covid-19 in

Wuhan [5, 6]. Covid-19 patients with diabetes had poorer outcomes than sex- and age-matched patients without diabetes. Older age and comorbid hypertension contributed independently to in-hospital deaths among patients with diabetes [7, 8].

While earlier studies in Wuhan and Beijing show that close contact is related to infection, recent studies in the US and UK have found different social determinants linked with Covid-19 infection. Yancy reported that African American or black people in New York City were contracting the virus at higher rates and were more likely to die than others [2]. Also, in New York City, Borjas found that people who lived in poor or immigrant neighbourhoods were more likely to become infected with Covid-19 than people who lived in wealthier and non-immigrant neighbourhoods [9]. In a recent study, Nasar and Hill reported disproportionate infection and mortality rates in Black, Asian and minority ethnic (BAME) communities in the UK [10]. Verhagen and colleagues have explained that hospitals in some areas of the UK face a disproportionate risk of excessive pressure due to Covid-19 as a result of socio-economic differences and the demographic composition of their populations [11].

Health disparities and socio-economic status are also linked with Covid-19 deaths in the US, UK and other wealthy countries. Richardson et al. reported patients in the New York City area with hypertension, obesity, and diabetes to be at high risk of death from Covid-19 [12]. In the UK and Italy, Covid-19 deaths have been mainly observed among older male patients with multiple comorbidities [13, 14]. A higher burden of comorbidities, male sex, and older age may be considered more substantial determinants of higher risk of death in Italy than in China [15]. These studies indicate that health disparities and socio-economic status seem to be important for Covid-19 infection in six high-income countries. These characteristics are aligned with demographic and epidemiological features in those countries.

As the pandemic spreads across the world, developing countries appear to be the disease's next target. The outbreak could devastate parts of those countries as they differ from wealthier countries in terms of demographic composition, the sources of people's livelihoods, and health system capacity. Covid-19 mitigation interventions applied in high-income countries may not fit developing countries. For example, as the largest numbers of deaths in high-income countries are taking place among older people, public health mitigation is focusing on care home mitigation and social care resilience strategies. With their younger populations, developing countries may consider different mitigation strategies. Hence, identifying social determinants of health and inequalities around Covid-19 infections and deaths in developing countries are very important for public health mitigation strategies.

Indonesia is a developing country and home to the world's fourth-largest population and second-largest urban area. With its huge population and weak healthcare system, some scholars and analysts predict that the country could be the next Covid-19 hot spot in Asia [16-18]. Currently, the WHO is reporting that Indonesia has the highest rate of Covid-19 infection and death among ASEAN countries [17, 19]. The number of Covid-19 cases has increased sharply each day since April 2020. As of December 30, 2020, as many as 727,122 cases have been officially confirmed in the country, with 21,703 deaths recorded thus far. The virus has spread to all of the country's 34 provinces. Java Island is the epicentre, with East Java and Jakarta, the country's largest region and its capital city, respectively, as the most densely infected areas. The number of total polymerase chain reaction (PCR) tests in the country is low at 26,275 tests per million individuals [19]; it is therefore probable that the actual number of infections is higher than the central government's official reported number. It is also expected that the number of cases will continue to increase as the government eases restrictions under the "new normal policy" in effect since the beginning of June 2020. With limited medical staff, hospital beds and intensive care facilities as well as a lack of government (especially local government) capacity to provide Covid-19 treatments and medications, early prevention and mitigation are particularly crucial in rural areas, where the deficit of Covid-19 health facilities and workers is significant. Densities of doctors and nurses in Indonesia are the second lowest among South East Asia countries, reaching 3.9 doctors per 10,000 population and 13,8 nurses per 10,000 in 2020 [20]. The number of hospital bed per 1,000 population is 1,1, lower than WHO requirement (minimum 3 beds per 1,000 population) [21].

In The Lancet Infectious Diseases, Ranscombe recently highlighted the need to take a systematic approach to tackling the Covid-19 crisis rather than focusing solely on urban areas [22]. He posited that the adoption of a systematic approach should include examining the socio-medical, socio-economic, and socio-political implications of confronting the pandemic in rural areas, which often have a significant scarcity of health facilities and workers for Covid-19 treatment as well as insufficient knowledge about Covid-19 infection. Accordingly, studies have shown huge disparities in healthcare access between rural and urban areas in Indonesia and other developing countries, a factor that is associated with citizens' health and well-being [22, 24]. Studies have also documented the differences between rural and urban Indonesia in terms of individual socio-economic characteristics that are associated with health status [23]. Thus, this study aims to examine whether those inequalities are associated with Covid-19 infection and death in rural Indonesia. To achieve that aim, the study addresses two questions. Firstly, which groups in rural Indonesia are most vulnerable to infection and death due to Covid-19? Identifying those most vulnerable to Covid-19 is crucial as the pandemic adds significantly to the pressure on fragile local health services. Under such conditions, we are likely to see a spread of human suffering and very high mortality rates. Secondly, what are the most important social determinants of health associated with Covid-19 infection and death in rural Indonesia? Following Marmot and Wilkinson, we define social determinants of health as the conditions under which people are born, grow, live, work and age and which determine their health [25]. Marmot and Wilkinson explain that social determinants of health include factors such as socio-demographic status, education, neighbourhood and physical environment, and employment as well as access to health care [25, 26]. To guide policymakers in formulating more focussed mitigation strategies, it is vital to identify the most important social determinants of health associated with Covid-19 infection and death in rural contexts.

Methods

Study design and settings

This study used a non-random cross-sectional design based on official Covid-19 tracing data collected by the Malang District Health Authority (DHA) from March 1 to July 29, 2020 and administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 [27]. This study was conducted in Malang District in East Java, Indonesia. Malang is located quite close to the city of Surabaya, which is currently the biggest Covid-19 epicentre in Indonesia. Malang area covers 3,535 square kilometres, with an agricultural emphasis on rice and sugar cane. Malang's total population of 2,544,315 is distributed across 33 sub-districts, 390 villages and 3,125 community neighbourhoods [28]. A subdistrict consists of come villages, and a village consists of some community neighbourhoods. The number of people in each village and community neighbourhood in Malang District on average are 6400 and 746, respectively [28].

Data sources

Covid-19 contact tracing data

Covid-19 contact tracing data were collected by the Malang DHA based on the Indonesian Ministry of Health Covid-19 prevention and control guidelines. Formal permission was given by the authority to analyse the data. The total number of individuals traced during from March 1 to July 29, 2020 was 14,264. This tracing data covered all population in Malang District (2,544,315 individuals). Covid-19 contact tracing refers to the process of identifying all individuals who fulfil one of these criteria: (1) having had contact with a confirmed Covid-19 patient within the previous two weeks, (2) having one of the Covid-19 symptoms; and (3) having travelled from one of the Covid-19 epicentre areas in Indonesia or abroad [29]. Close contact was identified by health workers in each village with criteria: those who live in the same household or who has been close to someone who has tested positive for Covid-19 [29].

The tracing was organised by the Malang DHA based on the Ministry of Health surveillance guidelines for SARS-CoV-2 infection (see **Supplementary materials**). Written informed consent was obtained by the Malang DHA from all individuals before data collection. Prior to interviewing, individuals were informed about the importance of participating in the contact tracing activities. Confidentiality and anonymity were ensured [31]. Malang contact tracers were selected by the Ministry of Health Covid-19 task force through recommendations from the provincial and district health authority team. Overall, 78 medical doctors and 780 nurses across 39 primary healthcare centres (*Pusat Kesehatan Masyarakat* or *Puskesmas*)/supporting primary healthcare centres (*Puskesmas Pembantu*) and 390 village health posts (*Pondok Kesehatan Desa* or *Ponkesdes*) have been employed for tracing services in Malang district. All recruited contact tracers underwent a thorough three-day training to learn and practice methods of detection, prevention, response and control for Covid-19 risk communication and Covid-19 case management. Thirty-nine additional Malang DHA staff members worked to facilitate the logging and cataloguing of data, coordinating logistics and checking the quality of filled Covid-19 surveillance forms.

During data collection, the tracing team members are equipped with several items of personal protective equipment for public screening, including hazardous material suits (Kodaichi Coverall), medical mask (N95 3M Type 9010), face shield (headgear with clear visor), surgical gloves (golden gloves latex), boots or closed work shoes, and hand sanitiser. They were also instructed to carry an infrared thermometer KODYEE CF-818, and the Covid-19 surveillance and monitoring forms provided by the DHA. Interviews with individuals suspected of carrying Covid-19 were conducted at a distance of 1.5 to 3 meters [31].

Contact tracing was conducted in several venues, but most interviews were conducted via home visit door-to-door tracing to suspect individuals who met one of the three criteria above. Based on the reports, the contact tracing team creates lists of triaged contact for further assignment. All individuals on the contact lists were notified by the contact tracing team before the team interviewed them in their houses or at secure locations such as a *Ponkesdes* office. Subsequently, nurses in each village are responsible for monitoring all contacts to which individual nurses were assigned for at least fourteen days. In addition, the team conducted Covid-19 tracing in several public places including bus stations, train stations, the local airport and other public gathering places to track people travelling from other cities or abroad.

The team refers patients with severe Covid-19 symptoms requiring inpatient services to a Covid-19 referral hospital. Patients receive a repeat reverse transcription polymerase chain reaction (RT-PCR) swab test at the hospital. Patients with only mild or no symptoms are tested using a rapid test. If the result of this first rapid test is negative, the patient is to self-isolate for 14 days and take another rapid test at the end of the self-isolation period. A second negative result on a rapid test shows that the individual was likely not infected at the time. Patients receiving a positive result from the second rapid test are required to undergo two RT-PCR swab tests on two consecutive days. If the RT-PCR swab test result is negative, an individual is likely not infected at the time. A positive result on an RT-PCR swab test confirms Covid-19 infection, and patients require protective steps to prevent others from becoming infected. If the first rapid test shows positive results, the patient is required to undergo two RT-PCR swab tests on two consecutive days. If the RT-PCR swab test result is negative, the individual is likely not infected at the time. If the RT-PCR swab test result is positive, the individual must take protective steps to prevent others from becoming infected. Confirmed Covid-19 patients with mild or no symptoms can self-isolate at home, while those with moderate and severe symptoms are referred to hospitals. Patients with positive rapid test, but negative RT-PCT swab test will not need to self-isolated. The procedures for Covid-19 tracing and testing are explained in the supporting information (**Supplementary materials**).

The Malang DHA provided a form to record information on every individual who died due to Covid-19. Mortality data are collected by all public and private hospitals in Malang district. Mortality data on individuals who died outside health facilities are collected by the village nurses on the form provided. The Malang DHA recorded the cause of death for every individual who died due to Covid-19 on the medical death certificate. The authority's elapsed time to obtain information on deaths due to Covid-19 is fourteen days [29, 31].

Indonesia's Village Potential Census (Podes) data 2020

We merged the contact tracing data with administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 (Podes) [27]. The Podes is a longstanding tradition of collecting data at the lowest administrative tier of local government. Podes consists of 83,931 villages (*desa*) across 514 districts in Indonesia. The census has been conducted every two years since 1983 by the Indonesian Central Bureau of Statistics (*Biro Pusat Statistik*). Detailed information is gathered on a range of characteristics from public infrastructure to village finances. Information is gathered from *kepala desa* (rural village heads) and *lurah* (urban neighbourhood heads). From the 2020 census, we retrieved the following data for each village: number of health workers, number of community-based healthcare interventions and number of indigenous socio-cultural activities as well as hospital access, poverty and distance to a Covid-19 epicentre city [27].

Variables

The outcome variables in this study are Covid-19 infections and Covid-19 deaths. RT-PCR) swab tests are used by the Malang District Health Authority to determine the presence of Covid-19 infection. The authority determines that an individual is infected if the RT-PCR swab test shows a positive result. The Indonesian Ministry of Health follows the WHO definition of death due to Covid-19 as a 'death resulting from a clinically compatible illness, in a probable or confirmed Covid-19 case, unless there is a clear alternative cause of death that cannot be related to Covid-19' (e.g., traffic accident or trauma) [31-33]. Deaths due to Covid-19 cannot attributed to another disease (e.g., cancer) and are counted independently of preexisting conditions that are suspected of triggering a severe course of Covid-19 (e.g., coronary artery disease, type 2 diabetes, or chronic obstructive pulmonary disease).

Following Marmot and Wilkinson, Tian et al. and WHO [4,25,26], we included individual socio demographic characteristics such as age, sex, and job types, number of community-based health interventions, village poverty, number of indigenous socio-cultural activities, distance to a Covid-19 referral hospital and distance to a Covid-19 epicentre city to measure the social determinants of health. Previous studies have documented that village poverty status and the number of community-based healthcare interventions are linked with access to healthcare [34-36]. The number of indigenous socio-cultural activities and distance to a Covid-19 epicentre city was included to measure risk of Covid-19 infection [36].

Age is categorised into four groups referring to Indonesia's demographic groups: 17 years and younger, 18-44 years, 45-60 years, and 61 years and older. Job types are divided into nine categories: health workers, civil servant non-health workers (i.e., teachers, village and district government staff, police, army and other civil servants who provide direct community service during the pandemic), labourers (i.e., factory workers or construction workers), professional workers (i.e., bank staff or company staff), traders, farmers, housewives, students, and retired persons. For Covid-19 deaths, we include patients' comorbidity history of diabetes, cardiovascular diseases, hypertension, autoimmune diseases and kidney diseases. We also include pre-RT-PCR test diagnosis by a medical doctor of pneumonia, chronic obstructive pulmonary disease (COPD), and respiratory failure. Individuals receiving Covid-19 hospital inpatient services and hospital intensive care unit services were also included to control for Covid-19 deaths.

Community-based healthcare intervention refers to neighbourhood or community activities aiming to provide healthcare support within a community [35, 37-39]. In Malang, such interventions are conducted by voluntary health workers or *kader* in *Posbindu* (*Pos pembinaan* *terpadu* or integrated health posts for NCDs) and *Posyandu/Posyandu Lansia* (*Pos pelayanan terpadu lanjut usia* or integrated healthcare service posts for children and older people) [37]. All these data were retrieved from Podes 2020 census. In the census, the number of community-based health care interventions was measured by the number of *Posbindu* and *Posyandu/Posyandu Lansia* in each village. During the outbreak, these community-based health care interventions play an important role in supporting district governments in increasing Covid-19 awareness among villagers. The district governments empower health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* as community Covid-19 task force teams responsible for monitoring persons suspected of infection and disseminating Covid-19 early mitigation strategies.

We also included indigenous socio-cultural activities since such activities may facilitate Covid-19 infection in rural areas. Indigenous socio-cultural activities refer to native people's communal activities such as Javanese wedding ceremonies (*mantenan*), Javanese traditional circumcision ceremonies (*khitan*), traditional birth celebration (*tasyakuran melahirkan*), religious meetings (*pengajian*), the obligation to visit and attend to sick or dying neighbours (*mbesuk* or *melayat*) and other communal activities that form a part of rural Javanese traditional cultures [41, 42]. The Podes 2020 measured these activities as the number of socio-cultural in each village per month. Such activities may directly mediate Covid-19 infection within and between villages as most villagers are culturally obligated to take part in them.

Village poverty is measured by the ratio of families living below Indonesia's poverty line. These numbers were based on village administrative data collected by village government authorities. Distance to a Covid-19 epicentre city was the distance of each village from a closed epicentre city in kilometres. For Covid-19 deaths, we include the number of health workers and the distance of each village to a Covid-19 referral hospital to capture whether healthcare access may be linked to Covid-19 patients' odds of dying from the disease.

Patient and public involvement

Neither patients nor the public were involved in the design or conduct of this study. Participants also did not contribute to the writing or editing of this manuscript. Informed written consent was sought from each participant by the authority before the interview.

Statistical methods

Multilevel or hierarchical regression analyses were applied to take full advantage of the village clustering information available from the data. These regression analyses are able to account for the clustering of individuals by separating individual variances of Covid-19 infections and Covid-19 deaths from village variances. This type of regression is therefore more appropriate than simple regression, which does not take village-level clustering data into account. For these analyses, hierarchical logistic regression was used to estimate factors associated with Covid-19 infection and Covid-19 deaths. The mathematical formula for both models can be written as follows, considering an individual i nested in village j:

$$E_{ij*} = \beta_o + \Sigma\, \beta_j W_j + \beta_{ij} X_{ij} + \mu_j + \epsilon_{ij}$$

With:

$E_{ij*=}$ logit (P ($E_{ij*=}$ 1 or 0)) as a binary variable indicating an individual who has been infected with or died from Covid-19 (i.e. 1 = Covid-19 infection or death; 0 = No)

W_j as a set of village determinants (j= number of community-based healthcare interventions, number of indigenous socio-cultural activities, village poverty, distance to a Covid-19 epicentre city, number of health workers, and distance from village to a Covid-19 referral hospital)

X_{ij} as a set of individual determinants (i= age, sex, type of jobs, symptoms, comorbidity, etc.)

μ_j as a random intercept of villages with mean zero and variance σ_μ^2

ϵ_{ij} normally distributed with zero and variance σ_ϵ^2.

We estimated a hierarchical logit model using multilevel mixed-effects logistic regression (*melogit*). In this study, *melogit* fits mixed-effects models for binary responses. The conditional distribution of the response given the random effects is assumed to be Bernoulli, with success probability determined by the logistic cumulative distribution function. We used maximum likelihood estimation to fit all models. Odds ratios were used to compare the magnitude of each social determinant of health for individual Covid-19 infections and deaths. We carried out two-level logistic regression using STATA 16.0 software.

Results

Characteristics of the sample

Table 1 presents the characteristics of the sample in this study, which is divided into two categories: all Covid-19 contact tracking individuals (N=14,264) and individuals confirmed infected with Covid-19 (N=551). We found that 4% (N=551) of traced individuals were confirmed infected, and 11% (N=62) of those infected individuals died. Most of the tracked and infected individuals were male (64% and 53% respectively). Most were young adults (18-44 years) and middle-aged adults (45-60), and most were labourers and traders who regularly worked in epicentre cities, i.e., Malang City or Surabaya City. Among those who were infected, 29% reported having contact with individuals with confirmed Covid-19 cases, and 17% reported having contact with individuals with suspected Covid-19 cases. Fever, cough and shortness of breath were the most common symptoms of Covid-19 confirmed cases (39%, 32% and 27% respectively). We found that 13% of infected individuals had at least one symptom, while 46% of those who died of Covid-19 had reported having at least one symptom. Among tracked individuals, 23% and 14% reported having hypertension and diabetes, respectively. Of those who died of Covid-19, 60% and 49% had reported having hypertension and diabetes. Almost half of the infected patients (40%) were diagnosed as having pneumonia, and a small percentage were diagnosed as having acute respiratory distress syndrome and respiratory failure. Half of the infected individuals reported receiving inpatient treatment at a hospital. The number of community-based healthcare interventions varied across the 390 villages, ranging from 0 to 149. Likewise, the number of indigenous socio-cultural activities varied, with an average of 11 activities in each village. On average, the distance of a village to an epicentre city (Malang or Surabaya) was 34 kilometres, while the average distance to a Covid-19 referral hospital was approximately 11 kilometres. The average number of health workers in each village was eight, while the average proportion of people living in poverty was 20% across all villages.

Table 1. Sample characteristics of all tracked individuals and Covid-19 confirmed cases

Variables	All tracked individuals (N=14,264)				Covid-19 confirmed cases (N=551)			
	% or mean	SD	Min	Max	% or mean	SD	Min	Max
Covid-19 infections	4%				100%			
Covid-19 deaths	0.4%				11.3%			
Male	63.9%				53.2%			
Age								
≤ 17	12.6%				6.0%			
18-44	63.6%				39.6%			
45-60	19.4%				38.8%			
> 60	4.4%				15.6%			
Job type								
Civil servant, non-health worker	0.4%				2.5%			
Health worker	0.4%				2.2%			
Professional worker	0.4%				0.9%			
Labourer	28.7%				63.0%			

Trader	16.5%	53.5%
Farmer	15.9%	6.7%
Housewife	14.6%	30.9%
Student	20.0%	7.6%
Retired	1.6%	4.5%
Had contact with confirmed Covid-19 case	3.6%	28.9%
Had contact with suspected Covid-19 case	2.5%	16.7%
Visited animal market	0.1%	0.2%
Symptoms		
Fever	6.9%	38.5%
Cough	8.4%	32.3%
Runny nose	3.8%	10.5%
Sore throat	2.0%	7.3%
Shortness of breath	4.5%	26.7%
Shivering	0.8%	3.1%
Headache	1.3%	5.4%
Fatigue	3.2%	13.8%
Muscle aches	0.9%	3.8%
Nausea	1.7%	10.0%
Abdominal pain	0.8%	3.6%
Diarrhoea	0.5%	2.5%
Having at least one symptom	12.8%	45.7%
Presence of comorbidities		
Diabetes	14.2%	48.5%
Heart diseases	0.6%	1.5%
Hypertension	22.5%	60.4%
Chronic kidney diseases	0.1%	0.7%
Auto-immune diseases	0.1%	0.4%
Chronic obstructive pulmonary disease	0.2%	0.7%
Medical doctor diagnosis before RT-PCR		
Pneumonia	4.5%	40.3%
Acute respiratory distress syndrome	0.2%	1.3%
Respiratory failure	0.8%	2.0%

Inpatient	5.8%				50.1%			
ICU	0.2%				1.1%			
Village determinants								
Number of community-based health interventions	134	20	0	149	111	41	0	147
Number of indigenous socio-cultural activities	11	5	3	32	14	6	4	32
Distance to a Covid-19 referral hospital (km)	10	9.1	0.0	43.0	3.9	4.6	0.0	36.5
Number of health workers	8	9	0	69	13	14	1	69
Village poverty	20%				22%			
Distance to a Covid-19 epicentre city (km)	34.2	16.0	1.0	79.0	18.8	10.0	4.0	68.0
N (villages)	390				152			

Figures 1 and 2 describe the distribution of Covid-19 infections and Covid-19 deaths across 390 villages in the district. In terms of Covid-19 infection, the number of infected individuals was larger in villages closer to a Covid-19 epicentre.

[Figure 1. Distribution of Covid-19 infection in 390 villages of Malang district East Java Indonesia, July 29 2020]

[Figure 2. Distribution of Covid-19 mortality in 390 villages of Malang district East Java Indonesia, July 29 2020]

Multilevel logistic results for Covid-19 infection

Table 2 shows the multivariate odds ratios for the effects of individual and village-level determinants on Covid-19 infection. The unadjusted odds ratio of Covid-19 infection shows that being older was associated with a higher risk of infection. The effect remained fairly stable even after adjusting for socio-economic and health variables at the individual and village levels. Male respondents had an approximately 30% lower risk (95% confidence interval (CI) 0.57 to

0.85) of Covid-19 infection in the unadjusted model, but that association dissipated in the fully adjusted model. Civil servants who were non-health workers had 5.6 times higher odds of having Covid-19 in the fully adjusted model. Although health workers had 1.5 times higher odds of having Covid-19 in the unadjusted model, this difference was not significant in the fully adjusted model (adjusted odds ratio 1.57, 95% CI 0.67 to 3.66). Traders and housewives had higher odds of contracting Covid-19 in the unadjusted model, but those relationships disappeared in the fully adjusted model.

Table 2. Unadjusted and adjusted multilevel logistic regressions for Covid-19 infection ($N_{individual}$=14,264, $N_{village}$=152)

Variables	Unadjusted OR	95% CI	*p*-value	Adjusted OR	95% CI	*p*-value
Individual determinants						
Age, reference: 17 years and younger						
18-44	2.09	1.39-3.15	<0.001	2.15	1.31-3.51	0.002
45-60	5.05	3.33-7.66	<0.001	3.32	1.90-5.82	<0.001
61 years and older	5.36	3.34-8.63	<0.001	2.93	1.59-5.38	0.001
Male	0.70	0.57-0.85	<0.001	0.71	0.50-1.00	0.054
Job type, reference: Student or retired						
Health worker	2.58	1.17-5.67	0.018	1.57	0.67-3.66	0.293
Civil servant, non-health worker	9.30	3.93-22.00	<0.001	6.63	2.74-16.03	<0.001
Professional worker	0.45	0.16-1.23	0.122	0.33	0.09-1.10	0.073
Labourer	1.17	0.80-1.71	0.413	0.69	0.44-1.08	0.108
Trader	1.51	1.03-2.21	0.032	0.88	0.57-1.36	0.578
Farmer	1.45	0.94-2.22	0.086	0.93	0.56-1.56	0.809
Housewife	1.87	1.47-2.38	<0.001	0.94	0.63-1.40	0.762
Had contact with confirmed Covid-19 cases	12.98	9.36-18.00	<0.001	18.39	11.94-28.33	<0.001
Had contact with suspected Covid-19 cases	5.19	3.63-7.43	<0.001	0.87	0.53-1.43	0.586
Visited animal market	1.06	0.09-11.85	0.960	0.11	0.00-1.42	0.091
Symptoms						
Fever	2.59	2.04-3.29	<0.001	2.68	1.98-3.63	<0.001
Cough	1.02	0.80-1.31	0.823	0.76	0.54-1.09	0.142
Runny nose	0.59	0.42-0.83	0.003	0.77	0.49-1.19	0.243
Sore throat	0.83	0.55-1.24	0.382	0.81	0.50-1.33	0.419
Difficulty breathing	2.27	1.74-2.96	<0.001	2.91	2.07-4.08	<0.001
Shivering	0.97	0.53-1.80	0.948	0.56	0.27-1.14	0.114

Headache	1.58	0.97-2.58	0.062	0.97	0.55-1.71	0.920
Fatigue	1.81	1.30-2.50	<0.001	0.74	0.49-1.11	0.155
Muscle aches	1.60	0.88-2.88	0.118	1.07	0.54-2.13	0.825
Nausea	2.09	1.42-3.07	<0.001	1.44	0.89-2.34	0.135
Abdominal pain	1.20	0.67-2.15	0.531	0.86	0.43-1.69	0.667
Diarrhoea	2.11	1.01-4.37	0.044	1.90	0.81-4.43	0.135
Presence of comorbidities						
Diabetes	4.98	3.98-6.24	<0.001	1.09	0.69-1.72	0.697
Heart diseases	0.41	0.18-0.92	0.031	0.13	0.05-0.33	<0.001
Hypertension	5.65	4.51-7.10	<0.001	4.83	3.19-7.34	<0.001
Auto-immune diseases	7.02	0.98-50.13	0.052	2.56	0.40-16.18	0.315
Chronic obstructive pulmonary disease	5.08	1.32-19.44	0.018	1.33	0.34-5.07	0.675
Village determinants						
Number of community-based health interventions	0.96	0.95-0.98	<0.001	0.98	0.97-0.99	0.002
Number of indigenous socio-cultural activities	1.11	1.05-1.17	<0.001	1.03	0.99-1.08	0.100
Village poverty status	3.30	1.27-8.56	0.014	1.44	0.73-2.85	0.288
Distance to Covid-19 epicentre city	0.91	0.89-0.93	<0.001	0.92	0.91-0.94	<0.001
ICC				0.37	0.28-0.46	
Likelihood				-1346.11		

Contact history with confirmed Covid-19 patients was associated with an increased risk of contracting Covid-19 (unadjusted odds ratio 12.98, 95% CI 9.36 to 18.00). This effect remained stable after adjusting for other risk factors. Respondents with contact history with suspected Covid-19 patients had a 4.1 times higher risk in the unadjusted model, but this association dissipated in the fully adjusted model. Fever and difficulty breathing were associated with 1.5 (95% CI 1.98 to 3.63) and 1.2 times higher risks (95% CI 2.07 to 4.08) of having Covid-19, respectively, in the unadjusted model. These associations remain in the fully adjusted model. Hypertension (adjusted odds ratio 4.83, 95% CI 3.19 to 7.34) showed a positive and significant association with a higher risk of Covid-19 infection, while respondents with heart disease had an 87% lower risk of Covid-19 infection (95% CI 0.05 to 0.33). Turning to the village-level determinants, a greater number of community-based health interventions (adjusted odds ratio 0.98, 95% CI 0.97 to 0.99) and greater distance to a Covid-19 epicentre city (adjusted odds ratio

0.92, 95% CI 0.91 to 0.94) were related to a lower risk of Covid-19 infection. A greater number of indigenous socio-cultural activities (unadjusted odds ratio 1.11, 95% CI 1.05 to 1.17) and living in a poor village (adjusted odds ratio 3.30, 95% CI 1.27 to 8.56) were associated with a higher risk of Covid-19 infection. However, adjusting for individual and other village-level covariates eliminated the effects of both indigenous socio-cultural activities and living in a poor village on Covid-19 infection. The ICC of 0.37 indicates that 37 % of the variation in Covid-19 infection is located in villages.

Multilevel logistic results for Covid-19 mortality

Table 3 presents the analysis of Covid-19 mortality among the confirmed cases. The odds of dying of Covid-19 were higher among respondents aged 45 years and older (adjusted odds ratio for age group 45-60 years 24.96, 95% CI 2.07 to 300.89; adjusted odds ratio for age group 61 years and older 91.00, 95% CI 5.01 to 1652.84). Working as a labourer or farmer was associated with decreased Covid-19 mortality in the fully adjusted model. Respondents diagnosed by health professionals as having pneumonia had 13 times higher odds of Covid-19 mortality after adjusting for other individual and village-level covariates. Living near a Covid-19 referral hospital was associated with a lower risk of Covid-19 mortality (adjusted odds ratio 1.24, 95% CI 1.02 to 1.51). The ICC is very small (2.48e-34), indicating that variation between villages provides little explanation of Covid-19 mortality.

Table 3. Unadjusted and adjusted multilevel logistic regressions for mortality among patients with Covid-19 ($N_{individual}$=551, $N_{village}$=390)

Variables	Unadjusted OR	95% CI	*p*-value	Adjusted OR	95% CI	*p*-value
Individual determinants						
Age, reference: 17 years and younger						
18-44	0.51	0.10-2.58	0.420	1.21	0.12-12.51	0.875
45-60	2.62	0.59-11.52	0.201	24.96	2.07-300.89	0.011

61 years and older	5.32	1.17-24.10	0.030	91.00	5.01-1652.84	0.002
Male	1.45	0.84-2.49	0.176	8.19	1.41-47.47	0.019
Job type, reference: Student or retired						
Professional worker	0.97	0.07-12.05	0.985	1.22	0.05-25.51	0.896
Labourer	0.01	0.00-0.13	0.000	0.0006	0.00-0.01	0.000
Trader	0.37	0.06-2.12	0.270	0.06	0.00-1.36	0.078
Farmer	0.24	0.08-0.66	0.006	0.01	0.00-0.17	0.000
Had contact with confirmed Covid-19 cases	0.10	0.03-0.35	0.000	0.33	0.04-2.84	0.312
Had contact with suspected Covid-19 cases	0.22	0.07-0.74	0.014	0.57	0.03-9.48	0.694
Presence of comorbidities						
Diabetes	2.91	1.63-5.18	0.000	0.08	0.00-1.88	0.119
Heart diseases	2.68	0.52-13.59	0.233	0.12	0.00-4.49	0.250
Hypertension	2.22	1.21-4.08	0.010	18.74	1.02-345.10	0.049
Chronic obstructive pulmonary disease	24.81	2.53-242.40	0.006	95.04	0.05-189978.80	0.240
Inpatient	18.03	6.38-50.95	0.000	3.01	0.38-24.03	0.300
ICU	8.28	1.51-45.12	0.015	8.62	0.00-129920.00	0.661
Medical doctor diagnosis before RT-PCR						
Pneumonia	13.07	5.99-28.53	0.000	12.73	2.05-78.92	0.006
Acute respiratory distress syndrome	11.16	2.43-51.13	0.002	7.76	0.26-229.94	0.236
Respiratory failure	3.05	0.78-11.84	0.106	27.70	0.92-837.88	0.056
Village determinants						
Number of community-based health interventions	0.99	0.99-1.00	0.252	0.99	0.97-1.02	0.582
Number of indigenous socio-cultural activities	1.00	0.96-1.04	0.833	0.96	0.85-1.09	0.557
Village poverty status	0.59	0.28-1.22	0.162	2.39	0.25-23.08	0.452
Distance to Covid-19 epicentre city	0.99	0.96-1.02	0.660	0.97	0.91-1.04	0.446
Number of health workers	0.99	0.97-1.01	0.507	0.99	0.94-1.05	0.764
Distance to Covid-19 referral hospital	1.01	0.95-1.07	0.715	1.24	1.02-1.51	0.031
ICC				2.48e-34	7.85e-18	
Likelihood				-44.31		

Discussion

Understanding the social determinants of Covid-19 infection and death is vital for effective Covid-19 early detection and mitigation strategies. Using official government contact tracing data from Malang District, East Java, Indonesia, this study identifies individual socio-demographic factors, village characteristics and variations in healthcare access that are associated with Covid-19 infection and mortality.

The pattern of the pandemic spread is reflected in our finding that greater distance to a Covid-19 epicentre is associated with lower risk of infection. This relationship may reflect patterns of the pandemic spread in Indonesia and especially in Malang district, which appears to follow the pattern of regional economic growth concentrated in urban areas and cities [42-44]. As centres for business and economic activities, urban areas and cities are places where large numbers of people work, shop, and sell agricultural products. As there were fewer restrictions on human mobility in Malang early in the pandemic, the virus spread first to neighbouring villages around the epicentre and then moved to more remote areas. Hence, people living near epicentre cities, who have more frequent contacts and more exposure to the virus, have a higher risk of infection than rural people who live far from epicentres, have fewer contacts with outsiders, and therefore have less exposure to the virus.

As documented in several studies, the characteristics of healthcare system development in Indonesia follow the pattern of regional economic development, which is biased toward urban areas and cities [45-47]. Covid-19 referral hospitals in Indonesia, including in Malang, are concentrated in city centres and are more likely to have a larger number of specialised medical doctors and better hospital facilities. For example, most hospitals in Malang City have more isolation rooms and ventilators than those in Malang district. Malang Regency has four Covid-19 referral hospitals with a total of 126 isolation rooms. All of these hospitals are located in

Kepanjen and *Gondanglegi* sub-districts as the central areas of Malang Regency. Rural residents who live in other sub-districts must travel about 2-3 hours to those hospitals. With very limited transportation available during the outbreak, infected villagers often were not taken to hospitals or were taken when their conditions were already critical, placing them at higher risk of death. On the other hand, villagers who lived near a referral hospital were able to obtain medical treatments more quickly. Our findings, which show a positive association between distance to a referral hospital and mortality, illustrate the inequalities of health care access. Hence, the pandemic has clarified the acute problem of Indonesia's health care system, which is biased towards cities and leaves rural areas behind [45-47].

The weakness of health systems and unequal access to health care in handling the outbreak is also reflected in the insignificant findings on the relationships of inpatient and ICU services, number of health workers, and village poverty status to mortality due to Covid-19. We found no significant difference in Covid-19 mortality between patients who received hospital treatment and those who did not receive hospital treatment. One of the plausible explanations is that patients with severe Covid-19 symptoms did not receive proper treatment. At the beginning of the outbreak, most of the referral hospitals ran out of ventilators and essential medicines. As of July 2020, all Covid-19 referral hospitals in Malang had only 13 ventilators and were caring for 275 Covid-19 patients.

The number of area health workers has no significant association with the risk of death due to Covid-19. There are several plausible explanations for this finding. Firstly, the limited number of health workers in most villages in Malang Regency is due to the fact that most of them are concentrated in areas near the city centre. Secondly, the finding may reflect most health workers' lack of skills and experience in handling Covid-19 patients as they received no training on Covid-19 treatment at the beginning of the outbreak. Most health workers are nurses and midwives whose main roles are in Covid-19 health promotion and not Covid-19 treatment. This lack of healthcare capacity was not only found in Malang Regency but also in many regions across the country, demonstrating the acute issue of unequal access to health care between urban and rural areas documented in various studies. The insignificant relationship between village poverty and Covid-19 infection and mortality further explains the lack of healthcare capacity in managing the outbreak. Although wealthier areas may have larger numbers and better quality health care providers, they are not necessarily able to successfully manage the pandemic. As a result, the risk of infection and death across poor and rich communities was not significantly different.

The contrasting relationship between community-based health care and Covid-19 infection and mortality also indicates the capacity of the healthcare system to respond to the outbreak. The negative effect of community-based health care on Covid-19 infection levels may indicate the benefits of community-based healthcare interventions for Covid-19 prevention in rural areas, which often have limited access to various resources such as information related to Covid-19 prevention. At the district level, community-based health care is vital in supporting district government in increasing Covid-19 awareness among villagers. The district government empowers health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* as community Covid-19 task force teams responsible for monitoring individuals with suspected cases and disseminating Covid-19 early mitigation information. Previous studies have also demonstrated the benefits of such community activities to promote community resilience and to provide basic healthcare services in resource-poor settings [39, 48, 51]. However, the numbers of community-based health care interventions and health workers were not associated with reducing the number of

Covid-19 deaths. As discussed above, the insignificance of this association may reflect the roles of the community interventions and health workers, especially nurses at the village level, who focus on prevention, for example, disseminating Covid-19 information and conducting contact tracing. These health workers have little influence on Covid-19 patient treatment.

Another village characteristic that we hypothesised to be associated with Covid-19 infection is the number of indigenous socio-cultural activities such as traditional wedding ceremonies (*mantenan*), traditional circumcision ceremonies (*khitan*), traditional birth celebrations (*tasyakuran melahirkan*), religious meetings (*pengajian*) and other socio-cultural activities at which individuals within the community and between communities often gather. The result of our unadjusted odd ratio logistic regression indicates a positive and significant association with Covid-19 infection. However, null findings were shown within the adjusted model. These null findings may indicate that most of the indigenous socio-cultural activities took place in villages in rural areas, where infection rates were still low in the early phase of the pandemic. However, given that the local authorities are struggling to control such traditional gatherings within communities, these socio-cultural events may cause further Covid-19 clusters in the future.

Gender inequality also appears in to play a role in access to Covid-19 testing in Malang (Table 1). We found that only one-third of the contact tracing individuals were female, while the sex ratio of the 2018 Malang population was 101 males to 100 females. Covid-19 contact tracing policy selects individuals who have had contact with a Covid-19 patient, who have one of the Covid-19 symptoms, or who have travelled from a Covid-19 epicentre area within Indonesia or abroad. This policy seems to favour males as the district employment status was dominated by males [27]. Males as workers have higher mobility than females who most of them stay at home as a housewife. Hence, males have higher opportunity to access Covid-19 tracing and test in the district. Hence, though the availability of Covid-19 tests overall in Indonesia is inadequate, women's lack of access to Covid-19 testing magnifies the issue. For rural women, accessing testing can be especially hard, because the health system is not enabling testing in places and in ways in which women can access it. The gender inequality in healthcare access in Indonesia has been well documented in the literature [51, 52]. Moreover, women in rural areas also face cultural, physical and economic obstacles such as needing a male relative's permission, not being able to afford transportation to a Covid-19 referral hospital, or fear of a confirmed diagnosis because they cannot afford treatment. Hence, our findings highlight that institutionalised gender roles and culturally entrenched roles and norms may influence who is able to receive a test and who is most at risk of infection [52].

Despite the findings related to healthcare system and village characteristics, we also found some social determinants that are associated with Covid-19 infection and mortality. Individuals age 18 and older (young adults, middle-aged adults and older adults), civil servants (non-health workers), individuals with direct contact with confirmed Covid-19 cases and individuals with hypertension constitute the groups most vulnerable to Covid-19 infection. In contrast with earlier studies in Wuhan, China, which reported visitors to and workers at seafood and wet animal wholesale markets as being at high risk, we did not find individuals who visited animal markets to be at increased risk for infection [3]. We did, however, find individuals having had close contact with confirmed Covid-19 patients to be at higher risk of infection. These findings confirm earlier studies in China and other countries [4, 53]. Similar to other studies, we found that most individuals aged 18 and older are at higher risk of infection than those aged 17 years and younger. In rural Indonesia, individuals aged 18 and older are of working age; most people in this group must work outside home, while those 17 years and younger are students who were instructed to stay at home during the outbreak.

However, civil servants (non-health workers) such as village public servants, police officers, members of the army, and some public-school teachers (who were obliged to go to their workplaces, provide services or manage office administration) were at higher risk of infection than retired people and students, most of whom were staying at home. One of the plausible explanations for this is that most civil servants lacked sufficient protective Covid-19 equipment, which may be due to the shortages of protective equipment typical in rural areas [54]. On July 29, 2020, it was reported that government offices was among the Covid-19 clusters in Indonesia, and the number is reported to have risen since then. In the Jakarta government alone, 68 distinct office clusters had been found as of July 26, which included buildings belonging to public institutions, ministries, and state-owned enterprises, among other places. A lack of awareness of the health protocols has led to high Covid-19 transmission among employees in government offices.

Among respondents with confirmed Covid-19 cases, we found that males, individuals age 45 years and older (middle-aged adults and older adults), individuals with hypertension, and those diagnosed with pneumonia and respiratory failure were at higher risk of death. The demographic pattern of Covid-19 deaths in Malang seems to differ from patterns in developed countries, in which larger proportions of deaths were found among members of older age groups (≥80 years) [2]. However, parallel to findings in developed countries, we found males and those with a history of hypertension to be at higher risk of death. In fact, the rate of death due to hypertension in Malang is very high. One plausible explanation for this is the prevalence of undetected cardio-metabolic conditions in Indonesia: through our work in 2014 and 2018, we discovered that more than two-thirds of Indonesian adults aged 40 and older have unmet needs for cardiovascular care [7-9]. Moreover, we found a higher risk of Covid-19 infection among individuals with hypertension. As conveyed in prior studies and government reports, hypertension is quite common among older adults in Indonesia [55-57]. Hence, the elevated likelihood of Covid-19 infection among individuals with hypertension may be linked to the high proportion of adult Indonesians with hypertension. Accordingly, patients diagnosed with pneumonia and respiratory failure had a higher likelihood of dying of Covid-19 than others. Previous studies have reported that pneumonia and respiratory failure may indicate Covid-19 as the infection may result in severe pneumonia and respiratory failure [58-61].

Confirming previous studies, we found that the only symptoms associated with Covid-19 infection were fever and shortness of breath. There was null association with other symptoms. These findings are consistent with earlier studies in China and developed countries which have also shown that fever and shortness of breath are common symptoms associated with Covid-19 infection [7, 61]. Accordingly, we found that about half of infected individuals had at least one symptom, while other infected individuals reported no symptoms. These results match those observed in earlier studies, which found a high ratio of asymptomatic Covid-19 infection [4, 62]. Given this large ratio of asymptomatic infection, the prevention of Covid-19 infection in the district will prove challenging as villagers generally still have little awareness of the virus.

Taken together, the findings of this rapid assessment offer two important policy implications that can aid in preparing for Covid-19 outbreaks in rural Indonesia. First, with the lack of healthcare capacity to handle the pandemic in most rural areas, government should prioritise the implementation of strategies to control the pandemic while improving essential facilities for Covid-19 treatment in rural areas. For example, a system to monitor villagers' mobility (i.e., how villagers are traveling and where they are going) and learn how rural communities are affected by the movement of people who were in cities and have now returned to the countryside should be developed soon. Our findings show that community-based healthcare interventions may be used as an effective local institution to mitigate Covid-19 infection in rural settings, which often face limited basic health services and knowledge about Covid-19 infection. Such institutions may be effective in facilitating the dissemination of information in rural communities to help spread public health messages related to Covid-19 [20]. A policy restricting human mobility should likewise be implemented to control the spread of the disease to rural areas. A realistic travel restriction would accommodate villagers who must travel to work in cities, while providing regular Covid-19 tests for them to monitor virus spread. As many government offices become Covid-19 clusters, the authorities should strengthen the implementation of Covid-19 health protocols in government offices by providing protective Covid-19 equipment. The authorities should also implement regular Covid-19 monitoring for civil servants, especially those who live in rural villages and those who are highly mobile. Moreover, public health mitigation strategies should strengthen physical and social distancing policies, especially for middle-aged males and older males, as well as groups with generally high mobility as most of their members work in informal sectors [10, 11].

Second, as the pandemic now threatens rural areas, providing Covid-19 emergency services for rural areas is vital for reducing mortality. Providing Covid-19 emergency transportation is crucial as Covid-19 patients from rural villages tend to arrive at referral hospitals only when their condition has become critical. The authorities should also prepare to build an emergency Covid-19 hospital in rural areas rather than in urban areas when the number of Covid-19 patients from rural areas has increased. Covid-19 mitigation strategies should also ensure the provision of essential medications, especially for males aged 45 years and older who have cardio-metabolic conditions, specifically hypertension [7, 8, 12, 14]. This is particularly important because the lack of essential medicine is a frequent issue in rural public health facilities in Indonesia. By prioritising the strengthening of the healthcare system in rural areas during the pandemic, the government may also be able to reduce inequality in healthcare services following the outbreak.

More importantly, the authorities must also address the issue of gender inequality in Covid-19 healthcare by implementing universal Covid-19 tests and treatments. Unequal access to testing can lead to late diagnosis and preventable deaths due to undetected Covid-19 among rural people, especially women. The government needs to quickly accelerate its testing capacity. Detecting cases early and isolating people who test positive is effective in reducing transmission and can thus improve health outcomes. Mass testing and centralised quarantine have been identified as the primary drivers for flattening the epidemic curve in several countries such as Singapore, Canada, China and South Korea [7,10]. To be effective in reducing transmission from asymptomatic patients, testing must reach the majority of the population, not only those with means. Thus, the government must implement and enforce mass testing as the highest priority across the archipelago. Moreover, continued investigations should focus not only on biological variables, but also on social variables and their influence on Covid-19 exposure and vulnerability. This will be necessary to understand and therefore manage this unprecedented pandemic. In fact, a recent study also pointed out that minority groups are being disproportionately affected by Covid-19 [1,2,58-60].

The empirical results reported herein should be considered in light of several limitations. This study has least three limitations. First, this is a rapid healthcare assessment which is based on four months of contact tracking data. The results may change as Covid-19 infections in the district increase. The contact tracing data used were not based on random sampling and not a mass testing data; rather, they were selected based on three criteria of Covid-19 tracing. Thus, it may be subject to selection bias (e.g., the slightly lower proportion of female respondents), capturing Malang's working population rather than representing the overall demographic characteristics of the district. However, the lower proportion of women may also relate to the abovementioned inequality in the provision of Covid-19 tests. Hence, we suggest that future research investigate the contribution of social norms and gender roles in order to identify how gender may influence risk of infection and access to care. Second, we are unable to include certain main socio-economic determinants such as income and education as the data are unavailable or not yet integrated with citizen registration data. Therefore, future studies may examine whether income distribution and education level are associated with Covid-19 infection and deaths. Third, some of the variables in this study were based on retrospective data, especially regarding respondents' histories of heart disease and diabetes. These data were thus subject to recall bias. Future studies may use medical record data collected from primary healthcare centres or hospitals to address the issue of recall bias.

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Contributions:
SS: Conceptualisation, Data curation, Formal analysis, Methodology, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. AM: Conceptualisation, Formal analysis, Methodology, Supervision, Validation, Writing - review & editing. GT: Supervision, Validation, Writing - review & editing.

Words count: 10405

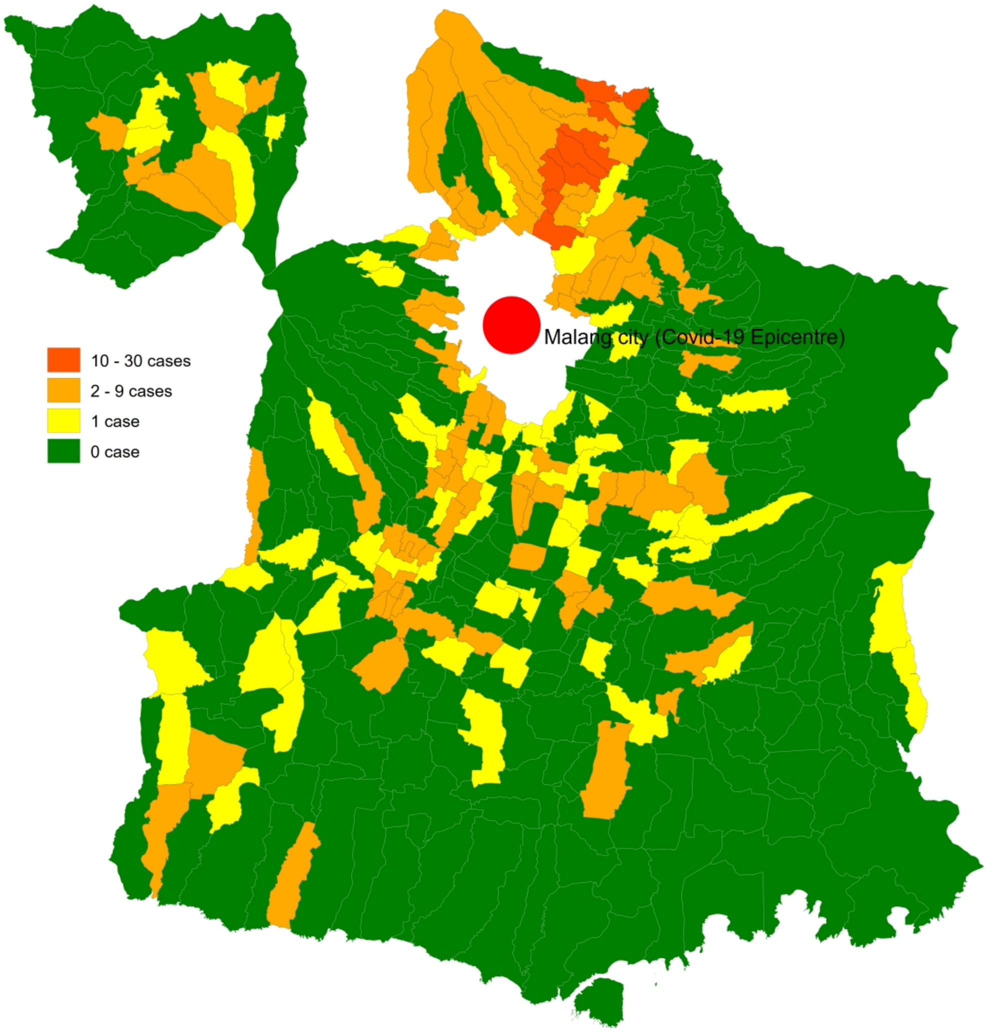


Figure 1. Distribution of Covid-19 infection in 390 villages of Malang district East Java Indonesia, July 29 2020

1411x1474mm (72 x 72 DPI)

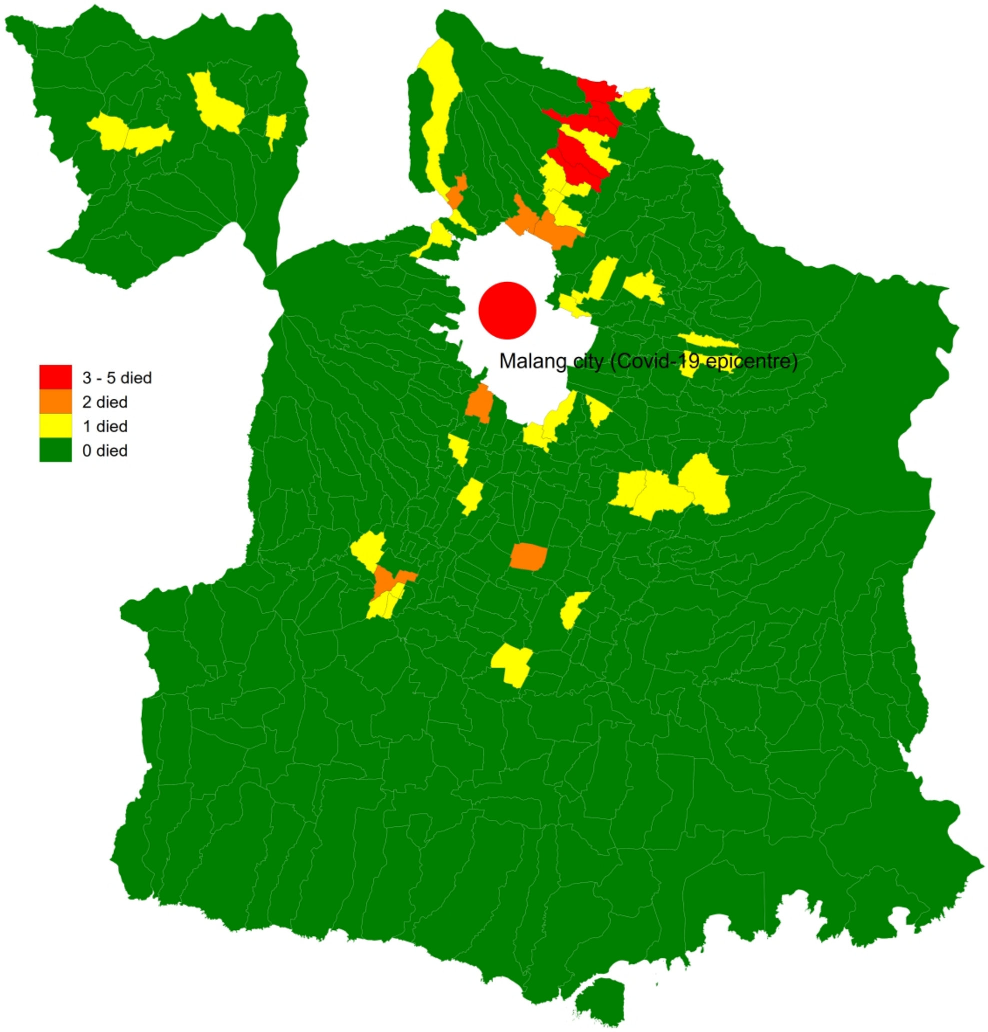


Figure 2. Distribution of Covid-19 mortality in 390 villages of Malang district East Java Indonesia, July 29 2020

1411x1474mm (72 x 72 DPI)

INDONESIAS MINISTRY OF HEALTH

EPIDEMIOLOGICAL INVESTIGATION FORM CORONAVIRUS DISEASE (COVID-19)

Name of health care provider:

Interviewer name:

Interview Date:

IDENTITY					
Patient Name			Criteria: ☐ Suspected patient (PDP) ☐ People under monitoring (ODP) ☐ Probable case ☐ Confirmed Case ☐ Local Transmission (close contact)		
ID number			Parents Name:		
Date of Birth:	……/………/……..	Jobs:	☐ Male ☐ Female	Age	Date of Birth:
Address	Street : Village name : Sub-district : Districts/City : Phone Number:				
Clinical Information					
First symptoms date (onset)	…. …. / …. ….. / …. …..		Weak (malaise)	☐ Yes ☐ No ☐ Don't know	
Fever / Fever history	…. …… ….^{0}C Fever History: ☐ Yes ☐ No ☐ Don't know		Muscle ache	☐ Yes ☐ No ☐ Don't know	
Cough	☐ Yes ☐ No ☐ Don't know		Nausea	☐ Yes ☐ No ☐ Don't know	
Runny nose	☐ Yes ☐ No ☐ Don't know		Abdominal Pain	☐ Yes ☐ No ☐ Don't know	
Sore throat	☐ Yes ☐ No ☐ Don't know		Diarrhea	☐ Yes ☐ No ☐ Don't know	

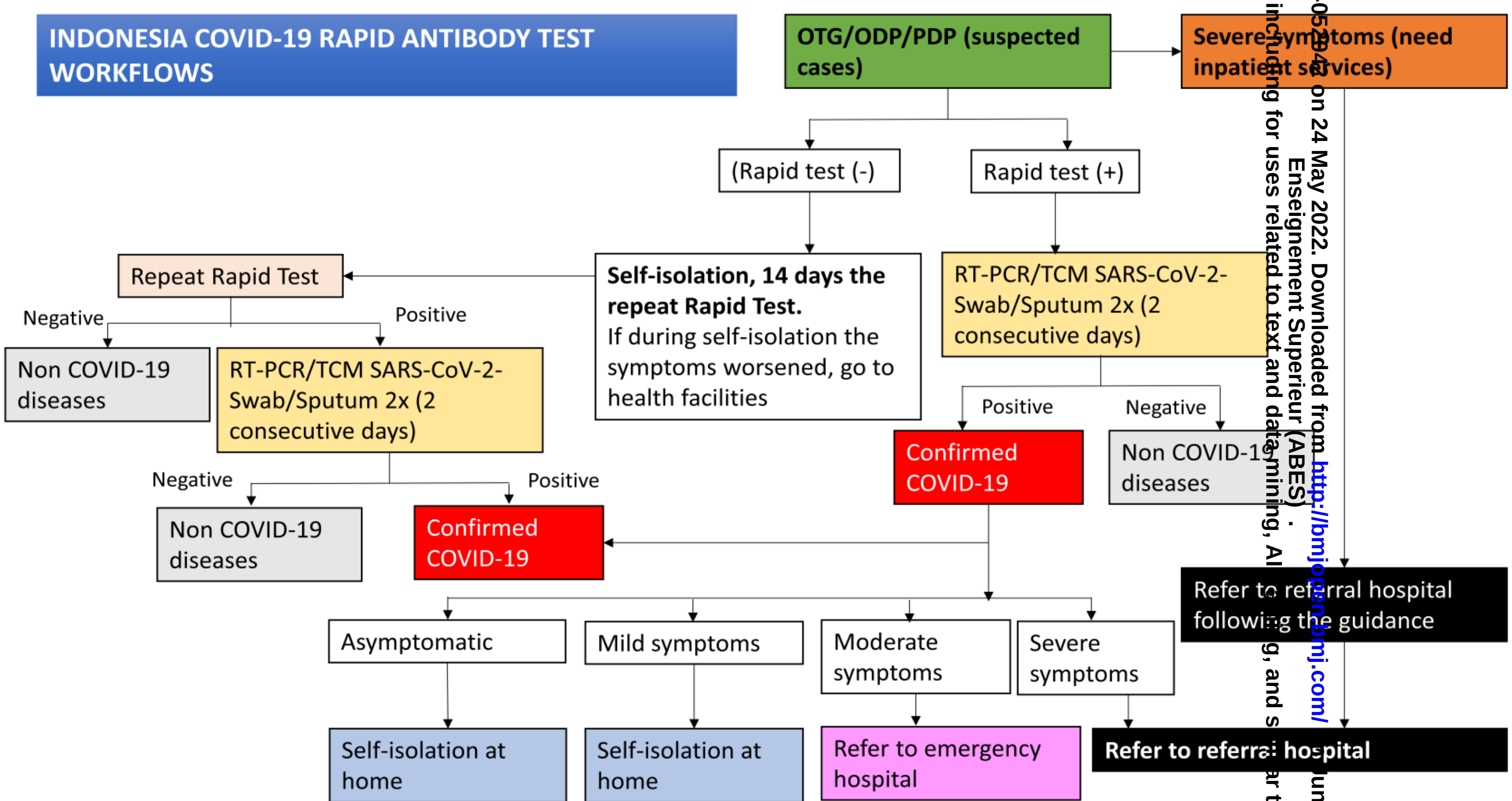
Shortness of breath	☐ Yes ☐ No ☐ Don't know	Others (write down):
Shivering	☐ Yes ☐ No ☐ Don't know	
Headache	☐ Yes ☐ No ☐ Don't know	

Additional Medical Information			
Pregnant Diabetes Coronary heart disease Hypertension Cancer	Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____	Immunological disorders Chronic kidney disease (CKD) Chronic heart disease (CHD) Chronic obstructive pulmonary disease (COPD) Other (write down):	Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ …………………………………….

Did the patient hospitalized?	Yes ___ No_____ Check in date ………………. Hospital Name………………….. Room: If Yes, Did He/She sent into ICU room? Yes ___ No_____ Intubation Yes ___ No_____ Extracorporeal membrane oxygenation (ECMO) uses Yes ___ No_____ Last patient status: Recovered ……. Deaths ……….
Diagnose	Pneumonia (Clinical or Radiologycal) Yes_____ No_____ Don't know_____ ARDS (Acute Respiratory Distress Syndrome) Yes_____ No_____ Don't know_____ Other diagnoses, write down……………..
	Did the patient have any diagnoses or another etiology of their respiratory disease? Yes_____ No_____ Don't know_____ If yes, please write down…………………

EXPOSE/CONTACT FACTOR	
In 14 days before ill, did the patient has travel history? If Yes, please mention the visited places? Country and City …………………………………………………………………… ……………………………………………………………………	 Visit date – Arrival date to Indonesia …………………………………………………………………… ……………………………………………………………………
In 14 days before illness,	Yes_____ No_____ Don't know_____

Did the patient get close contact with COVID-19 suspected person?
In 14 days before illness, Yes_____ No_____ Don't know_____ Did the patient get close contact with COVID-19 confirmed patient?
In 14 days before illness, Yes_____ No_____ Don't know_____ Had the patient visited to animal/pet shop? If Yes, Please mention the location/city/country………………………
Are you a health worker? Yes_____ No_____ Don't know_____ If Yes, what protective equipment do you use? ___Gown ___Medical mask ____Gloves ___NIOSH-N95 Mask, AN EU STANDARD FFP2 ___FFP3 ____Protective glass (goggle) ___nothing has used Are you doing procedures which creates aerosol? Yes____ No____; Write down ………
In 14 days before illness, Yes_____ No_____ Don't know_____ Had you visited to health care providers (as a patient, staff, or visitor)? If Yes, please mention the location/city/country………………………
Are the patient includes to acute respiratory infection (person with Fever and pneumonia who needs to hospitalize) with unknown causes where the COVID-19 case have been checked? Yes__ No__ Don't know_____
Others, Please write down…


INDONESIA COVID-19 RAPID ANTIBODY TEST WORKFLOWS
OTG/ODP/PDP (suspected cases)
Severe symptoms (need inpatient services)
(Rapid test (-)
Rapid test (+)
Repeat Rapid Test
Self-isolation, 14 days the repeat Rapid Test.
If during self-isolation the symptoms worsened, go to health facilities
RT-PCR/TCM SARS-CoV-2-Swab/Sputum 2x (2 consecutive days)
Negative
Positive
Non COVID-19 diseases
RT-PCR/TCM SARS-CoV-2-Swab/Sputum 2x (2 consecutive days)
Positive
Negative
Confirmed COVID-19
Non COVID-19 diseases
Negative
Positive
Non COVID-19 diseases
Confirmed COVID-19
Refer to referral hospital following the guidance
Asymptomatic
Mild symptoms
Moderate symptoms
Severe symptoms
Self-isolation at home
Self-isolation at home
Refer to emergency hospital
Refer to referral hospital

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RESEARCH PROTOCOL

Social determinants of Covid-19 infection and death in a rural Indonesia
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1. Background

In The Lancet Infectious Diseases, Ranscombe recently highlighted the need to take a systematic approach to tackling the Covid-19 crisis rather than focusing solely on urban areas [1]. He posited that the adoption of a systematic approach should include examining the socio-medical, socio-economic, and socio-political implications of confronting the pandemic in rural areas, which often have a significant scarcity of health facilities and workers for Covid-19 treatment as well as insufficient knowledge about Covid-19 infection. Accordingly, studies have shown huge disparities in healthcare access between rural and urban areas in Indonesia and other developing countries, a factor that is associated with citizens' health and well-being [2]. Studies have also documented the differences between rural and urban Indonesia in terms of individual socio-economic characteristics that are associated with health status [3]. This study aims to examine whether those inequalities are associated with Covid-19 infection and death in rural Indonesia.

2. Study objectives

This study has two objectives. Firstly, to examine which groups in rural Indonesia are most vulnerable to infection and death due to Covid-19? Identifying those most vulnerable to Covid-19 is crucial as the pandemic adds significantly to the pressure on fragile local health services. Under such conditions, we are likely to see a spread of human suffering and very high mortality rates. Secondly, to examine what are the most important social determinants of health associated with Covid-19 infection and death in rural Indonesia?

3. Study design

This study will use a non-random cross-sectional design based on official Covid-19 tracing data collected by the Malang District Health Authority (DHA) from March 1 to July 29, 2020 and administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 [4]. This study will be conducted in Malang District in East Java, Indonesia. Malang is located quite close to the city of Surabaya, which is currently the biggest Covid-19 epicentre in Indonesia. Malang area covers 3,535 square kilometres, with an agricultural emphasis on rice and sugar cane. Malang's total population of 2,544,315 is distributed across 33 sub-districts, 390 villages and 3,125 community neighbourhoods [5]. A subdistrict consists of come villages, and a village consists of some community

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neighbourhoods. The number of people in each village and community neighbourhood in Malang District on average are 6400 and 746, respectively [6].

4. Participation selection

This study will use all individuals screened for Covid-19 infection by Malang District Health Authority (DHA) from March 1 to July 29, 2020.

5. Study plan

Covid-19 contact tracing data will be collected by the Malang DHA based on the Indonesian Ministry of Health Covid-19 prevention and control guidelines. The total number of individuals traced during from March 1 to July 29, 2020. This tracing data covers all population in Malang District (estimated 2,544,315). Based on the national guidelines, Covid-19 contact tracing refers to the process of identifying all individuals who fulfil one of these criteria: (1) having had contact with a confirmed Covid-19 patient within the previous two weeks, (2) having one of the Covid-19 symptoms; and (3) having travelled from one of the Covid-19 epicentre areas in Indonesia or abroad [29]. Close contact was identified by health workers in each village with criteria: those who live in the same household or who has been close to someone who has tested positive for Covid-19 [6,7].

The data will be merged the contact tracing data with administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 (Podes) [5]. The Podes is a longstanding tradition of collecting data at the lowest administrative tier of local government. Podes consists of 83,931 villages (*desa*) across 514 districts in Indonesia. The census has been conducted every two years since 1983 by the Indonesian Central Bureau of Statistics (*Biro Pusat Statistik*). Detailed information is gathered on a range of characteristics from public infrastructure to village finances. Information is gathered from *kepala desa* (rural village heads) and *lurah* (urban neighbourhood heads). From the 2020 census, we will used the following data for each village: number of health workers, number of community-based healthcare interventions and number of indigenous socio-cultural activities as well as hospital access, poverty and distance to a Covid-19 epicentre city.

Variables

The outcome variables in this study are Covid-19 infections and Covid-19 deaths. *RT-PCR*) swab tests are used by the Malang District Health Authority to determine the presence of Covid-19 infection. The authority determines that an individual is infected if the RT-PCR swab test shows a positive result. The Indonesian Ministry of Health follows the WHO definition of death due to Covid-19 as a 'death resulting from a clinically compatible illness, in a probable or confirmed Covid-19 case, unless there is a clear alternative cause of death that cannot be related to Covid-19' (e.g., traffic accident or trauma) [7]. Deaths due to Covid-19 cannot attributed to another disease (e.g., cancer) and are counted independently of preexisting conditions that are suspected of triggering a severe course of Covid-19 (e.g., coronary artery disease, type 2 diabetes, or chronic obstructive pulmonary disease).

Following Marmot and Wilkinson and WHO [8,9], we will include individual socio demographic characteristics, number of community-based health interventions, number of indigenous socio-cultural activities, distance to a Covid-19 referral hospital, village poverty and distance to a Covid-19 epicentre city to measure the social determinants of health.

In addition, we will include village-level social determinants which captured individual access to health care, risk of infection and poverty. Previous studies have documented that village poverty status and the number of community-based healthcare interventions are linked with access to healthcare [34-36]. In addition, we included the number of indigenous socio-cultural activities and distance to a Covid-19 epicentre city to measure risk of Covid-19 infection.

Age is categorised into four groups referring to Indonesia's demographic groups: 17 years and younger, 18-44 years, 45-60 years, and 61 years and older. Job types are divided into nine categories: health workers, civil servant non-health workers (i.e., teachers, village and district government staff,

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police, army and other civil servants who provide direct community service during the pandemic), labourers (i.e. factory workers or construction workers), professional workers (i.e. bank staff or company staff), traders, farmers, housewives, students, and retired persons. For Covid-19 deaths, we include patients' comorbidity history of diabetes, cardiovascular diseases, hypertension, autoimmune diseases and kidney diseases. We also include pre-RT-PCR test diagnosis by a medical doctor of pneumonia, chronic obstructive pulmonary disease (COPD), and respiratory failure. Individuals receiving Covid-19 hospital inpatient services and hospital intensive care unit services were also included to control for Covid-19 deaths.

Village determinants for Covid-19 infection include the number of community-based healthcare interventions, the number of indigenous socio-cultural activities, village poverty status, and distance to a Covid-19 epicentre city. We included community-based healthcare intervention to examine whether such community interventions facilitate controlling Covid-19 infection. Community-based healthcare intervention refers to neighbourhood or community activities aiming to provide healthcare support within a community [5,6]. In Malang, such interventions are conducted by voluntary health workers or *kader* in *Posbindu* (*Pos pembinaan terpadu* or integrated health posts for NCDs) and *Posyandu/Posyandu Lansia* (*Pos pelayanan terpadu lanjut usia* or integrated healthcare service posts for children and older people) [5]. All these data were retrieved from Podes 2020 census. In the census, the number of community-based health care interventions was measured by the number of *Posbindu* and *Posyandu/Posyandu Lansia* in each village. During the outbreak, these community-based health care interventions play an important role in supporting district governments in increasing Covid-19 awareness among villagers.

The district governments empower health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* as community Covid-19 task force teams responsible for monitoring persons suspected of infection and disseminating Covid-19 early mitigation strategies. We also included indigenous socio-cultural activities since such activities may facilitate Covid-19 infection in rural areas. Indigenous socio-cultural activities refer to native people's communal activities such as Javanese wedding ceremonies (*mantenan*), Javanese traditional circumcision ceremonies (*khitan*), traditional birth celebration (*tasyakuran melahirkan*), religious meetings (*pengajian*), the obligation to visit and attend to sick or dying neighbours (*mbesuk* or *melayat*) and other communal activities that form a part of rural Javanese traditional cultures [5,6]. The Podes 2020 measured these activities as the number of socio-cultural in each village per month. Such activities may directly mediate Covid-19 infection within and between villages as most villagers are culturally obligated to take part in them. Village poverty is measured by the ratio of families living below Indonesia's poverty line. These numbers were based on village administrative data collected by village government authorities. Distance to a Covid-19 epicentre city was the distance of each village from a closed epicentre city in kilometres. For Covid-19 deaths, we include the number of health workers and the distance of each village to a Covid-19 referral hospital to capture whether healthcare access may be linked to Covid-19 patients' odds of dying from the disease.

The ethical approval for this study will be submitted to the Ethical Committee, Ministry of Education and Culture, Brawijaya University.

6. Patient and public involvement

Neither patients nor the public were involved in the design or conduct of this study. Participants also did not contribute to the writing or editing of this manuscript. Informed written consent was sought from each participant by the Malang DHA before the interview.

7. Statistical Considerations

Multilevel or hierarchical regression analyses will be applied to take full advantage of the village clustering information available from the data. These regression analyses are able to account for the

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clustering of individuals by separating individual variances of Covid-19 infections and Covid-19 deaths from village variances. This type of regression is therefore more appropriate than simple regression, which does not take village-level clustering data into account. For these analyses, hierarchical logistic regression was used to estimate factors associated with Covid-19 infection and Covid-19 deaths. We will estimate a hierarchical logit model using multilevel mixed-effects logistic regression (*melogit*). In this study, *melogit* fits mixed-effects models for binary responses. We will carry out two-level logistic regression using STATA 16.0 software.

8. Storage and Archiving of Study Documents

The data that support the findings of this study will be available for public in the Zenodo repository.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	12-14
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-11
Bias	9	Describe any efforts to address potential sources of bias	32
Study size	10	Explain how the study size was arrived at	8-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	12-14
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	14
		(*b*) Describe any methods used to examine subgroups and interactions	na
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	na
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	na
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	16
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	16-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	18-23

		(*b*) Report category boundaries when continuous variables were categorized	na
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	na
Discussion			
Key results	18	Summarise key results with reference to study objectives	23
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	32-33
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	32-33
Generalisability	21	Discuss the generalisability (external validity) of the study results	32-33
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	38

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Sociodemographic characteristics and health access associated with Covid-19 infection and death: A cross-sectional study in Malang District, Indonesia

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Sociodemographic characteristics and health access associated with Covid-19 infection and death: A cross-sectional study in Malang District, Indonesia

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Sociodemographic characteristics and health access associated with Covid-19 infection and death: A cross-sectional study in Malang District, Indonesia

Abstract

Objectives This study aims to examine sociodemographic characteristics and health access associated with Covid-19 infection and death in Malang District, Indonesia.

Design A non-random cross-sectional study

Setting Population in 390 villages in Malang District, East Java Province, Indonesia

Participants We used Malang district government Covid-19 contact tracing data from 14,264 individuals, spanning from March 1, 2020, to July 29, 2020.

Primary outcome measures The outcome variables in this study are Covid-19 infections and Covid-19 deaths. The associations between sociodemographic characteristics and health access of Covid-19 infection and death were analysed using multilevel logistic regression.

Results Among the 14,264 samples, 551 individuals were confirmed as being infected with Covid-19; 62 individuals died of Covid-19. Females, individuals with direct contact with confirmed Covid-19 cases, and individuals with hypertension constituted the groups most vulnerable to Covid-19 infection. Among respondents with confirmed Covid-19 cases, males, individuals aged 61 years and older, individuals with hypertension, and those diagnosed with pneumonia and respiratory failure were at higher risk of death. The number of community-based healthcare interventions was significantly associated with lower Covid-19 infection and Covid-19 mortality. Greater distance to a Covid-19 referral hospital increased risk of Covid-19 mortality.

Conclusions Covid-19 infection and death were related not only to sociodemographic characteristics of individuals but also to the presence of community-based healthcare interventions and access to hospital care. Strategies in public health, including improving healthcare access, are required to reduce Covid-19 infections among the most susceptible groups in Indonesia.

Keywords: social determinants; community health; public health; Covid-19

Strengths and limitations of this study:

- This study examines the association between sociodemographic characteristics, health access and Covid-19 infection and death in a unique rural setting.
- Multilevel or hierarchical regression analyses were applied to take full advantage of the village clustering information available from the data.
- This is a rapid healthcare assessment based on four months of contact tracing data.
- Some of the variables in this study were based on retrospective data, especially regarding respondents' histories of heart disease and diabetes.

Introduction

Understanding sociodemographic characteristics and health access associated with Covid-19 infections and deaths is vital for the development of effective mitigation strategies [1, 2]. By identifying various sociodemographic characteristics such as age, gender, education, income, employment and living area as well as access to healthcare for infected individuals, we can determine conditions associated with Covid-19 infection and mortality. Hence, we may be able to identify certain vulnerable groups in the community whose members are at high risk of infection and death due to the virus. Policymakers need this information to formulate early detection and mitigation strategies to protect the community from Covid-19 infection risks and, most importantly, to minimise the number of deaths caused by the virus.

Earlier studies in Wuhan, China have shown that certain types of jobs are related to Covid-19 infection. It has been reported that occupational groups at risk include workers (and visitors) at seafood and wet animal wholesale markets [3]. Healthcare workers have been recognised as another group at high risk of infection [3]. In Beijing, it was found that individuals who had close contact with people with confirmed cases of Covid-19, as well as those who had been to Wuhan, were at risk of infection [4-6]. Studies have also reported that male sex, older age, and comorbidities, especially cardiovascular metabolic diseases, confer a greater risk of death due to Covid-19 in Wuhan [5, 6]. Covid-19 patients with diabetes had poorer outcomes than sex- and age-matched patients without diabetes. Older age and comorbid hypertension contributed independently to in-hospital deaths among patients with diabetes [7, 8].

While earlier studies in Wuhan and Beijing have shown that close contact is related to infection, recent studies in the US and UK have found additional sociodemographic characteristics, particularly ethnicity and socio-economic background, to be linked with Covid-19 infection. Yancy reported that African American or Black people in New York City were contracting the virus at higher rates and were more likely to die than White Americans [2]. Also in New York City, Borjas found that people who lived in poor or immigrant neighbourhoods were more likely to become infected with Covid-19 than people who lived in wealthier, non-immigrant neighbourhoods [9]. In a recent study, Nasar and Hill reported disproportionate infection and mortality rates in Black, Asian and minority ethnic (BAME) communities in the UK [10]. Verhagen and colleagues have explained that hospitals in some areas of the UK face a disproportionate risk of excessive pressure due to Covid-19 as a result of socio-economic differences and the demographic composition of their populations, leaving poor families and poor regions behind [11].

Health disparities and socio-economic status have also been linked with Covid-19 deaths in the US, UK and other wealthy countries. Richardson et al. reported patients in the New York City area with hypertension, obesity, and diabetes to be at high risk of death from Covid-19 [12]. In the UK and Italy, Covid-19 deaths have been mainly observed among older male patients with multiple comorbidities [13, 14]. A higher burden of comorbidities, male sex, and older age may be considered more substantial determinants of higher risk of death in Italy than in China [15]. These studies indicate that health disparities and socio-economic status seem to be important for Covid-19 infection in six high-income countries. These characteristics are aligned with demographic and epidemiological features in those countries.

As the pandemic spreads across the world, developing countries appear to be the disease's next target [16]. The outbreak could devastate parts of those countries as they differ from wealthier countries in terms of demographic composition, the sources of people's livelihoods, and health system capacity. Covid-19 mitigation interventions applied in high-income countries may not fit developing countries. For example, as the largest numbers of deaths in high-income countries are taking place among older people, public health mitigation is focusing on care home mitigation and social care resilience strategies. With their younger populations, developing countries may consider different mitigation strategies. Hence, identifying social determinants of health and inequalities around Covid-19 infections and deaths in developing countries is very important for public health mitigation strategies.

Indonesia is a developing country and home to the world's fourth-largest population and second-largest urban area. With its huge population and weak healthcare system, some scholars and analysts predict that the country could be the next Covid-19 hot spot in Asia [16-18]. Currently, the WHO is reporting that Indonesia has the highest rate of Covid-19 infection and death among ASEAN countries [17, 19]. The number of Covid-19 cases has increased sharply each day since April 2020. As of August 17, 2021, as many as 4,008,166 cases have been officially confirmed in the country, with 128,252 deaths recorded thus far. The virus has spread to all of the country's 34 provinces. Java Island is the epicentre, with East Java and Jakarta, the country's largest region and its capital city, respectively, as the most densely infected areas. The number of total polymerase chain reaction (PCR) tests in the country is low at 26,275 tests per million individuals [19]; it is therefore probable that the actual number of infections is higher than the central government's official reported number. It is also expected that the number of cases will continue to increase as the government eases restrictions under the "new normal policy" in effect since the beginning of June 2020. With limited medical staff, hospital beds and intensive care facilities as well as a lack of government (especially local government) capacity to provide Covid-19 treatments and medications, early prevention and mitigation are particularly crucial in rural areas, where the deficit of Covid-19 health facilities and workers is significant. Densities of doctors and nurses in Indonesia, at 3.9 doctors per 10,000 population and 13.8 nurses per 10,000 in 2020, are the second lowest among Southeast Asian countries [20]. The number of hospital beds per 1,000 population is 1.1, which is lower than the WHO requirement (a minimum of 3 beds per 1,000 population) [21].

Ranscombe recently highlighted the need to take a systematic approach to tackling the Covid-19 crisis, focusing on rural areas [22]. He posited that the adoption of a systematic approach should include examining the socio-medical, socio-economic, and socio-political implications of confronting the pandemic in rural areas, which often have a significant scarcity of health facilities and workers for Covid-19 treatment as well as insufficient knowledge about Covid-19 infection. Accordingly, studies have shown limited healthcare access in rural Indonesia as a key factor of citizens' health and well-being [22-24]. Various community-based healthcare interventions which play a vital role in improving individual health status exist within villages [25, 26-28]. Poverty is major characteristics of Indonesia's rural population, and they partially determine citizens' health status [23]. Village community is also place of indigenous socio-cultural activities as such activities may increase transmission of Covid-19 in rural areas [29-31]. Such activities may directly mediate Covid-19 infection within and between villages as most villagers are culturally obliged to take part in them.

Hence, this study aims to examine whether those sociodemographic characteristics and healthcare access are associated with Covid-19 infection and death in rural Indonesia. By identifying the most vulnerable group based on sociodemographic characteristics and health access, better targeting of local health services for Covid-19 prevention and treatment can be achieved within communities. It is vital to identify the most important social and health access determinants associated with Covid-19 infection and morbidity to guide policymakers in formulating more focussed mitigation strategies.

Methods

Study design and settings

This study used a non-random cross-sectional design based on official Covid-19 tracing data collected by the Malang District Health Authority (DHA) from March 1 to July 29, 2020, and administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 [32]. This study was conducted in Malang District in East Java, Indonesia. Malang is located quite close to the city of Surabaya, which is currently the biggest Covid-19 epicentre in Indonesia (Figure 1).

[Figure 1. Malang District East Java Indonesia]

Malang's area covers 3,535 square kilometres, with an agricultural emphasis on rice and sugar cane. Malang's total population of 2,544,315 is distributed across 33 sub-districts, 390 villages and 3,125 community neighbourhoods [33]. A sub-district consists of villages, and a village consists of community neighbourhoods. The number of people in each village and community neighbourhood in Malang District averages 6,400 and 746, respectively [33].

Data sources

Covid-19 contact tracing data

Covid-19 contact tracing data were collected by the Malang DHA based on the Indonesian Ministry of Health Covid-19 prevention and control guidelines. Formal permission was given by the authority to analyse the data. The total number of individuals traced from March 1 to July 29, 2020, was 14,264. The tracing data covered the entire population of Malang District (2,544,315 individuals). Covid-19 contact tracing refers to the process of identifying all individuals who fulfil one of these criteria: (1) having had contact with a confirmed Covid-19 patient within the previous two weeks, (2) having one of the Covid-19 symptoms, or (3) having travelled from one of the Covid-19 epicentre areas in Indonesia or abroad [34]. Close contact was identified by health workers in each village using the following criteria: those living in the same household with or having been close to someone who had tested positive for Covid-19 [34].

The tracing was organised by the Malang DHA based on the Ministry of Health surveillance guidelines for SARS-CoV-2 infection (see **Supplementary materials**). Written informed consent was obtained by the Malang DHA from all individuals before data collection. Prior to interviewing, individuals were informed about the importance of participating in the contact tracing activities. Confidentiality and anonymity were ensured [35]. Malang contact tracers were selected by the Ministry of Health Covid-19 task force through recommendations from the provincial and district health authority team. Overall, 78 medical doctors and 780 nurses across 39 primary healthcare centres (*Pusat Kesehatan Masyarakat* or *Puskesmas*) supporting primary healthcare centres (*Puskesmas Pembantu*) and 390 village health posts (*Pondok Kesehatan Desa* or *Ponkesdes*) were involved in tracing services in Malang District. All recruited contact tracers underwent a thorough three-day training to learn and practice methods of detection, prevention, response and control for Covid-19 risk communication and Covid-19 case management. Thirty-nine additional Malang DHA staff members worked to facilitate the logging and cataloguing of data, coordinating logistics and checking the quality of filled Covid-19 surveillance forms.

During data collection, the tracing team members were equipped with several items of personal protective equipment for public screening, including hazardous material suits (Kodaichi Coverall), medical masks (N95 3M Type 9010), face shields (headgear with clear visor), surgical gloves (Golden Glove latex), boots or closed work shoes, and hand sanitiser. They were also instructed to carry an infrared thermometer (KODYEE CF-818) as well as the Covid-19 surveillance and monitoring forms provided by the DHA. Interviews with individuals suspected of carrying Covid-19 were conducted at a distance of 1.5 to 3 meters [36].

Contact tracing was conducted in several venues, but most interviews with individuals suspected of meeting one of the three criteria above were conducted via home visit/door-to-door tracing. Based on the reports, the contact tracing team created lists of triaged contacts for further assignment. All individuals on the contact lists were notified by the contact tracing team before the team interviewed them at their homes or at secure locations such as a *Ponkesdes* office. Subsequently, nurses in each village were responsible for monitoring all contacts to which individual nurses were assigned for at least fourteen days. In addition, the team conducted Covid-19 tracing in several public places including bus stations, train stations, the local airport and other public gathering places to track people travelling from other cities or abroad.

The team referred patients with severe Covid-19 symptoms requiring inpatient services to a Covid-19 referral hospital. Patients received a repeat reverse transcription polymerase chain reaction (RT-PCR) swab test at the hospital. Patients with only mild or no symptoms were tested using a rapid test. If the result of this first rapid test was negative, the patient was asked to self-isolate for 14 days and take another rapid test at the end of the self-isolation period. A second negative result on a rapid test showed that the individual was likely not infected at the time. Patients receiving a positive result from the second rapid test were required to undergo two RT-PCR swab tests on two consecutive days. If the RT-PCR swab test result was negative, an individual was likely not infected at the time. A positive result on an RT-PCR swab test confirmed Covid-19 infection, and patients were required to take protective steps to prevent others from becoming infected. If the first rapid test showed positive results, the patient was required to undergo two RT-PCR swab tests on two consecutive days. If the RT-PCR swab test result was negative, the individual was likely not infected at the time. If the RT-PCR swab test result was positive, the individual was required to take protective steps to prevent others from becoming infected. Confirmed Covid-19 patients with mild or no symptoms were permitted to self-isolate at home, while those with moderate or severe symptoms were referred to hospitals. Patients with a positive rapid test but a negative RT-PCT swab test were not required to self-isolated. The procedures for Covid-19 tracing and testing are explained in the supporting information in Figure 2.

[Figure 2. Procedure for Covid-19 tracing and testing]

The Malang DHA provided a form to record information on every individual who died due to Covid-19. Mortality data were collected by all public and private hospitals in Malang District. Mortality data on individuals who died outside health facilities were collected by the village nurses on the forms provided. The Malang DHA recorded the cause of death for every individual who died due to Covid-19 on the medical death certificate. The authority's elapsed time to obtain information on deaths due to Covid-19 was fourteen days [34-36].

Indonesia's Village Potential Census (Podes) data 2020

We merged the contact tracing data with administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 (Podes) [33]. The Podes represents a longstanding tradition of collecting data at the lowest administrative tier of local government. Podes consists of 83,931 villages (*desa*) across 514 districts in Indonesia. The census has been conducted every two years since 1983 by the Indonesian Central Bureau of Statistics (*Biro Pusat Statistik*). Detailed information was gathered on a range of characteristics from public infrastructure to village finances. Information was gathered from *kepala desa* (rural village heads) and *lurah* (urban neighbourhood heads). From the 2020 census, we retrieved the following data for each village: number of health workers, number of community-based healthcare interventions and number of indigenous socio-cultural activities as well as hospital access, poverty and distance to a Covid-19 epicentre city [32].

Variables

The outcome variables in this study are Covid-19 infections and Covid-19 deaths. RT-PCR swab tests are used by the Malang District Health Authority to determine the presence of Covid-19 infection. The authority determines that an individual is infected if the RT-PCR swab test shows a positive result. The Indonesian Ministry of Health follows the WHO definition of death due to Covid-19 as a 'death resulting from a clinically compatible illness, in a probable or confirmed Covid-19 case, unless there is a clear alternative cause of death that cannot be related to Covid-19' (e.g., traffic accident or trauma) [36-38]. Deaths due to Covid-19 cannot be attributed to another disease (e.g. cancer) and are counted independent of pre-existing conditions suspected of triggering a severe case of Covid-19 (e.g. coronary artery disease, type 2 diabetes, or chronic obstructive pulmonary disease).

Marmot and Wilkinson, Tian et al. and WHO define social determinant of health as the conditions in which people are born, grow, live, work and age [39,40]. They include determinants such as socio-economic status, education, neighbourhood and physical environment, employment status, and social support networks, as well as access to health care. In this study, we used job type, number of community-based health interventions, village poverty, number of indigenous socio-cultural activities, distance to a Covid-19 referral hospital and distance to a Covid-19 epicentre city to investigate sociodemographic characteristics and health access.

Job types were divided into nine categories: health workers, civil servant non-health workers (i.e., teachers, village and district government staff, police, army and other civil servants providing direct community service during the pandemic), labourers (i.e., factory workers or construction workers), professional workers (i.e., bank staff or company staff), traders, farmers, housewives, students, and retired persons. We used health workers as the reference group as this group is among those with the highest risk for Covid-19 infection and death.

Previous studies have documented that village poverty status and the number of community-based healthcare interventions are linked with individual health status and well-being [41-43]. We therefore wanted to examine whether these determinants were associated with Covid-19 infection and mortality. In this study, we used government Central Bureau of Statistics data for village poverty. The Malang Central Bureau of Statistics authority follows the national guideline for measuring poverty, which is based on $3.20 a day purchasing power parity, corresponding to conditions in lower-middle-income countries [33]. The authority provides data on the ratio of families living below poverty line in all 390 villages.

Community-based healthcare interventions refer to neighbourhood or community activities aiming to provide healthcare support within a community [26-28]. In Malang, such interventions are conducted by voluntary health workers or *kader* in *Posbindu* (*Pos pembinaan terpadu* or integrated health posts for NCDs) and *Posyandu/Posyandu Lansia* (*Pos pelayanan terpadu lanjut usia* or integrated healthcare service posts for children and older people), which play a vital role in improving individual health status within villages [28].

In this study, community-based healthcare data was retrieved from the Podes 2020 census. In the census, the number of community-based healthcare interventions was measured by the number of *Posbindu* and *Posyandu/Posyandu Lansia* in each village. During the outbreak, these community-based healthcare interventions were important for supporting district governments in increasing Covid-19 awareness among villagers. The district governments authorised health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* to serve as community Covid-19 task force teams responsible for monitoring persons suspected of infection and disseminating Covid-19 early mitigation strategies.

We also included indigenous socio-cultural activities as such activities may increase transmission of Covid-19 in rural areas. Indigenous socio-cultural activities refer to native communal activities such as Javanese wedding ceremonies (*mantenan*), Javanese traditional circumcision ceremonies (*khitan*), traditional birth celebrations (*tasyakuran melahirkan*), religious meetings (*pengajian*), the obligation to visit and attend to sick or dying neighbours (*mbesuk* or *melayat*) and other communal activities that form part of rural Javanese traditional cultures [29-31]. The Podes 2020 measured these activities as the number of socio-cultural in each village per month. Such activities may directly mediate Covid-19 infection within and between villages as most villagers are culturally obliged to take part in them.

Distance to a Covid-19 epicentre city was measured as the distance of each village from an epicentre city in kilometres. To capture whether healthcare access may be linked to Covid-19 patients' odds of dying from the disease, we included the total number of health workers and the distance of each village to a Covid-19 referral hospital. The number of indigenous socio-cultural activities and the distance to a Covid-19 epicentre city was included to measure risk of Covid-19 infection [32].

Other individual sociodemographic and medical characteristics related to Covid-19 infection and died were also included, such as age, sex, the presence of Covid-19 symptoms, having had contact with individuals with confirmed or suspected cases of Covid-19, the presence of comorbidities, medical diagnosis before RT-PCR, inpatient treatment, and ICU treatment. Age was categorised into four groups based on Indonesia's demographic groups: 17 years and younger, 18-44 years, 45-60 years, and 61 years and older. Among people with confirmed cases, we include whether respondents had symptoms such as fever, cough, runny nose, sore throat, shortness of breath, shivering, headache, fatigue, muscle aches, nausea, abdominal pain or diarrhoea. We also asked whether respondents had had contact with people with confirmed Covid-19 cases, had had contact with people suspected of being infected with Covid-19, or had visited an animal market in the previous two weeks. Among patients who died of Covid-19, we included comorbidities through history of diabetes, cardiovascular diseases, hypertension, autoimmune diseases and kidney diseases. We also included pre-RT-PCR test diagnosis of pneumonia, chronic obstructive pulmonary disease (COPD), and respiratory failure by a medical doctor. Individuals receiving Covid-19 hospital inpatient services and hospital intensive care unit services were also included to control for Covid-19 deaths. The dataset for the study are available online at Zenodo Repository [33].

Ethical clearance, patient and public involvement

This study received ethical approval from the Ministry of Education and Culture, University of Brawijaya (Number 331/EC/KEPK/2020). The review board certified that all procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration. Neither patients nor the public were involved in the design or conduct of this study. Participants did not contribute to the writing or editing of this manuscript. The authority sought and received informed written consent from each participant or family members in some cases if the patients might have been alive but intubated or otherwise incapable of giving permission themselves before the interview.

Statistical methods

Multilevel or hierarchical regression analyses were applied to take full advantage of the village clustering information available from the data. These regression analyses are able to account for the clustering of individuals by separating individual variances of Covid-19 infections and Covid-19 deaths from village variances. This type of regression is therefore more appropriate than simple regression, which does not take village-level clustering data into account. For these analyses, hierarchical logistic regression was used to estimate factors associated with Covid-19 infection and Covid-19 mortality. The mathematical formula for both models can be written as follows, considering an individual i nested in a village j:

$$E_{ij*} = \beta_o + \Sigma \beta_j W_j + \beta_{ij} X_{ij} + \mu_j + \epsilon_{ij}$$

With:

351 $E_{ij^*=}$ logit (P ($E_{ij^*=}$ 1 or 0)) as a binary variable indicating an individual who has been infected with or died from Covid-19 (i.e. 1 = Covid-19 infection or death; 0 = No)

353 W_j as a set of village determinants (j= number of community-based healthcare interventions, number of indigenous socio-cultural activities, village poverty, distance to a Covid-19 epicentre city, number of health workers, and distance from village to a Covid-19 referral hospital)

356 X_{ij} as a set of individual determinants (i= age, sex, job type, symptoms, comorbidities, etc.)

357 μ_j as a random intercept of villages with mean zero and variance σ_μ^2

358 ϵ_{ij} normally distributed with zero and variance σ_ϵ^2.

359 We estimated a hierarchical logit model using multilevel mixed-effects logistic regression (*melogit*). In this study, *melogit* fits mixed-effects models for binary responses. The conditional distribution of the response given the random effects is assumed to be Bernoulli, with success probability determined by the logistic cumulative distribution function. We used maximum likelihood estimation to fit all models. Odds ratios were used to compare the magnitude of each social determinant of health for individual Covid-19 infections and deaths. We carried out two-level logistic regression using STATA 16.0 software.

366 Results

367 Characteristics of the sample

368 Table 1 presents the characteristics of the sample in this study, which is divided into two categories: all Covid-19 contact traced individuals (N=14,264) and individuals confirmed infected with Covid-19 (N=551). We found that 4% (N=551) of tracked individuals were confirmed infected, and 11% (N=62) of those infected individuals died. Most of the tracked and infected individuals were male (64% and 53%, respectively). Most were young adults (18-44 years) and middle-aged adults (45-60), and most were labourers and traders who regularly

worked in epicentre cities, i.e. Malang City or Surabaya City. Among those who were infected, 29% reported having contact with individuals with confirmed Covid-19 cases, and 17% reported having had contact with individuals with suspected Covid-19 cases. Fever, cough and shortness of breath were the most common symptoms among those with confirmed cases of Covid-19 (39%, 32% and 27%, respectively). We found that 13% of infected individuals had at least one symptom, while 46% of those who died of Covid-19 had reported having at least one symptom. Among traced individuals, 23% and 14% reported having hypertension and diabetes, respectively. Of those who died of Covid-19, 60% and 49% had reported having hypertension and diabetes. Almost half of the infected patients (40%) were diagnosed as having pneumonia, and a small percentage were diagnosed as having acute respiratory distress syndrome and/or respiratory failure. Half of the infected individuals reported receiving inpatient treatment at a hospital. The number of community-based healthcare interventions varied across the 390 villages, ranging from 0 to 149. Likewise, the number of indigenous socio-cultural activities varied, with an average of 11 activities in each village. On average, the distance from a village to an epicentre city (Malang or Surabaya) was 34 kilometres, while the average distance to a Covid-19 referral hospital was approximately 11 kilometres. The average number of health workers in each village was eight, while the average proportion of people living in poverty was 20% across all villages.

Table 1. Sample characteristics of all tracked individuals and Covid-19 confirmed cases

Variables	All sample (N=14,264)				Covid-19 confirmed cases (N=551)			
	% or mean	SD	Min	Max	% or mean	SD	Min	Max
Covid-19 infections	551 (3.9%)				551 (100%)			
Covid-19 deaths	62 (0.4%)				62 (11.3%)			
Male	9,109 (63.9%)				293 (53.2%)			
Age								
≤ 17	1,794 (12.6%)				33 (6.0%)			
18-44	9,049 (63.6%)				218 (39.6%)			
45-60	2,766 (19.4%)				214 (38.8%)			
> 60	632 (4.4%)				86 (15.6%)			
Job type								
Civil servant, non-health worker	62 (0.4%)				14 (2.5%)			
Health worker	58 (0.4%)				12 (2.2%)			
Professional worker	59 (0.4%)				5 (0.9%)			
Labourer	4,092 (28.7%)				347 (63.0%)			
Trader	2,349 (16.5%)				295 (53.5%)			
Farmer	2,265 (15.9%)				37 (6.7%)			
Housewife	2,085 (14.6%)				170 (30.9%)			
Student	2,864 (20.0%)				42 (7.6%)			
Retired	227 (1.6%)				25 (4.5%)			
Had contact with confirmed Covid-19 case	512 (3.6%)				159 (28.9%)			
Had contact with suspected Covid-19 case	354 (2.5%)				92 (16.7%)			
Visited animal market	14 (0.1%)				1 (0.2%)			
Symptoms								
Fever	983 (6.9%)				212 (38.5%)			
Cough	1,200 (8.4%)				178 (32.3%)			
Runny nose	549 (3.8%)				58 (10.5%)			
Sore throat	288 (2.0%)				40 (7.3%)			
Shortness of breath	640 (4.5%)				147 (26.7%)			
Shivering	121 (0.8%)				17 (3.1%)			
Headache	180 (1.3%)				30 (5.4%)			
Fatigue	457 (3.2%)				76 (13.8%)			
Muscle aches	133 (0.9%)				21 (3.8%)			
Nausea	241 (1.7%)				55 (10.0%)			
Abdominal pain	113 (0.8%)				20 (3.6%)			

Diarrhoea	68 (0.5%)				14 (2.5%)			
Having at least one symptom	1,824 (12.8%)				299 (45.7%)			
Presence of comorbidities								
Diabetes	2,026 (14.2%)				267 (48.5%)			
Heart diseases	80 (0.6%)				8 (1.5%)			
Hypertension	3,213 (22.5%)				333 (60.4%)			
Chronic kidney diseases	19 (0.1%)				4 (0.7%)			
Auto-immune diseases	15 (0.1%)				2 (0.4%)			
Chronic obstructive pulmonary disease	32 (0.2%)				4 (0.7%)			
Medical doctor diagnosis before RT-PCR								
Pneumonia	648 (4.5%)				222 (40.3%)			
Acute respiratory distress syndrome	23 (0.2%)				7 (1.3%)			
Respiratory failure	0.8%				11 (2.0%)			
Inpatient	5.8%				276 (50.1%)			
ICU	0.2%				6 (1.4%)			
Village determinants								
Number of community-based health interventions	134	20	0	149	111	41	0	147
Number of indigenous socio-cultural activities	11	5	3	32	14	6	4	32
Distance to a Covid-19 referral hospital (km)	10	9.1	0.0	43.0	3.9	4.6	0.0	36.5
Number of health workers	8	9	0	69	13	14	1	69
Village poverty	0.2	0.04	0.01	0.4	0.2	0.05	0.03	0.3
Distance to a Covid-19 epicentre city (km)	34.2	16.0	1.0	79.0	18.8	10.0	4.0	68.0
N (villages)	390				152			

395 Figures 3 and 4 describe the distribution of Covid-19 infections and Covid-19 deaths across 390 villages in the district. In terms of Covid-19 infection, the number of infected individuals was larger in villages closer to a Covid-19 epicentre.

398 [Figure 3. Distribution of Covid-19 infection in 390 villages of Malang district East Java Indonesia, July 29, 2020]

401 [Figure 4. Distribution of Covid-19 mortality in 390 villages of Malang district East Java Indonesia, July 29, 2020]

Multilevel logistic results for Covid-19 infection

405 Table 2 shows the multivariate odds ratios for the effects of individual and village-level determinants on Covid-19 infection. The unadjusted odds ratio of Covid-19 infection shows that being older was associated with a higher risk of infection. However, the associations were not statistically significant after adjusting for socio-economic and health variables at the individual and village levels. Male respondents had an approximately 30% lower risk (95% confidence interval (CI) 0.57 to 0.85) of Covid-19 infection in the unadjusted model. The association remained statistically significant in the fully adjusted model. Also in the fully adjusted model, students and retirees had 83% and 78% lower probability, respectively, of having Covid-19 than health workers. Traders and housewives had higher odds of contracting Covid-19 in the unadjusted model, but those relationships disappeared in the fully adjusted model.

418 Table 2. Unadjusted and adjusted multilevel logistic regressions for Covid-19 infection ($N_{individual}$=14,264, $N_{village}$=152)

420

Variables	Unadjusted OR	95% CI	p-value	Adjusted OR	95% CI	p-value
Individual determinants						
Age, reference: 17 years and younger						
18-44	2.09	1.39-3.15	<0.001	0.83	0.36-1.95	0.673
45-60	5.05	3.33-7.66	<0.001	1.02	0.41-2.55	0.968
61 years and older	5.36	3.34-8.63	<0.001	1.14	0.43-3.03	0.799
Male	0.70	0.57-0.85	<0.001	0.74	0.56-0.98	0.033
Job type, reference: health worker						
Civil servant, non-health worker	9.30	3.93-22.00	<0.001	6.09	0.44-85.18	0.180
Professional worker	0.45	0.16-1.23	0.122	0.37	0.05-2.76	0.330
Labourer	1.17	0.80-1.71	0.413	0.42	0.13-1.38	0.153
Trader	1.51	1.03-2.21	0.032	0.39	0.12-1.26	0.115
Farmer	1.45	0.94-2.22	0.086	0.37	0.11-1.27	0.113
Housewife	1.87	1.47-2.38	<0.001	0.42	0.13-1.38	0.153
Student	0.32	0.23-0.44	0.000	0.17	0.05-0.66	0.011
Retired	3.18	2.08-4.86	0.000	0.22	0.06-0.81	0.023
Had contact with confirmed Covid-19 cases	12.98	9.36-18.00	<0.001	20.56	12.96-32.62	0.000
Had contact with suspected Covid-19 cases	5.19	3.63-7.43	<0.001	0.86	0.51-1.47	0.583
Visited animal market	1.06	0.09-11.85	0.960	0.10	0.01-1.23	0.072
Symptoms						
Fever	2.59	2.04-3.29	<0.001	2.68	1.95-3.71	0.000
Cough	1.02	0.80-1.31	0.823	0.85	0.58-1.23	0.386
Runny nose	0.59	0.42-0.83	0.003	0.80	0.51-1.27	0.343
Sore throat	0.83	0.55-1.24	0.382	0.78	0.46-1.30	0.334
Difficulty breathing	2.27	1.74-2.96	<0.001	3.03	2.11-4.36	0.000
Shivering	0.97	0.53-1.80	0.948	0.58	0.27-1.25	0.165
Headache	1.58	0.97-2.58	0.062	1.26	0.70-2.27	0.439
Fatigue	1.81	1.30-2.50	<0.001	0.72	0.47-1.12	0.151
Muscle aches	1.60	0.88-2.88	0.118	0.89	0.43-1.85	0.758
Nausea	2.09	1.42-3.07	<0.001	1.54	0.93-2.56	0.091
Abdominal pain	1.20	0.67-2.15	0.531	0.73	0.35-1.55	0.414
Diarrhoea	2.11	1.01-4.37	0.044	1.83	0.76-4.42	0.180
Presence of comorbidities						
Diabetes	4.98	3.98-6.24	<0.001	1.08	0.68-1.72	0.749
Heart diseases	0.41	0.18-0.92	0.031	0.16	0.07-0.40	0.000
Hypertension	5.65	4.51-7.10	<0.001	4.36	2.76-6.88	0.000
Auto-immune diseases	7.02	0.98-50.13	0.052	4.06	0.65-25.13	0.132
Chronic obstructive pulmonary disease	5.08	1.32-19.44	0.018	0.43	0.08-2.40	0.337

Village determinants						
Number of community-based healthcare interventions	0.96	0.95-0.98	<0.001	0.99	0.98-1.00	0.008
Number of indigenous socio-cultural activities	1.11	1.05-1.17	<0.001	1.03	0.99-1.08	0.156
Village poverty status	3.30	1.27-8.56	0.014	14.86	0.21-10.75	0.216
Distance to Covid-19 epicentre city	0.91	0.89-0.93	<0.001	0.94	0.92-0.96	0.000
ICC				0.37	0.28-0.46	
Likelihood				-1346.11		

Contact history with confirmed Covid-19 patients was associated with an increased risk of contracting Covid-19 (unadjusted odds ratio 12.98, 95% CI 9.36 to 18.00). This effect remained stable after adjusting for other risk factors. Respondents with a history of contact with suspected Covid-19 patients and those having visited an animal market had 5.19 times and 1.06 times higher risk, respectively, in the unadjusted model, but these associations disappeared in the fully adjusted model.

Fever and difficulty breathing were associated with 2.59 (95% CI 2.04 to 3.29) and 2.27 times higher risk (95% CI 1.74 to 2.96) of having Covid-19, respectively, in the unadjusted model. These associations remained in the fully adjusted model. Hypertension (adjusted odds ratio 4.36, 95% CI 2.76 to 6.88) showed a positive and significant association with a higher risk of Covid-19 infection, while respondents with heart disease had an 84% lower risk of Covid-19 infection (95% CI 0.07 to 0.40).

Turning to the village-level determinants, a greater number of community-based health interventions (adjusted odds ratio 0.99, 95% CI 0.98 to 1.00) and greater distance to a Covid-19 epicentre city (adjusted odds ratio 0.94, 95% CI 0.92 to 0.96) were related to a lower risk of Covid-19 infection. A greater number of indigenous socio-cultural activities (unadjusted odds ratio 1.11, 95% CI 1.05 to 1.17) and living in a poor village (adjusted odds ratio 3.30, 95% CI

1.27 to 8.56) were associated with a higher risk of Covid-19 infection. However, adjusting for individual and other village-level covariates eliminated the effects of both indigenous socio-cultural activities and living in a poor village on Covid-19 infection. The ICC of 0.37 indicates that 37% of the variation in Covid-19 infection was located in villages.

Multilevel logistic results for Covid-19 mortality

Table 3 presents the analysis of Covid-19 mortality among the confirmed cases. The odds of dying of Covid-19 were higher among respondents aged 61 years and older (adjusted odds ratio for age group 61 years and older 364.22, 95% CI 88.57-1497.70). Working as a professional worker or labourer was associated with decreased Covid-19 mortality in the fully adjusted model. Respondents with diabetes, hypertension and chronic obstructive pulmonary diseases had higher odds of Covid-19 mortality. However, this association was only found in the unadjusted model. In the adjusted model, we found that respondents with hypertension had 17.1 times higher odds of Covid-19 mortality.

Respondents who received inpatient and ICU treatment had 30.48 times and 12.03 times higher odds of Covid-19 mortality, respectively. Respondents diagnosed by health professionals as having pneumonia and acute respiratory distress syndrome had 4.75 times and 5.99 times higher odds of Covid-19 mortality after adjusting for other individual and village-level covariates. The number of community-based healthcare interventions was significantly associated with lower Covid-19 mortality (adjusted odds ratio 0.98, CI 0.97-1.00). Living near a Covid-19 referral hospital was associated with a lower risk of Covid-19 mortality (adjusted odds ratio 1.45, 95% CI 1.02 to 1.51). The ICC is very small (2.48e-34), indicating that variation between villages provides little explanation of Covid-19 mortality.

462 **Table 3. Unadjusted and adjusted multilevel logistic regressions for mortality among**
463 **patients with Covid-19 (N $_{individual}$=551, N $_{village}$=390)**

Variables	Unadjusted OR	95% CI	*p*-value	Adjusted OR	95% CI	*p*-value
Individual determinants						
Age, reference: 17 years and younger						
18-44	0.51	0.10-2.58	0.420	10.52	3.29-33.59	0.000
45-60	2.62	0.59-11.52	0.201	186.00	49.32-701.39	0.000
61 years and older	5.32	1.17-24.10	0.030	364.22	88.57-1497.70	0.000
Male	1.45	0.84-2.49	0.176	2.93	1.49-5.75	0.002
Job type, reference: health workers						
Professional worker	0.97	0.07-12.05	0.985	0.01	0.00-0.19	0.003
Labourer	0.01	0.00-0.13	0.000	0.00	0.00-0.03	0.000
Trader	0.37	0.06-2.12	0.270	1.00	omitted	
Farmer	0.24	0.08-0.66	0.006	0.20	0.02-2.51	0.210
Retired	5.02	2.11-11.92	0.000	3.41	0.32-0.30	0.384
Had contact with confirmed Covid-19 cases	0.10	0.03-0.35	0.000	0.62	0.13-2.98	0.548
Had contact with suspected Covid-19 cases	0.22	0.07-0.74	0.014	0.64	0.10-3.90	0.627
Presence of comorbidities						
Diabetes	2.91	1.63-5.18	0.000	1.10	0.43-4.37	0.211
Heart diseases	2.68	0.52-13.59	0.233	1.75	0.51-5.98	0.375
Hypertension	2.22	1.21-4.08	0.010	17.01	5.34-54.20	0.000
Chronic obstructive pulmonary disease	24.81	2.53-242.40	0.006	2.12	0.47-9.66	0.330
Inpatient	18.03	6.38-50.95	0.000	30.48	13.68-67.91	0.000
ICU	8.28	1.51-45.12	0.015	12.03	2.73-53.20	0.001
Medical doctor diagnosis before RT-PCR						
Pneumonia	13.07	5.99-28.53	0.000	4.75	2.33-9.65	0.000
Acute respiratory distress syndrome	11.16	2.43-51.13	0.002	5.99	1.23-29.17	0.027
Respiratory failure	3.05	0.78-11.84	0.106	2.12	0.81-5.54	0.127
Village determinants						
Number of community-based health interventions	0.99	0.99-1.00	0.252	0.98	0.97-1.00	0.008
Number of indigenous socio-cultural activities	1.00	0.96-1.04	0.833	0.96	0.90-1.03	0.251
Village poverty status	0.59	0.28-1.22	0.162	0.97	0.00-312.57	0.306
Distance to Covid-19 epicentre city	0.99	0.96-1.02	0.660	0.99	0.92-0.98	0.513

Number of health workers	0.99	0.97-1.01	0.507	0.70	0.95-1.02	0.909
Distance to Covid-19 referral hospital	1.01	0.95-1.07	0.715	1.45	1.02-1.51	0.031
ICC				2.48e-34	7.85e-18	
Likelihood				-44.31		

Discussion

Using official government contact tracing data from Malang District, East Java, Indonesia, this study identifies sociodemographic characteristics and health access that are associated with Covid-19 infection and mortality. We found that females, individuals having had direct contact with people with confirmed Covid-19 cases, individuals with fever and difficulty breathing, and individuals with hypertension constitute the groups most vulnerable to Covid-19 infection. In contrast with earlier studies in Wuhan, China, which reported visitors to and workers at seafood and wet animal wholesale markets as being at high risk, we did not find individuals who visited animal markets to be at increased risk for infection [3]. We did, however, find individuals having had close contact with confirmed Covid-19 patients to be at higher risk of infection. Retired individuals and students had lower risk of COVID-19 infection than health workers. As school was in session only online, students may have had less social contact than others. Similarly, retired individuals tend to socialize less than other people. These findings confirm earlier studies in China and other countries which found that health workers are at higher risk of infection [4, 42].

Among respondents with confirmed Covid-19 cases, we found that males, individuals aged 61 years and older, individuals with hypertension, and those diagnosed with pneumonia and respiratory failure were at higher risk of death. The demographic pattern of Covid-19 deaths in Malang seems similar to patterns previous findings which reported that larger proportions of deaths were found among members of older age groups [2]. Accordingly, we found males and those with a history of hypertension to be at higher risk of death. In fact, the rate of death due to hypertension in Malang is very high. One plausible explanation for this is the prevalence of undetected cardio-metabolic conditions in Indonesia: through our work in 2014 and 2018, we discovered that more than two-thirds of Indonesian adults aged 40 and older have unmet needs for cardiovascular care [7-9]. Moreover, we found a higher risk of Covid-19 infection among individuals with hypertension. As conveyed in prior studies and government reports, hypertension is quite common among older adults in Indonesia [43-45]. Hence, the elevated likelihood of Covid-19 infection among individuals with hypertension may be linked to the high proportion of adult Indonesians with hypertension. Accordingly, patients diagnosed with pneumonia and respiratory failure had a higher likelihood of dying of Covid-19 than others. Previous studies have reported that pneumonia and respiratory failure may indicate Covid-19 as the infection may result in severe pneumonia and respiratory failure [46-49].

Confirming previous studies, we found that the only symptoms associated with Covid-19 infection were fever and shortness of breath. There was null association with other symptoms. These findings are consistent with earlier studies in China and developed countries, which have also shown that fever and shortness of breath are common symptoms associated with Covid-19 infection [7, 50]. Accordingly, we found that about half of infected individuals had at least one symptom, while other infected individuals reported no symptoms. These results match those of prior studies, which found a high ratio of asymptomatic Covid-19 infection [4, 51]. Given this ratio, prevention of Covid-19 infection in the district will prove challenging as villagers generally still have little awareness of the virus.

The pattern of the pandemic spread is reflected in our finding that greater distance to a Covid-19 epicentre is associated with lower risk of infection. This appears, also in Malang District, to follow the pattern of regional economic growth concentrated in urban areas and cities [52-55]. As centres for business and economic activities, urban areas and cities are places where large numbers of people work, shop, and sell agricultural products. As there were fewer restrictions on human mobility in Malang early in the pandemic, the virus spread first to neighbouring villages around the epicentre and then moved to more remote areas. Hence, people living near epicentre cities, who have more frequent contacts and thus more exposure to the virus, have a higher risk of infection than rural people who live far from epicentres, have fewer contacts with village outsiders, and therefore have less exposure to the virus.

As documented in several studies, the characteristics of healthcare system development in Indonesia follow the pattern of regional economic development, which is biased toward urban areas and cities [56-59]. Covid-19 referral hospitals in Indonesia, including in Malang, are concentrated in city centres and are more likely to have a larger number of specialised medical doctors and better hospital facilities. For example, most hospitals in Malang City have more isolation rooms and ventilators than those in Malang District. Malang District has four Covid-19 referral hospitals with a total of 126 isolation rooms. All of these hospitals are located in *Kepanjen* and *Gondanglegi* sub-districts as the central areas of Malang District.

Rural residents who live in other sub-districts must travel approximately 2-3 hours to reach those hospitals. With very limited transportation available during the outbreak, infected villagers often were not taken to hospitals or were taken when already in critical condition, placing them at higher risk of death. On the other hand, villagers who lived near a referral hospital were able to obtain medical treatment more quickly. Our findings, which show a positive association between distance to a referral hospital and mortality, illustrate the inequalities of healthcare access. Hence, the pandemic has illuminated an acute problem in Indonesia's healthcare system, which favours cities and leaves rural areas behind [56-59].

The number of area health workers has no significant association with the risk of death due to Covid-19. There are several plausible explanations for this finding. Firstly, the limited number of health workers in most villages in Malang Regency is due to the fact that most health workers are concentrated in areas near the city centre. Secondly, the finding may reflect most health workers' lack of skills and experience in handling Covid-19 patients as they received no training in Covid-19 treatment at the beginning of the outbreak. Most health workers are nurses and midwives whose main roles are in Covid-19 health promotion and not Covid-19 treatment. This lack of healthcare capacity is found not only in Malang Regency but also in many regions across the country, demonstrating the acute issue of unequal access to health care between urban and rural areas documented in various studies. The insignificant relationship between village poverty and Covid-19 infection and mortality further explains the lack of healthcare capacity in managing the outbreak. Although wealthier areas may have larger numbers of better-quality healthcare providers, they are not necessarily able to successfully manage the pandemic. As a result, we did not find the risk of infection and death across poor and rich communities to be significantly different.

The negative association of community-based health care with Covid-19 infection and Covid-19 mortality may indicate the benefits of community-based healthcare interventions for Covid-19 prevention in rural areas, which often have limited access to various resources such as information related to Covid-19 prevention. At the district level, community-based health care is vital in supporting district governments in increasing Covid-19 awareness among villagers. The district government empowers health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* as community Covid-19 task force teams responsible for monitoring individuals with suspected cases and disseminating Covid-19 early mitigation information. Previous studies have also demonstrated the benefits of such community activities to promote community resilience and to provide basic healthcare services in resource-poor settings [56,60].

Another village characteristic that we hypothesised to be associated with Covid-19 infection is the number of indigenous socio-cultural activities such as traditional wedding ceremonies (*mantenan*), traditional circumcision ceremonies (*khitan*), traditional birth celebrations (*tasyakuran melahirkan*), religious meetings (*pengajian*) and other socio-cultural activities at which individuals within the community and between communities often gather [60]. The result of our unadjusted odd ratio logistic regression indicates a positive and significant association with Covid-19 infection. However, null findings were shown within the adjusted model. These null findings may indicate that most of the indigenous socio-cultural activities took place in villages in rural areas, where infection rates were still low in the early phase of the pandemic. However, given that the local authorities are struggling to control such traditional gatherings within communities, these socio-cultural events may cause further Covid-19 clusters in the future.

Taken together, the findings of this rapid assessment offer two important policy implications that can aid in preparing for Covid-19 outbreaks in rural Indonesia. First, with the lack of healthcare capacity to handle the pandemic in most rural areas, government should prioritise the implementation of strategies to control the pandemic while improving essential facilities for Covid-19 treatment in rural areas. For example, a system should soon be developed to monitor villagers' mobility (i.e. how villagers are traveling and where they are going) and learn how rural communities are affected by the movement of people who were in cities and have now returned to the countryside.

Our findings show that community-based healthcare interventions may be used as an effective local institution to mitigate Covid-19 infection in rural settings, which often face limited basic health services and knowledge about Covid-19 infection. Such institutions may be effective in facilitating the dissemination of information in rural communities to help spread public health messages related to Covid-19 [20]. A policy restricting human mobility should likewise be implemented to control the spread of the disease to rural areas. A realistic travel restriction would accommodate villagers who must travel to work in cities while providing them with regular Covid-19 tests to monitor virus spread.

As many government offices become Covid-19 clusters, the authorities should strengthen the implementation of Covid-19 health protocols in government offices by providing protective Covid-19 equipment. The authorities should also implement regular Covid-19 monitoring for civil servants, especially those who live in rural villages and those who are highly mobile. Moreover, public health mitigation strategies should strengthen physical and social distancing policies, especially for middle-aged males and older males as well as groups with generally high mobility, as most of their members work in informal sectors [10, 11].

Second, as the pandemic now threatens rural areas, providing Covid-19 emergency services for rural areas is vital for reducing mortality. Providing Covid-19 emergency transportation is crucial as Covid-19 patients from rural villages tend to arrive at referral hospitals only when their condition has become critical. The authorities should also prepare to build emergency Covid-19 hospitals in rural areas rather than in urban areas when the number of Covid-19 patients from rural areas has increased. Covid-19 mitigation strategies should also ensure the

597 provision of essential medications, especially for males aged 45 years and older who have cardio-metabolic conditions, specifically hypertension [7, 8, 12, 14]. This is particularly important because the lack of essential medicine is a frequent issue in rural public health facilities in Indonesia. By prioritising the strengthening of the healthcare system in rural areas during the pandemic, the government may also be able to reduce inequality in healthcare services following the outbreak.

603 The empirical results reported herein entail consideration of several limitations, of which this study has least three. First, this is a rapid healthcare assessment which is based on four months of contact tracking data. The results may change as Covid-19 infections in the district increase. The contact tracing data used were based on neither random sampling nor mass testing data; rather, they were selected based on three criteria of Covid-19 tracing. Thus, the data may be subject to selection bias (e.g., the slightly lower proportion of female respondents), capturing Malang's working population rather than representing the overall demographic characteristics of the district. However, the lower proportion of women may also relate to the abovementioned inequality in the provision of Covid-19 tests. Hence, we suggest that future research investigate the contribution of social norms and gender roles in order to identify how gender may influence risk of infection and access to care.

614 Second, we are unable to include certain main socio-economic determinants such as income and education as the data are unavailable or not yet integrated with citizen registration data. Therefore, future studies may examine whether income distribution and education level are associated with Covid-19 infections and deaths.

618 Third, some of the variables in this study were based on retrospective data, especially regarding respondents' histories of heart disease and diabetes. These data were thus subject to recall bias.

Future studies may use medical record data collected from primary healthcare centres or hospitals to address the issue of recall bias.

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Contributions:

SS: Conceptualisation, Data curation, Formal analysis, Methodology, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. AM: Conceptualisation, Formal analysis, Methodology, Supervision, Validation, Writing - review & editing.

Competing interest statements

All authors have completed the ICMJE uniform disclosure form and declare: all authors had financial support from The Directorate General of Higher Education, Ministry of Education and Culture, Republic of Indonesia for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Data sharing statement

Data are available in a public, open access repository. The data that support the findings of this study are available in the Zenodo repository: https://zenodo.org/record/4408744#.X-75ntgzZPY with the following digital object identifier: http://doi.org/10.5281/zenodo.4408744

Word count: 9859

Figure 1. Malang District East Java Indonesia

3527x1178mm (72 x 72 DPI)

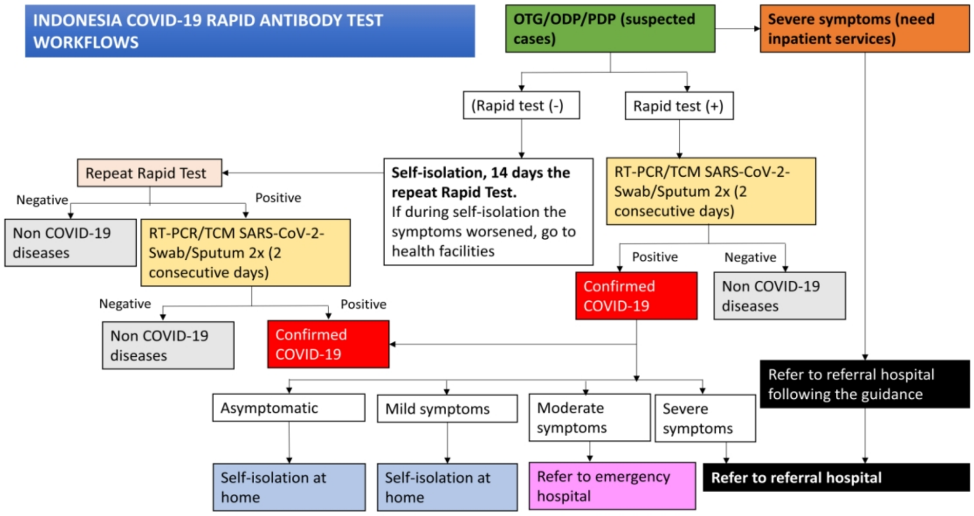


Figure 2. Procedure for Covid-19 tracing and testing

187x102mm (240 x 240 DPI)

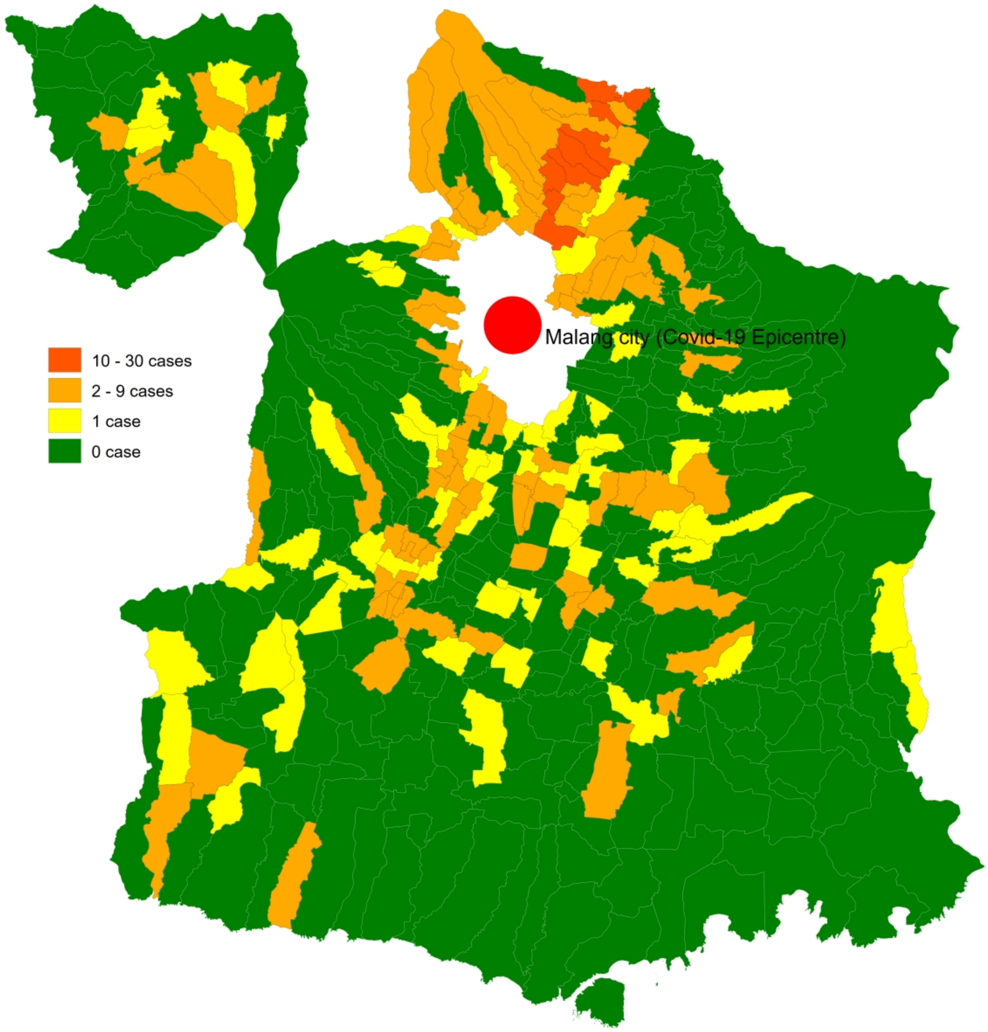


Figure 3. Distribution of Covid-19 infection in 390 villages of Malang district East Java Indonesia, July 29, 2020

1411x1474mm (72 x 72 DPI)

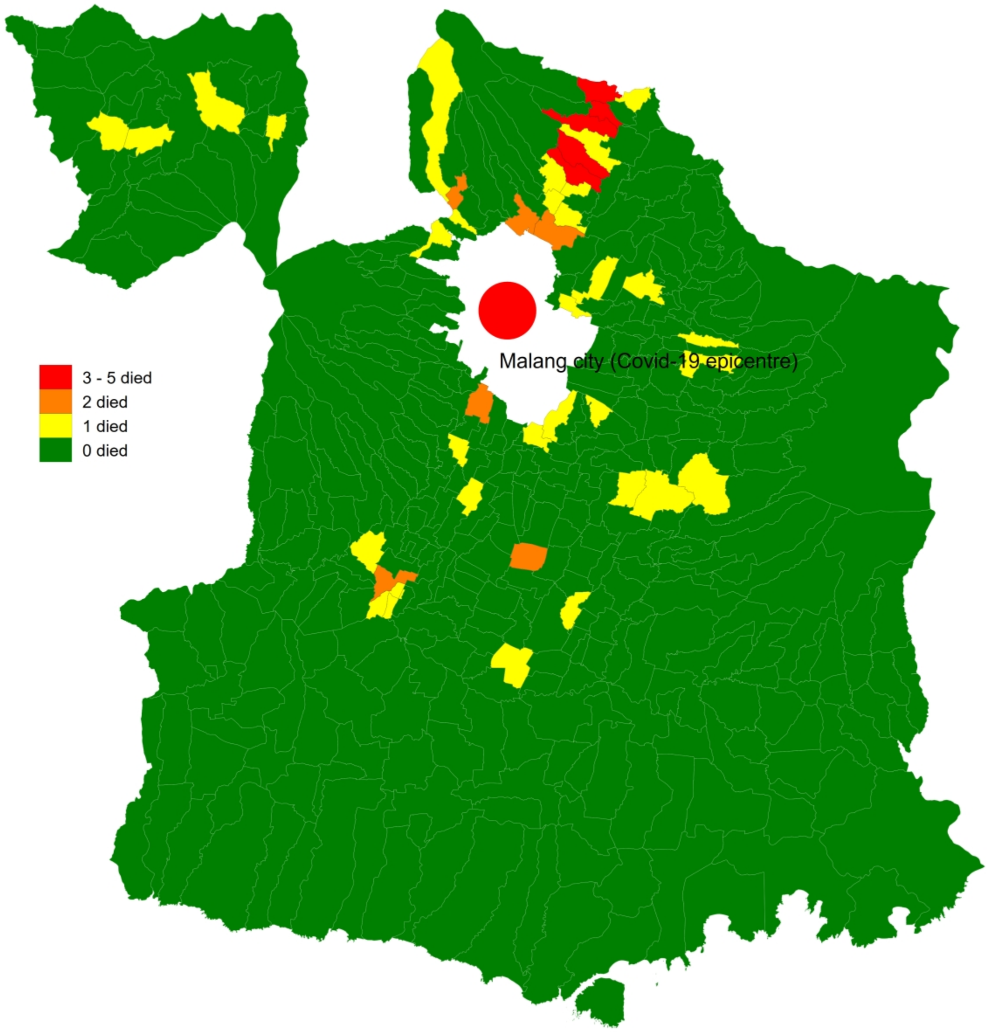


Figure 4. Distribution of Covid-19 mortality in 390 villages of Malang district East Java Indonesia, July 29, 2020

1411x1474mm (72 x 72 DPI)

INDONESIAS MINISTRY OF HEALTH

EPIDEMIOLOGICAL INVESTIGATION FORM CORONAVIRUS DISEASE (COVID-19)

Name of health care provider:

Interviewer name:

Interview Date:

IDENTITY					
Patient Name			Criteria: ☐ Suspected patient (PDP) ☐ People under monitoring (ODP) ☐ Probable case ☐ Confirmed Case ☐ Local Transmission (close contact)		
ID number			Parents Name:		
Date of Birth:	……/………/……..	Jobs:	☐ Male ☐ Female	Age	Date of Birth:
Address	Street : Village name : Sub-district : Districts/City : Phone Number:				
Clinical Information					
First symptoms date (onset)	…. …. / …. ….. / …. …..		Weak (malaise)	☐ Yes ☐ No ☐ Don't know	
Fever / Fever history	…. …… ….^{0}C Fever History: ☐ Yes ☐ No ☐ Don't know		Muscle ache	☐ Yes ☐ No ☐ Don't know	
Cough	☐ Yes ☐ No ☐ Don't know		Nausea	☐ Yes ☐ No ☐ Don't know	
Runny nose	☐ Yes ☐ No ☐ Don't know		Abdominal Pain	☐ Yes ☐ No ☐ Don't know	
Sore throat	☐ Yes ☐ No ☐ Don't know		Diarrhea	☐ Yes ☐ No ☐ Don't know	

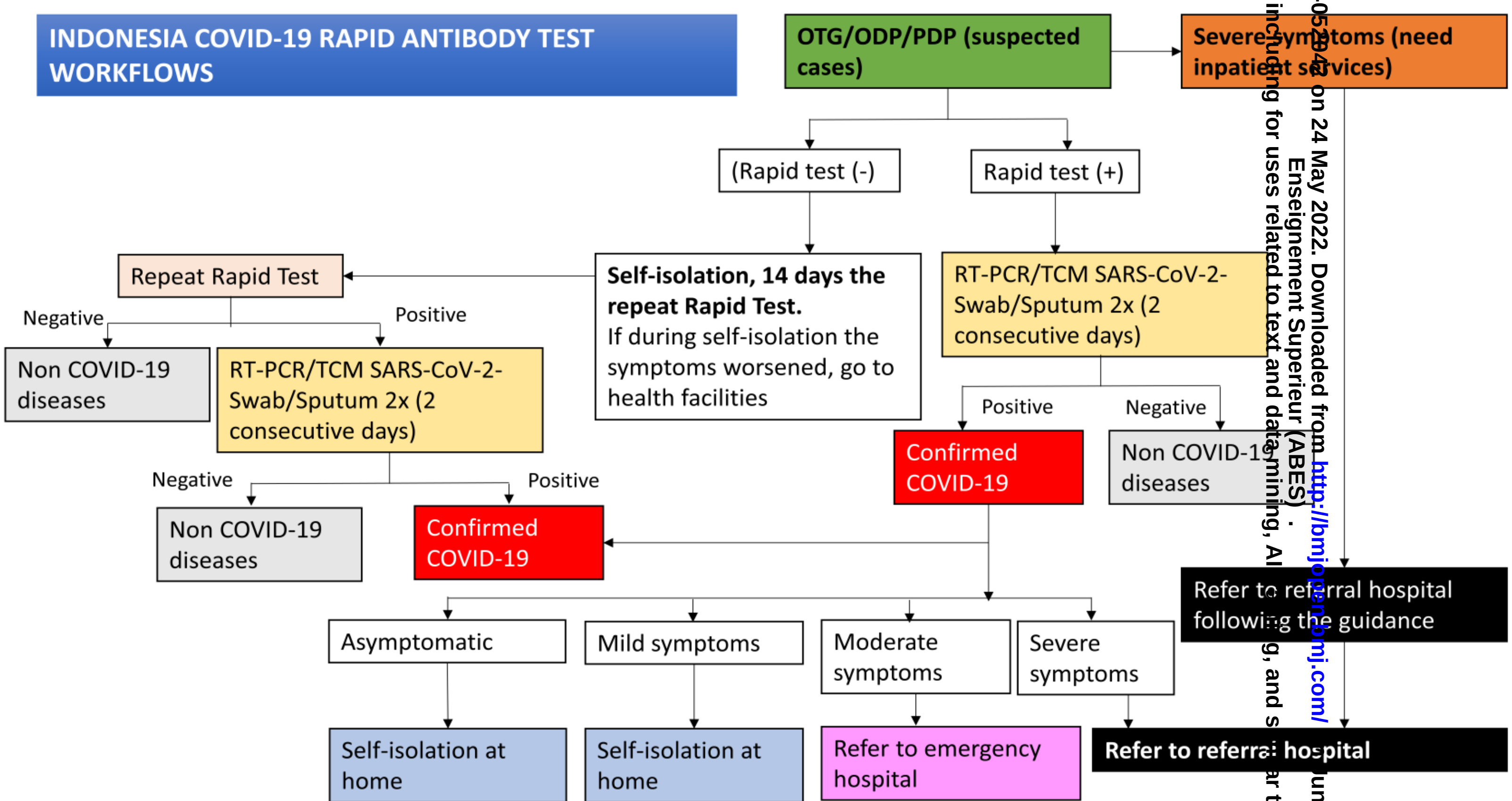
Shortness of breath	☐ Yes ☐ No ☐ Don't know	Others (write down):
Shivering	☐ Yes ☐ No ☐ Don't know	
Headache	☐ Yes ☐ No ☐ Don't know	

Additional Medical Information			
Pregnant Diabetes Coronary heart disease Hypertension Cancer	Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____	Immunological disorders Chronic kidney disease (CKD) Chronic heart disease (CHD) Chronic obstructive pulmonary disease (COPD) Other (write down):	Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ Yes ___ No_____ ……………………………………

Did the patient hospitalized?	Yes ___ No_____ Check in date ………………. Hospital Name…………………. Room: If Yes, Did He/She sent into ICU room? Yes ___ No_____ Intubation Yes ___ No_____ Extracorporeal membrane oxygenation (ECMO) uses Yes ___ No_____ Last patient status: Recovered ……. Deaths ……….
Diagnose	Pneumonia (Clinical or Radiologycal) Yes_____ No_____ Don't know_____ ARDS (Acute Respiratory Distress Syndrome) Yes_____ No_____ Don't know_____ Other diagnoses, write down……………..
	Did the patient have any diagnoses or another etiology of their respiratory disease? Yes_____ No_____ Don't know_____ If yes, please write down…………………

EXPOSE/CONTACT FACTOR	
In 14 days before ill, did the patient has travel history? If Yes, please mention the visited places? Country and City …………………………………………………………………… ……………………………………………………………………	 Visit date – Arrival date to Indonesia …………………………………………………………………… ……………………………………………………………………
In 14 days before illness,	Yes_____ No_____ Don't know_____

Did the patient get close contact with COVID-19 suspected person?
In 14 days before illness, Yes_____ No_____ Don't know_____ Did the patient get close contact with COVID-19 confirmed patient?
In 14 days before illness, Yes_____ No_____ Don't know_____ Had the patient visited to animal/pet shop? If Yes, Please mention the location/city/country……………………….
Are you a health worker? Yes_____ No_____ Don't know_____ If Yes, what protective equipment do you use? ___Gown ___Medical mask ____Gloves ___NIOSH-N95 Mask, AN EU STANDARD FFP2 ___FFP3 ____Protective glass (goggle) ___nothing has used Are you doing procedures which creates aerosol? Yes____ No____; Write down ………
In 14 days before illness, Yes_____ No_____ Don't know_____ Had you visited to health care providers (as a patient, staff, or visitor)? If Yes, please mention the location/city/country……………………….
Are the patient includes to acute respiratory infection (person with Fever and pneumonia who needs to hospitalize) with unknown causes where the COVID-19 case have been checked? Yes__ No__ Don't know_____
Others, Please write down…


INDONESIA COVID-19 RAPID ANTIBODY TEST WORKFLOWS
OTG/ODP/PDP (suspected cases)
Severe symptoms (need inpatient services)
(Rapid test (-)
Rapid test (+)
Repeat Rapid Test
Self-isolation, 14 days the repeat Rapid Test.
If during self-isolation the symptoms worsened, go to health facilities
RT-PCR/TCM SARS-CoV-2-Swab/Sputum 2x (2 consecutive days)
Negative
Positive
Non COVID-19 diseases
RT-PCR/TCM SARS-CoV-2-Swab/Sputum 2x (2 consecutive days)
Positive
Negative
Confirmed COVID-19
Non COVID-19 diseases
Negative
Positive
Non COVID-19 diseases
Confirmed COVID-19
Refer to referral hospital following the guidance
Asymptomatic
Mild symptoms
Moderate symptoms
Severe symptoms
Self-isolation at home
Self-isolation at home
Refer to emergency hospital
Refer to referral hospital

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RESEARCH PROTOCOL

Social determinants of Covid-19 infection and death in a rural Indonesia
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1. Background

In The Lancet Infectious Diseases, Ranscombe recently highlighted the need to take a systematic approach to tackling the Covid-19 crisis rather than focusing solely on urban areas [1]. He posited that the adoption of a systematic approach should include examining the socio-medical, socio-economic, and socio-political implications of confronting the pandemic in rural areas, which often have a significant scarcity of health facilities and workers for Covid-19 treatment as well as insufficient knowledge about Covid-19 infection. Accordingly, studies have shown huge disparities in healthcare access between rural and urban areas in Indonesia and other developing countries, a factor that is associated with citizens' health and well-being [2]. Studies have also documented the differences between rural and urban Indonesia in terms of individual socio-economic characteristics that are associated with health status [3]. This study aims to examine whether those inequalities are associated with Covid-19 infection and death in rural Indonesia.

2. Study objectives

This study has two objectives. Firstly, to examine which groups in rural Indonesia are most vulnerable to infection and death due to Covid-19? Identifying those most vulnerable to Covid-19 is crucial as the pandemic adds significantly to the pressure on fragile local health services. Under such conditions, we are likely to see a spread of human suffering and very high mortality rates. Secondly, to examine what are the most important social determinants of health associated with Covid-19 infection and death in rural Indonesia?

3. Study design

This study will use a non-random cross-sectional design based on official Covid-19 tracing data collected by the Malang District Health Authority (DHA) from March 1 to July 29, 2020 and administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 [4]. This study will be conducted in Malang District in East Java, Indonesia. Malang is located quite close to the city of Surabaya, which is currently the biggest Covid-19 epicentre in Indonesia. Malang area covers 3,535 square kilometres, with an agricultural emphasis on rice and sugar cane. Malang's total population of 2,544,315 is distributed across 33 sub-districts, 390 villages and 3,125 community neighbourhoods [5]. A subdistrict consists of come villages, and a village consists of some community

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neighbourhoods. The number of people in each village and community neighbourhood in Malang District on average are 6400 and 746, respectively [6].

4. Participation selection

This study will use all individuals screened for Covid-19 infection by Malang District Health Authority (DHA) from March 1 to July 29, 2020.

5. Study plan

Covid-19 contact tracing data will be collected by the Malang DHA based on the Indonesian Ministry of Health Covid-19 prevention and control guidelines. The total number of individuals traced during from March 1 to July 29, 2020. This tracing data covers all population in Malang District (estimated 2,544,315). Based on the national guidelines, Covid-19 contact tracing refers to the process of identifying all individuals who fulfil one of these criteria: (1) having had contact with a confirmed Covid-19 patient within the previous two weeks, (2) having one of the Covid-19 symptoms; and (3) having travelled from one of the Covid-19 epicentre areas in Indonesia or abroad [29]. Close contact was identified by health workers in each village with criteria: those who live in the same household or who has been close to someone who has tested positive for Covid-19 [6,7].

The data will be merged the contact tracing data with administrative data from 390 villages retrieved from Indonesia's Village Potential Census 2020 (Podes) [5]. The Podes is a longstanding tradition of collecting data at the lowest administrative tier of local government. Podes consists of 83,931 villages (*desa*) across 514 districts in Indonesia. The census has been conducted every two years since 1983 by the Indonesian Central Bureau of Statistics (*Biro Pusat Statistik*). Detailed information is gathered on a range of characteristics from public infrastructure to village finances. Information is gathered from *kepala desa* (rural village heads) and *lurah* (urban neighbourhood heads). From the 2020 census, we will used the following data for each village: number of health workers, number of community-based healthcare interventions and number of indigenous socio-cultural activities as well as hospital access, poverty and distance to a Covid-19 epicentre city.

Variables

The outcome variables in this study are Covid-19 infections and Covid-19 deaths. *RT-PCR*) swab tests are used by the Malang District Health Authority to determine the presence of Covid-19 infection. The authority determines that an individual is infected if the RT-PCR swab test shows a positive result. The Indonesian Ministry of Health follows the WHO definition of death due to Covid-19 as a 'death resulting from a clinically compatible illness, in a probable or confirmed Covid-19 case, unless there is a clear alternative cause of death that cannot be related to Covid-19' (e.g., traffic accident or trauma) [7]. Deaths due to Covid-19 cannot attributed to another disease (e.g., cancer) and are counted independently of preexisting conditions that are suspected of triggering a severe course of Covid-19 (e.g., coronary artery disease, type 2 diabetes, or chronic obstructive pulmonary disease).

Following Marmot and Wilkinson and WHO [8,9], we will include individual socio demographic characteristics, number of community-based health interventions, number of indigenous socio-cultural activities, distance to a Covid-19 referral hospital, village poverty and distance to a Covid-19 epicentre city to measure the social determinants of health.

In addition, we will include village-level social determinants which captured individual access to health care, risk of infection and poverty. Previous studies have documented that village poverty status and the number of community-based healthcare interventions are linked with access to healthcare [34-36]. In addition, we included the number of indigenous socio-cultural activities and distance to a Covid-19 epicentre city to measure risk of Covid-19 infection.

Age is categorised into four groups referring to Indonesia's demographic groups: 17 years and younger, 18-44 years, 45-60 years, and 61 years and older. Job types are divided into nine categories: health workers, civil servant non-health workers (i.e., teachers, village and district government staff,

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police, army and other civil servants who provide direct community service during the pandemic), labourers (i.e. factory workers or construction workers), professional workers (i.e. bank staff or company staff), traders, farmers, housewives, students, and retired persons. For Covid-19 deaths, we include patients' comorbidity history of diabetes, cardiovascular diseases, hypertension, autoimmune diseases and kidney diseases. We also include pre-RT-PCR test diagnosis by a medical doctor of pneumonia, chronic obstructive pulmonary disease (COPD), and respiratory failure. Individuals receiving Covid-19 hospital inpatient services and hospital intensive care unit services were also included to control for Covid-19 deaths.

Village determinants for Covid-19 infection include the number of community-based healthcare interventions, the number of indigenous socio-cultural activities, village poverty status, and distance to a Covid-19 epicentre city. We included community-based healthcare intervention to examine whether such community interventions facilitate controlling Covid-19 infection. Community-based healthcare intervention refers to neighbourhood or community activities aiming to provide healthcare support within a community [5,6]. In Malang, such interventions are conducted by voluntary health workers or *kader* in *Posbindu* (*Pos pembinaan terpadu* or integrated health posts for NCDs) and *Posyandu/Posyandu Lansia* (*Pos pelayanan terpadu lanjut usia* or integrated healthcare service posts for children and older people) [5]. All these data were retrieved from Podes 2020 census. In the census, the number of community-based health care interventions was measured by the number of *Posbindu* and *Posyandu/Posyandu Lansia* in each village. During the outbreak, these community-based health care interventions play an important role in supporting district governments in increasing Covid-19 awareness among villagers.

The district governments empower health cadres at *Posbindu* and *Posyandu/Posyandu Lansia* as community Covid-19 task force teams responsible for monitoring persons suspected of infection and disseminating Covid-19 early mitigation strategies. We also included indigenous socio-cultural activities since such activities may facilitate Covid-19 infection in rural areas. Indigenous socio-cultural activities refer to native people's communal activities such as Javanese wedding ceremonies (*mantenan*), Javanese traditional circumcision ceremonies (*khitan*), traditional birth celebration (*tasyakuran melahirkan*), religious meetings (*pengajian*), the obligation to visit and attend to sick or dying neighbours (*mbesuk* or *melayat*) and other communal activities that form a part of rural Javanese traditional cultures [5,6]. The Podes 2020 measured these activities as the number of socio-cultural in each village per month. Such activities may directly mediate Covid-19 infection within and between villages as most villagers are culturally obligated to take part in them. Village poverty is measured by the ratio of families living below Indonesia's poverty line. These numbers were based on village administrative data collected by village government authorities. Distance to a Covid-19 epicentre city was the distance of each village from a closed epicentre city in kilometres. For Covid-19 deaths, we include the number of health workers and the distance of each village to a Covid-19 referral hospital to capture whether healthcare access may be linked to Covid-19 patients' odds of dying from the disease.

The ethical approval for this study will be submitted to the Ethical Committee, Ministry of Education and Culture, Brawijaya University.

6. Patient and public involvement

Neither patients nor the public were involved in the design or conduct of this study. Participants also did not contribute to the writing or editing of this manuscript. Informed written consent was sought from each participant by the Malang DHA before the interview.

7. Statistical Considerations

Multilevel or hierarchical regression analyses will be applied to take full advantage of the village clustering information available from the data. These regression analyses are able to account for the

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clustering of individuals by separating individual variances of Covid-19 infections and Covid-19 deaths from village variances. This type of regression is therefore more appropriate than simple regression, which does not take village-level clustering data into account. For these analyses, hierarchical logistic regression was used to estimate factors associated with Covid-19 infection and Covid-19 deaths. We will estimate a hierarchical logit model using multilevel mixed-effects logistic regression (*melogit*). In this study, *melogit* fits mixed-effects models for binary responses. We will carry out two-level logistic regression using STATA 16.0 software.

8. Storage and Archiving of Study Documents

The data that support the findings of this study will be available for public in the Zenodo repository.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	12-14
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-11
Bias	9	Describe any efforts to address potential sources of bias	32
Study size	10	Explain how the study size was arrived at	8-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	12-14
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	14
		(*b*) Describe any methods used to examine subgroups and interactions	na
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	na
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	na
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	16
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	16-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	18-23

		(*b*) Report category boundaries when continuous variables were categorized	na
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	na
Discussion			
Key results	18	Summarise key results with reference to study objectives	23
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	32-33
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	32-33
Generalisability	21	Discuss the generalisability (external validity) of the study results	32-33
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	38

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.