Association between socioeconomic status and self-reported, tested and diagnosed COVID-19 status during the first wave in the Northern Netherlands: a general population-based cohort from 49 474 adults

Yinjie Zhu,1 Ming-Jie Duan,1 Hermien H. Dijk,2 Roel D. Freriks,2 Louise H. Dekker,1,3 Jochen O. Mierau,2,3 Lifelines Corona Research initiative2,4,5,6

ABSTRACT

Objectives Studies in clinical settings showed a potential relationship between socioeconomic status (SES) and lifestyle factors with COVID-19, but it is still unknown whether this holds in the general population. In this study, we investigated the associations of SES with self-reported, tested and diagnosed COVID-19 status in the general population.

Design, setting, participants and outcome measures Participants were 49 474 men and women (46±12 years) residing in the Northern Netherlands from the Lifelines cohort study. SES indicators and lifestyle factors (i.e., smoking status, physical activity, alcohol intake, diet quality, sleep time and TV watching time) were assessed by questionnaire from the Lifelines Biobank. Self-reported, tested and diagnosed COVID-19 status was obtained from the Lifelines COVID-19 questionnaire.

Results There were 4711 participants who self-reported having had a COVID-19 infection, 2833 participants tested for COVID-19, and 123 positive cases were diagnosed in this study population. After adjustment for age, sex, lifestyle factors, body mass index and ethnicity, we found that participants with low education or low income were less likely to self-report a COVID-19 infection (OR [95% CI]: low education 0.78 [0.71 to 0.86]; low income 0.86 [0.79 to 0.93]) and be tested for COVID-19 (OR [95% CI]: low education 0.58 [0.52 to 0.66]; low income 0.86 [0.78 to 0.95]) compared with high education or high income groups, respectively.

Conclusion Our findings suggest that the low SES group was the most vulnerable population to self-reported and tested COVID-19 status in the general population.

INTRODUCTION

The ongoing COVID-19 pandemic has already infected 62 363 527 people worldwide (as of 1 December 2020).1 Many studies have reported a relationship between lifestyle factors (e.g., smoking2 and unhealthy diets3) or comorbidities associated with lifestyle factors (e.g., obesity4 and diabetes mellitus5) and worse outcomes for COVID-19. Since lifestyle factors are often associated with socioeconomic status (SES),6 several studies have revealed that people with low SES are more susceptible to COVID-19 infection, hospitalisation and mortality,7–11 the interplay between SES, lifestyle and COVID-19 status becomes a valid query and it is likely that SES is a determinant of COVID-19.

Therefore, a rising concern among policymakers and public health practitioners is that the COVID-19 pandemic might exacerbate the persistent socioeconomically patterned health inequalities over the life course.1213 Still, an in-depth investigation of the lifestyle and socioeconomic determinants of COVID-19 in the general population is needed because current COVID-19 studies mainly relied on individuals presenting with symptoms in a
clinical setting and focused on post-COVID-19 infection status (e.g., hospitalisation and intensive care). As such, we do not have enough knowledge on the validity of these early results for the general population.

This study aimed to investigate the extent to which SES and lifestyle factors were associated with a broader range of COVID-19 status, that is, self-reported COVID-19, tested COVID-19 and diagnosed COVID-19 in the general population.

**METHODS**

**Study design and participants**

To assess COVID-19 status in the general population, we used data from the Lifelines COVID-19 Cohort. The Lifelines COVID-19 Cohort is a questionnaire-based study in a part of the Dutch Lifelines cohort. To study the relationship between COVID-19 and SES, we linked data from the Lifelines COVID-19 questionnaire with data from the general Lifelines cohort, which contains a wide range of background data, such as demographics, lifestyles and SES. For the present study, 49,474 participants from both the Lifelines cohort and the Lifelines COVID-19 Cohort, who had available and reliable data on demographics, SES and lifestyle, were included in the analysis (online supplemental figure 1).

The Lifelines cohort study is a multidisciplinary prospective population-based cohort study based on a unique three-generation design. The participants were recruited from the three Northern provinces of the Netherlands between 2006 and 2013 and the first group of participants were recruited via local general practitioners. The participants could indicate whether their family members were interested to be recruited as well. In addition, individuals who were interested in the study could also participate through online self-registration. Participants with insufficient knowledge of the Dutch language, with severe psychiatric or physical illness and those with limited life expectancy (<5 years) were excluded from the study. The Lifelines cohort study employs a broad range of investigative procedures in assessing the biomedical, sociodemographic, behavioural, physical and psychological factors that contribute to health and disease. A detailed description of the Lifelines cohort study can be found elsewhere. Before study entry, a signed informed consent form was obtained from each participant. Adult participants (≥18 years) were asked to complete several questionnaires regarding various aspects, including demographics, SES and lifestyle.

The Lifelines COVID-19 Cohort collected data about COVID-19-related symptoms, current health issue and societal impacts from participants recruited from the Lifelines cohort. It is developed based on a COVID-19 questionnaire to identify genetic and environmental risk factors for COVID-19 and address the medical, social and psychological aspects of the pandemic. A detailed description of the Lifelines COVID-19 Cohort and the COVID-19 questionnaire can be found elsewhere. The COVID-19 questionnaire is sent out weekly since 30 March 2020 for 12 weeks. Of the 139,713 Lifelines participants invited, 74,268 (53.2%) completed at least one of the questionnaires in the 12-week programme.

**COVID-19 status**

There were three different COVID-19 statuses obtained in our study from the COVID-19 questionnaire: self-reported COVID-19, tested COVID-19 and diagnosed COVID-19. All COVID-19 statuses were coded as binary variables. Self-reported COVID-19 status was obtained by asking ‘if you must choose, do you think you have (or have had) a COVID-19 infection?’ or ‘has a doctor told you that you probably have (had) a coronavirus/COVID-19 infection?’; tested COVID-19 status was obtained from the question ‘have you been tested for coronavirus (COVID-19)?’; diagnosed COVID-19 status was defined by asking ‘do you have or have you had a coronavirus/COVID-19 infection?’ or ‘what was the result of your corona virus (COVID-19) test?’ when they had a COVID-19 test.

Since some of the COVID-related questions were worded such that it is not possible to infer whether the answer referred to the period between the last questionaire and the current questionnaire or to the beginning of the pandemic and the current questionnaire (e.g., “have you been tested for coronavirus (COVID-19)?”), the 12 questionnaires were condensed into a single observation per individual, indicating for each question whether the individual had at any point answered ‘yes’ during the study period.

**Socioeconomic status**

SES was indicated by (a) highest educational level achieved and (b) monthly net household income level separately from the Lifelines cohort study at baseline. Highest educational level achieved was categorised as: (1) low—junior general secondary education or lower (International Standard Classification of Education [ISCED] level 0, 1 or 2); (2) middle—secondary vocational education and senior general secondary education (ISCED level 3 or 4) and (3) high—higher vocational education or university (ISCED level 5 or 6);20 household net income level was categorised as: (1) low: <2000 euro/month; (2) middle: 2000–3000 euro/month and (3) high: >3000 euro/month.

**Lifestyle factors**

Six lifestyle factors (i.e., smoking status, alcohol consumption, diet quality, physical activity, TV watching time and sleep time) were selected from the Lifelines cohort study at baseline. Smoking status was categorised into never, former and current smoker. Alcohol intake and dietary consumption were derived from a validated 110-item semiquantitative food frequency questionnaire (FFQ) that assessed food consumption over the past month.21 Heavy drinking was defined as >40 g or >20 g average per day alcohol consumption for men and women, respectively. Lifelines Diet
Score was calculated to assess the overall diet quality based on the FFQ. This score ranks the relative intake of nine food groups with positive health effects (vegetables, fruit, whole grain products, legumes/nuts, fish, oils/soft margarines, unsweetened dairy, coffee and tea) and three food groups with negative health effects (red/processed meat, butter/hard margarines and sugar-sweetened beverages). The development of this score is described in detail elsewhere. Nonoccupational moderate-to-vigorous physical activity was calculated in minutes per week from the validated Short Questionnaire to ASsess Health-enhancing physical activity data, which incorporated leisure time and commuting physical activities, including sports, at moderate (4.0–6.4 metabolic equivalent of task [MET]) to vigorous (≥6.5 MET) intensity. TV watching time and sleep time were self-reported. Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in metres. The BMI was additionally categorised into underweight (BMI<18.5 kg/m²), normal (18.5 ≤BMI<25 kg/m²), overweight (25 ≤BMI<30 kg/m²) and obese (BMI≥30 kg/m²).

**Statistical analysis**

Nominal variables are presented as percentage (%). Continuous variables were shown as mean±standard deviation (SD) or median (interquartile range [IQR]). P values <0.05 were considered statistically significant. To analyse the associations of SES (i.e., education and income) with self-reported and tested COVID-19 status, we used logistic regression models to estimate ORs. Furthermore, we fitted robust Poisson regression models to estimate relative risk for associations between SES and diagnosed COVID-19 since the number of individuals with diagnosed COVID-19 was relatively low in this population. For all regression models, SES indicators were first entered into the model plus age and sex (model 1) and then adjusted for other covariates (model 2: model 1 plus six lifestyle factors; model 3: model 2 plus BMI; model 4: model 3 plus ethnicity). All statistical analyses were conducted using Stata, V.13.1 (StataCorp, Texas, USA) or RStudio, V.4.0 (RStudio PBC, Boston, USA). Sensitivity analyses were conducted by further adjusting for the total number of questionnaires filled by each participant (online supplemental table 1), by comparing the characteristics of study population and excluded participants (online supplemental table 2), and by treating lifestyle factors together as a mediator in the pathway between SES and COVID-19 status (online supplemental table 3).

**Patient and public involvement**

Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

**RESULTS**

Participant characteristics are shown in table 1. The average age of the study population was 46±12 years old and more women were recruited in this study (59.7%). More than 92% of the population characterised their ethnicity as White. The prevalence of overweight and obese was 40.0% and 14.5%, respectively (table 1). Out of the 49 474 participants who were recruited in both Lifelines cohort and Lifelines COVID-19 cohort, 4711 participants self-reported a COVID-19 infection, while 2833 participants reported having had a COVID-19 test and 123 participants reported having had a positive outcome of the COVID-19 test (table 1).

Self-reported, tested and diagnosed COVID-19 participants were more likely to be female, to have attained middle or high education, to have high income and to have never smoked (table 1). The association between education and different COVID-19 status is presented in table 2. Participants with low and middle education level were less likely to self-report COVID-19 (OR [95% CI]: low 0.78 [0.71 to 0.86]; middle 0.90 [0.84 to 0.97]) and to be tested for COVID-19 (OR [95% CI]: low 0.58 [0.52 to 0.66]; middle 0.72 [0.66 to 0.79]) compared with highly educated participants after adjustment for age, sex, lifestyle factors, ethnicity and BMI (table 2). In addition, compared with high education participants, participants with middle education level had almost two-fold higher risk to be infected with COVID-19 (OR [95% CI]: 1.73 [1.19 to 2.50]) (table 2, model 1) once they had been tested for COVID-19. The association was slightly attenuated after adjustment for lifestyle factors (OR [95% CI]: 1.69 [1.17 to 2.44]) (table 2, model 2) and lifestyle factors seemed to slightly mediate the association between self-reported COVID-19 status (proportion mediated: 9.9%) (online supplemental table 3), however, further adjustment for BMI and ethnicity did not change the results.

The association between income and different COVID-19 status is presented in table 3. Low or middle income groups were less likely to self-report COVID-19 (OR [95% CI]: low 0.86 [0.79 to 0.93]; middle 0.80 [0.74 to 0.87]) and to be tested for COVID-19 (OR [95% CI]: low 0.86 [0.78 to 0.95]; middle 0.86 [0.78 to 0.94]) compared with high-income group after adjustment for all covariates (table 3, model 4). Moreover, lifestyle factors only slightly mediated the association between self-reported and tested COVID-19 statuses (proportion mediated: 6.7% and 9.5%, respectively) (online supplemental table 3). Nevertheless, no risk differences were found between different income levels and diagnosed COVID-19 status, once tested.
Discussión

Este artículo ofrece evidencia e insight sobre desigualdades socioeconómicas en la autoinformación de COVID-19, la prueba de COVID-19 y el diagnóstico de COVID-19 en una población general. Se encontró que los grupos de SES bajos y medios, especialmente los participantes con bajo nivel educativo, eran menos propensos a autoinformar COVID-19 y a ser testeados para COVID-19. Además, los participantes con educación media se infectaron con COVID-19 con más frecuencia que aquellos que obtuvieron alta educación.

Nuestra investigación resaltó la importancia de mitigar el patrón socioeconómico de la pandemia COVID-19 al mostrar una relación clara entre SES y el estado del COVID-19, lo que puede ayudar a los políticos a responder adecuadamente a la pandemia y desarrollar medidas de salud pública. Es preocupante que el grupo de SES bajo se podría desatender durante la pandemia porque son menos propensos a autoinformar y a ser testeados para COVID-19. Dado el hecho de que también están en alto riesgo de enfermedades no contagiosas, una vez infectados con COVID-19 o otras enfermedades contagiosas en el futuro, individuos con bajo SES podrían sufrir desproporcionadamente de la enfermedad, que puede exacerbar la desigualdad de la salud. Por lo tanto, una acción o intervención de salud pública es necesaria para promover la igualdad de salud antes, durante y después de la pandemia COVID-19.

Una de las posibles explicaciones de la asociación inversa entre SES y estado del COVID-19 es la escasa alfabetización en salud. La alfabetización en salud se refiere a ‘la información, motivación y competencias de una persona para obtener, comprender, valorar y aplicar la información de salud en la vida diaria’.28 Es conocido que el SES bajo es el determinante más importante de la alfabetización en salud.29 Durante la pandemia COVID-19, las personas con alta SES podrían ser más conscientes de los síntomas y consecuencias de la salud de COVID-19, y puedan, por lo tanto, interpretar y comunicar y tomar decisiones sobre su propia condición de salud.30 31 En otras palabras, las personas con bajo SES...
might be less sensitive and aware of their COVID-19-related symptoms, or they might lack the ability to assess whether they could have had COVID-19 infection. Since they might lack health literacy, low SES people might be less likely to seek medical help even when they have symptoms because of the lack of practicing health-seeking behaviour and critical health resources.12 13 On the other hand, potentially low SES individuals had more difficulties obtaining a test even when they had sufficient health literacy. Our results also suggested that education level is a better determinant for COVID-19 status than income 29 because the association gradient was larger for low education participants than for low income participants. Further research is needed to fully understand the observed link between socioeconomic disparities and COVID-19.

Furthermore, there could be other explanations of the inverse association of SES and COVID-19 status. Despite the fact that the low SES group is at higher risk of noncommunicable disease, they also suffer from a higher general disease burden both mentally and financially during the pandemic.26 Therefore, they might be less likely to notice the relevant symptom due to the already existing disease burden. Additionally, the first wave of COVID-19 pandemic in the Netherlands covered the winter holiday, and people with high income and education were more likely to go for a relatively expensive skiing holiday compared with the low SES group. The skiing area in Italy has always been a popular destination for Dutch people and Northern Italy was the first outbreak centre during the first wave of this pandemic,32 so that people with high income or high education who came back from the skiing holiday in Italy were more likely to self-report and be tested for COVID-19.

Interestingly, lifestyle factors only slightly mediated the pathway between SES and self-reported, and tested COVID-19 status, and did not seem to be a mediator in the pathway between SES and diagnosed COVID-19 status in our study, which is different from a previous study that suggested an unhealthy lifestyle that was a profound risk factor for COVID-19 status.15 Some other studies also found that nutritional status33 34 and smoking2 might also be risk factors for COVID-19 disease severity, disease progression and mortality. Because of the differences of study population and COVID-19 outcome selection, our results were not comparable with previous studies. Nevertheless, this study provided a fresh message that in the general population, SES is a better determinant of self-reported, tested and diagnosed COVID-19 status

### Table 2  Association of education with different COVID-19 status

| Education | Self-reported | Tested | Diagnosed |
|-----------|---------------|--------|-----------|
|           | OR (95% CI)   | p      | OR (95% CI) | p | RR (95% CI) | p |
| Model 1   |               |        |            |    |            |   |
| Low       | 0.81 [0.75–0.89] | <0.001 | 0.58 [0.52–0.65] | <0.001 | 1.18 [0.67–2.07] | 0.6 |
| Middle    | 0.93 [0.87–0.99] | 0.03   | 0.73 [0.67–0.80] | <0.001 | 1.73 [1.19–2.50] | 0.004 |
| High      | Ref           |        |            |    |            |   |
| Model 2   |               |        |            |    |            |   |
| Low       | 0.79 [0.72–0.86] | <0.001 | 0.59 [0.53–0.66] | <0.001 | 1.11 [0.61–2.00] | 0.7 |
| Middle    | 0.91 [0.85–0.97] | 0.006  | 0.74 [0.68–0.81] | <0.001 | 1.69 [1.17–2.44] | 0.005 |
| High      | Ref           |        |            |    |            |   |
| Model 3   |               |        |            |    |            |   |
| Low       | 0.77 [0.71–0.85] | <0.001 | 0.59 [0.53–0.66] | <0.001 | 1.11 [0.61–2.00] | 0.7 |
| Middle    | 0.90 [0.84–0.96] | 0.002  | 0.74 [0.68–0.81] | <0.001 | 1.69 [1.16–2.45] | 0.006 |
| High      | Ref           |        |            |    |            |   |
| Model 4   |               |        |            |    |            |   |
| Low       | 0.78 [0.71–0.86] | <0.001 | 0.58 [0.52–0.66] | <0.001 | 1.10 [0.60–2.01] | 0.8 |
| Middle    | 0.90 [0.84–0.97] | 0.004  | 0.72 [0.66–0.79] | <0.001 | 1.77 [1.21–2.60] | 0.003 |
| High      | Ref           |        |            |    |            |   |

Model 1: adjusted for education, age and sex. Model 2: adjusted for education, age, sex, and six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker). Model3: adjusted for education, age, sex, six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker), and BMI. Model 4: adjusted for education, age, sex, six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker), BMI, and ethnicity.

BMI, body mass index; LLDS, lifelines diet score; MVPA, non-occupational moderate-to-vigorous physical activity; OR, odds ratio; RR, risk ratio.
status. In addition, unlike other COVID-19 studies that found, obesity and ethnicity were both risk factors of COVID-19 infection, hospitalisation and mortality, our results showed that obesity and ethnicity did not contribute substantially to the disparities in COVID-19 status, which indicates that obesity and ethnicity were not in the pathway between SES and self-reported, tested and diagnosed COVID-19 status.

This study has several strengths. First, this general population-based study about COVID-19 may to some extent mitigate the selection bias compared with studies conducted based in clinical settings and can allow us to thoroughly understand the relation between SES and COVID-19 in the general population. Second, we innovatively included a broader range of COVID-19 status, including self-reported and tested COVID-19 status, to better understand COVID-19-related health literacy and accessibility to health services. Still, this study failed to link the objective measures of COVID-19 infection status, which could cause some bias. Another limitation of the current study is the fact that the study population was predominantly white (more than 98%). Additionally, the Netherlands has a well-developed social security system. This may limit its generalisability to populations of other ethnicity, and in a different social context. One caveat of our study is that the relative low number of cases in the region, which is the nature of the COVID-19 outbreak in the Northern Netherlands (online supplemental table 4), might influence the statistical power of the study. However, we still find statistically significant results for SES and COVID-19 status. Another limitation is from the condensed observations about COVID-19 status since certain types of individuals might be more likely to fill in more questionnaires and are, therefore, more likely to report a positive COVID-19 status in at least one of the questionnaires. If these individuals predominantly belong to a specific SES group, this would bias the results. However, by further adjusting for the total number of questionnaires filled by each participants, we did not observe any difference from the current results (online supplemental table 1). Additionally, although we only observed minor effect of lifestyle factor on the association between SES and COVID-19 status, the true effect of lifestyle factors could be more pronounced since the low SES group tends to report their lifestyle according to the social desire. Finally, approximately 17% of the participants were dropped because of incomplete lifestyle information, which might bias the results given that people with low SES and worse lifestyle practices could be less likely to participant in the COVID-19 questionnaire. Nevertheless, both the study population and excluded participants have similar characteristics (online supplemental table 2). Consequently, it is less likely that there was a selection bias resulting from missing variables.

In conclusion, our findings of SES and self-reported, tested and diagnosed COVID-19 status indicate that individuals with lower SES may be more vulnerable and neglected during

| Table 3 | Association of income with different COVID-19 status |
|---|---|---|---|---|
| Income | Self-reported | Tested | Diagnosed |
| | OR (95% CI) | p | OR (95% CI) | p | RR (95% CI) | p |
| Model 1 | | | | | | |
| Low | 0.89 [0.83–0.96] | 0.002 | 0.85 [0.77–0.93] | 0.001 | 0.84 [0.54–1.31] | 0.4 |
| Middle | 0.82 [0.76–0.88] | <0.001 | 0.84 [0.77–0.92] | <0.001 | 1.14 [0.77–1.70] | 0.5 |
| High | Ref | | | | | |
| Model 2 | | | | | | |
| Low | 0.88 [0.81–0.95] | 0.001 | 0.87 [0.79–0.96] | 0.005 | 0.80 [0.51–1.25] | 0.3 |
| Middle | 0.82 [0.76–0.88] | <0.001 | 0.86 [0.78–0.94] | 0.001 | 1.10 [0.73–1.64] | 0.6 |
| High | Ref | | | | | |
| Model 3 | | | | | | |
| Low | 0.88 [0.81–0.95] | 0.001 | 0.87 [0.79–0.96] | 0.006 | 0.80 [0.51–1.25] | 0.3 |
| Middle | 0.81 [0.76–0.87] | <0.001 | 0.86 [0.78–0.94] | 0.001 | 1.10 [0.73–1.64] | 0.7 |
| High | Ref | | | | | |
| Model 4 | | | | | | |
| Low | 0.86 [0.79–0.93] | <0.001 | 0.86 [0.78–0.95] | 0.002 | 0.74 [0.47–1.18] | 0.2 |
| Middle | 0.80 [0.74–0.87] | <0.001 | 0.86 [0.78–0.94] | 0.002 | 1.05 [0.70–1.57] | 0.8 |
| High | Ref | | | | | |

Model 1: adjusted for income, age and sex. Model 2: adjusted for income, age, sex, and six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker). Model 3: adjusted for income, age, sex, six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker), and BMI. Model 4: adjusted for income, age, sex, six lifestyle factors (smoking status, TV watching time ≥ 4h/day, sleep time <7 or >9 h/day, MVPA<150 min/week, LLDS, and heavy drinker), BMI, and ethnicity.

BMI, body mass index; LLDS, lifelines diet score; MVPA, non-occupational moderate-to-vigorous physical activity; OR, odds ratio; RR, risk ratio.
COVID-19 pandemic, possibly because of disease burden, poor health literacy and access to healthcare, suggesting that health services and health promotion interventions should particularly focus on targeting individuals with lower SES to get them better prepared for future health emergencies.

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Patient consent for publication Not required.

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