




# BMJ Open Longitudinal Aging Study Amsterdam COVID-19 exposure index: a cross-sectional analysis of the impact of the pandemic on daily functioning of older adults

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## ABSTRACT

**Objectives** The aim of this study was to develop an index to measure older adults' exposure to the COVID-19 pandemic and to study its association with various domains of functioning.

**Design** Cross-sectional study.

**Setting** The Longitudinal Aging Study Amsterdam (LASA), a cohort study in the Netherlands.

**Participants** Community-dwelling older adults aged 62–102 years (n=1089) who participated in the LASA COVID-19 study (June–September 2020), just after the first wave of the pandemic.

**Primary outcome measures** A 35-item COVID-19 exposure index with a score ranging between 0 and 1 was developed, including items that assess the extent to which the COVID-19 situation affected daily lives of older adults.

Descriptive characteristics of the index were studied, stratified by several sociodemographic factors. Logistic regression analyses were performed to study associations between the exposure index and several indicators of functioning (functional limitations, anxiety, depression and loneliness).

**Results** The mean COVID-19 exposure index score was 0.20 (SD 0.10). Scores were relatively high among women and in the southern region of the Netherlands. In models adjusted for sociodemographic factors and prepandemic functioning (2018–2019), those with scores in the highest tertile of the exposure index were more likely to report functional limitations (OR: 2.24; 95% CI: 1.48 to 3.38), anxiety symptoms (OR: 3.14; 95% CI: 1.82 to 5.44), depressive symptoms (OR: 2.49; 95% CI: 1.55 to 4.00) and loneliness (OR: 2.97; 95% CI: 2.08 to 4.26) than those in the lowest tertile.

**Conclusions** Among older adults in the Netherlands, higher exposure to the COVID-19 pandemic was associated with worse functioning in the physical, mental and social domain. The newly developed exposure index may be used to identify persons for whom targeted interventions are needed to maintain or improve functioning during the pandemic or postpandemic.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study was based on a representative sample of older adults from three culturally different regions in the Netherlands.
- ⇒ The Longitudinal Aging Study Amsterdam COVID-19 study provides unique data on functioning of older adults in various life domains during the COVID-19 pandemic.
- ⇒ The items of the COVID-19 exposure index that was developed were based on self-report, more objective sources such as medical records were lacking.
- ⇒ The study covered the first months of the pandemic in the Netherlands, longitudinal data is needed to monitor functioning of older adults in later stages of the pandemic.

## INTRODUCTION

The COVID-19 pandemic has affected the daily lives of many older people, directly or indirectly. Some older adults or their close relatives have experienced the disease themselves, while others mainly experienced changes in their daily life related to measures taken by the government, such as lockdown and social distancing policies. Although the long-term effects of the pandemic on well-being and functioning of older adults are still unknown, there have been concerns about its negative effects on physical, psychological and social functioning.<sup>1–3</sup> Therefore, change in functioning of older adults during the pandemic has been the subject of various recent investigations.<sup>1–6</sup> However, these studies seldom incorporate measures of actual exposure to pandemic-related events and situations.

Previous studies on the impact of the pandemic on functioning of older adults were predominantly conducted in the field

of mental health, and show mixed results with regard to effects on psychological health outcomes,<sup>1 5 7–12</sup> both based on longitudinal<sup>5 7 12</sup> or cross-sectional data.<sup>1 8–11</sup> All studies have the common assumption that the included individuals were equally exposed to the COVID-19 pandemic. However, the extent to which people have been exposed to COVID-19 and to related governmental measures varies widely within the older population. Older adults may, among others, have been confronted with infection and sickness, hospitalisation, loss of income, loss of contact with friends or family, infection and sickness of family members and even death of important others. Quantifying this exposure would help to identify persons who are most strongly affected by the pandemic and would enable the monitoring of functioning of these people in the short term and long-term, to see whether tailored interventions are needed.

Measuring COVID-19 exposure can be achieved in various ways. So far, previous work focused on exposure to the actual COVID-19 infection only.<sup>13 14</sup> Some studies used a broader definition and explicitly asked about the impact of the pandemic on daily life.<sup>15–19</sup> However, these studies were mostly focused on specific domains such as lifestyle<sup>17</sup> and were seldom conducted among older populations.<sup>18 19</sup> Therefore, the aim of the current study was to develop an index to measure older adults' exposure to the COVID-19 pandemic. Such an index summarises the direct and indirect exposure to the pandemic on a broad range of topics relevant for older adults, such as COVID-19 infection and its consequences, financial problems, restrictions in healthcare use, social contact and physical activity. Second, we aimed to investigate whether higher exposure to the pandemic is associated with worse functioning, by studying the associations of the exposure index with various domains of functioning (ie, physical, mental and social functioning). Data are used from the COVID-19 study that is part of the Longitudinal Aging Study Amsterdam (LASA), an ongoing population-based cohort study among older adults in the Netherlands.<sup>20 21</sup>

## METHODS

### Study sample

LASA is an ongoing cohort study on various domains of functioning among older adults in the Netherlands.<sup>20 22</sup> The study started in 1992, with follow-up observations approximately every 3 years. The study included older adults aged 55–84 years at baseline, based on a representative sample of the older population in three regions in the Netherlands. Refresher cohorts of older adults aged 55–64 years were added to the study in 2002 and 2012, using the same sampling frame. More details on the design, sampling and data collection of LASA have been reported elsewhere.<sup>20 22 23</sup> In 2018–2019, the most recent regular LASA wave—with face-to-face and telephone interviews and clinical assessments—was completed, and the next wave was planned for 2021–2022. To monitor the impact of the COVID-19 pandemic more in-depth,

an additional self-completion questionnaire was sent to participants on 8 June 2020, just after the first wave of the pandemic in the Netherlands. The questionnaire included a broad range of measures to assess the impact of the COVID-19 situation on daily life, as well as a selection of measurements from regular LASA waves. In previous publications, the design and measurements of the LASA COVID-19 questionnaire were described in greater detail.<sup>21 24 25</sup>

Eligibility criteria for the LASA COVID-19 study were: participation in the 2018–2019 wave (n=1701) and being alive in March 2020 (n=61 excluded). Furthermore, some respondents were excluded because filling out the questionnaire was expected to be too much of a burden for them. These were mainly people who had short or proxy interviews in the 2018–2019 wave (n=155 excluded). This resulted in a selection of 1485 LASA respondents who received the COVID-19 questionnaire. Respondents were given the options to send back the questionnaire by mail or to fill out the questionnaire online (digital questionnaire). A telephone interview was offered to the oldest respondents (80+ years) who initially did not respond and for whom filling out a questionnaire appeared to be too difficult. Of 1485 respondents who received the questionnaire, 1128 (76%) participated. Data were received between 9 June 2020 and 8 October 2020. This included 909 written questionnaires, 198 digital questionnaires and 21 telephone interviews. Respondent characteristics differed by assessment mode: those who filled out the digital questionnaire were younger, more often men, higher educated and had less functional limitations (all  $p<0.001$ ). Of 1128 participants, 39 were excluded because of missing data on the newly developed COVID-19 exposure index (if more than seven items (>20%) of the exposure index were missing), leaving an analytical sample of 1089 participants. For these participants, we also used in one of the analytical models (see below) prepandemic data on functioning from the 2018–2019 LASA wave.

### Patient and public involvement

It was not possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of the LASA COVID-19 study.

### COVID-19 exposure index

The COVID-19 exposure index included variables that measured older adults' direct and indirect exposure to the COVID-19 pandemic. Pandemic-related issues, changes or life events were selected from the LASA COVID-19 questionnaire. These were all based on questions that explicitly referred to the COVID-19 pandemic.<sup>20</sup> This resulted in a 35-item index, including information on COVID-19 infection of respondents and their close relatives (including COVID-19-related hospitalisation and death), as well as items that assess the extent to which the COVID-19 situation affected healthcare use and access, providing and receiving personal care/homecare, the work situation, grocery shopping, lifestyle (eg, physical

**Table 1** Overview of the variables included in the COVID-19 exposure index

Item	Cut-off	Prevalence (%)
1. Tested positive for COVID-19 or probable COVID-19 (told by healthcare professional)	No=0, yes=1	2.7
2. Hospital admission/intensive care unit admission because of COVID-19	No=0, yes=1	0.4
3. Partner/parent/child with COVID-19 positive test	No=0, yes=1	3.5
4. Partner/parent/child with COVID-19 hospital admission or death	No=0, yes=1	1.3
5. Sibling/grandchild/other family member with COVID-19 hospital admission or death	No=0, yes=1	5.3
6. Neighbour/friend/other acquaintance with COVID-19 hospital admission or death	No=0, yes=1	30.0
7. Respondent has been in quarantine	No=0, yes=1	11.8
8. General practitioner (GP) visit cancelled by GP because of the COVID-19 situation	No=0, yes=1	9.5
9. GP visit replaced by telephone consultation because of the COVID-19 situation	No=0, yes=1	15.4
10. Respondent cancelled/postponed GP visit because of the COVID-19 situation	No=0, yes=1	6.9
11. Specialist outpatient visit cancelled by outpatient clinic because of the COVID-19 situation	No=0, yes=1	24.8
12. Specialist outpatient visit replaced by telephone consultation because of the COVID-19 situation	No=0, yes=1	21.4
13. Respondent cancelled/postponed specialist outpatient visit because of the COVID-19 situation	No=0, yes=1	7.5
14. Respondent postponed help seeking for physical/psychological complaints because of the COVID-19 situation	No=0, yes=1	8.3
15. Providing personal/household care: experience of increased burden during the COVID-19 pandemic	No=0, yes=1	2.7
16. Providing personal/household care: more than before the COVID-19 pandemic	No=0, yes=1	4.2
17. Decrease in received personal/household care during the COVID-19 pandemic	No=0, yes=1	4.5
18. Work situation: lower salary due to the COVID-19 pandemic	No=0, yes=1	1.0
19. Difficulties with grocery shopping because of the COVID-19 pandemic	No=0, sometimes or always=1	15.2
20. Weight loss/weight gain because of COVID-19 pandemic	No=0, sometimes or always=1	37.7
21. Less physical activity than before the COVID-19 pandemic	No=0, sometimes or always=1	49.8
22. Increased alcohol use during the COVID-19 pandemic	No=0, sometimes or always=1	13.8
23. Less social contact with family during the COVID-19 pandemic	No=0, yes=1	38.3
24. Less social contact with friends and acquaintances during the COVID-19 pandemic	No=0, yes=1	40.9
25. Less social contact with formal relationships during the COVID-19 pandemic	No=0, yes=1	12.3
26. Impact of job loss/financial problems of respondent during the COVID-19 pandemic	No impact=0, moderate or strong=1	8.8
27. Impact of job loss/financial problems of close relative during the COVID-19 pandemic	No impact=0, moderate or strong=1	15.5
28. Impact of cancellation of leisure activities during the COVID-19 pandemic	No impact=0, moderate or strong=1	70.8
29. Impact of not being able to visit bars, restaurants and/or shops during the COVID-19 pandemic	No impact=0, moderate or strong=1	72.5
30. Impact of experience of illness during the COVID-19 pandemic	No impact=0, moderate or strong=1	10.5
31. Impact of death or severe illness of partner or household member during the COVID-19 pandemic	No impact=0, moderate or strong=1	7.1
32. Death or severe illness of family member or friend during the COVID-19 pandemic	No impact=0, moderate or strong=1	29.3
33. Impact of no contact or less contact with children/grandchildren during the COVID-19 pandemic	No impact=0, moderate or strong=1	54.3
34. Impact of no contact or less contact with family/friends during the COVID-19 pandemic	No impact=0, moderate or strong=1	67.3
35. Impact of difficulties in obtaining essential medication during the COVID-19 pandemic	No impact=0, moderate or strong=1	5.8

activity and alcohol use), social behaviour and various life events or situations, such as financial problems and leisure activities. For a full overview of all items, see [table 1](#). For the calculation of the index, we followed a method that is often used for calculating indexes in research among older populations, such as frailty indexes.<sup>26 27</sup> For each

item, scores were dichotomised as 0 (no) or 1 (yes). Subsequently, the exposure index score was calculated by dividing the sum of item scores present by the total number of item scores measured in a respondent (considering missing items when needed). This resulted in a score between 0 and 1, where higher scores indicate higher

**Table 2** Sociodemographic characteristics of the total sample (n=1089) and by COVID-19 exposure index tertiles

	Total n (%)	COVID-19 exposure index			P value
		Lowest tertile 0–0.142 n (%)	Middle tertile 0.143–0.235 n (%)	Highest tertile >0.235 n (%)	
Sex					
Men	516 (47.4)	209 (56.6)	154 (42.5)	153 (42.7)	<0.001
Women	573 (52.6)	160 (43.4)	208 (57.5)	205 (57.3)	
Age					
<70 years	384 (35.3)	128 (34.7)	128 (35.4)	128 (35.8)	0.95
70–79 years	477 (43.8)	166 (45.0)	160 (44.2)	151 (42.2)	
≥80 years	228 (20.9)	75 (20.3)	74 (20.4)	79 (22.1)	
Partner status					
With partner	808 (74.2)	287 (77.8)	262 (72.4)	259 (72.3)	0.15
No partner	281 (25.8)	82 (22.2)	100 (27.6)	99 (27.7)	
Educational level					
Low	124 (11.4)	49 (13.3)	32 (8.8)	43 (12.0)	0.21
Medium	368 (33.8)	128 (34.7)	130 (35.9)	110 (30.7)	
High	597 (54.8)	192 (52.0)	200 (55.2)	205 (57.3)	
Region					
West (Amsterdam and surrounding)	476 (43.7)	180 (48.8)	160 (44.2)	136 (38.0)	<0.01
Northeast (Zwolle and surrounding)	359 (33.0)	117 (31.7)	126 (34.8)	116 (32.4)	
South (Oss and surrounding)	254 (23.3)	72 (19.5)	76 (21.0)	106 (29.6)	

P values are based on  $\chi^2$  tests.

exposure to the COVID-19 pandemic. For example, in a person with 9 positive items out of 35 measured items, the corresponding exposure index score is  $9/35=0.26$ . We calculated the index score only if respondents were missing seven (20% of 35 items) or less item scores. Most older adults had no (73%) or 1–3 (22%) missing item scores.

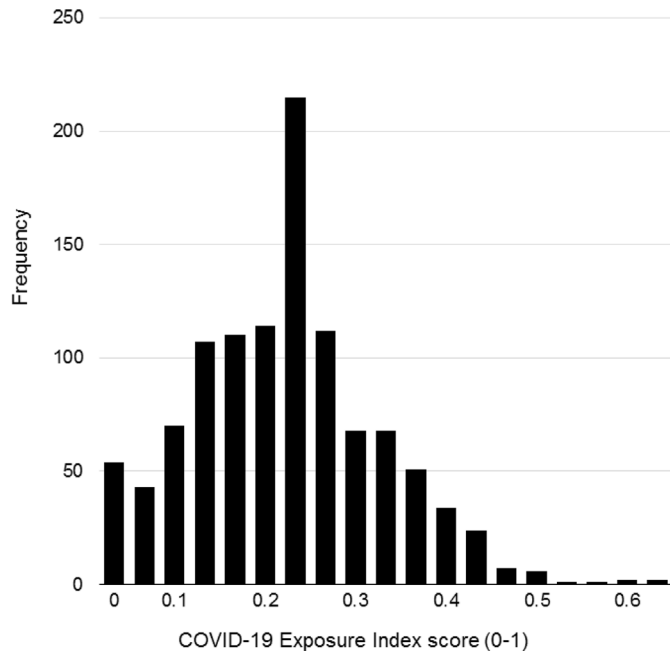
### Outcomes

Various functional domains were evaluated. From the physical domain, functional limitations were assessed. Respondents were asked about any difficulty with performing seven basic activities of daily living: dressing and undressing, climbing the stairs, sitting down and getting up from a chair, cutting one's own toenails, using transportation, walking 5min outdoors without resting and bathing (internal consistency: Cronbach's alpha 0.89). If respondents had difficulty with or could not perform at least one activity, functional limitations were considered to be present (no/yes). From the mental domain, we included anxiety and depressive symptoms. Anxiety symptoms were measured using the anxiety subscale of the Hospital Anxiety and Depression Scale (range 0–21, Cronbach's alpha 0.78). A cut-off score of  $\geq 8$  was applied to indicate the presence of clinically significant anxiety symptoms.<sup>28</sup> Depressive symptoms were assessed using the 10-item version of the Center for Epidemiologic Studies

Depression Scale (range 0–30, Cronbach's alpha 0.79). A cut-off score of  $\geq 10$  indicated the presence of clinically relevant depressive symptoms.<sup>29</sup> Finally, the social domain was covered by loneliness, measured by the De Jong Gierveld Loneliness scale (range 0–11, Cronbach's alpha 0.80). We applied the cut-off score of  $\geq 3$  to indicate the presence of loneliness.<sup>30</sup>

### Covariates

Sociodemographic characteristics included sex, age, partner status, educational level and region. Because of a non-linear association with most functional outcomes, age was categorised into: <70 years, 70–79 years and  $\geq 80$  years. Partner status was defined as having a partner inside or outside the household (1) or having no partner (0). The highest level of completed education was assessed, and three categories were distinguished: low (elementary school or less), medium (lower vocational or general intermediate education) and high (intermediate vocational education, general secondary school, higher vocational education, college or university). A region variable indicated the three regions in which LASA respondents were recruited: the western part of the Netherlands (in and around Amsterdam), the northeast (in and around Zwolle) and the south (in and around Oss).

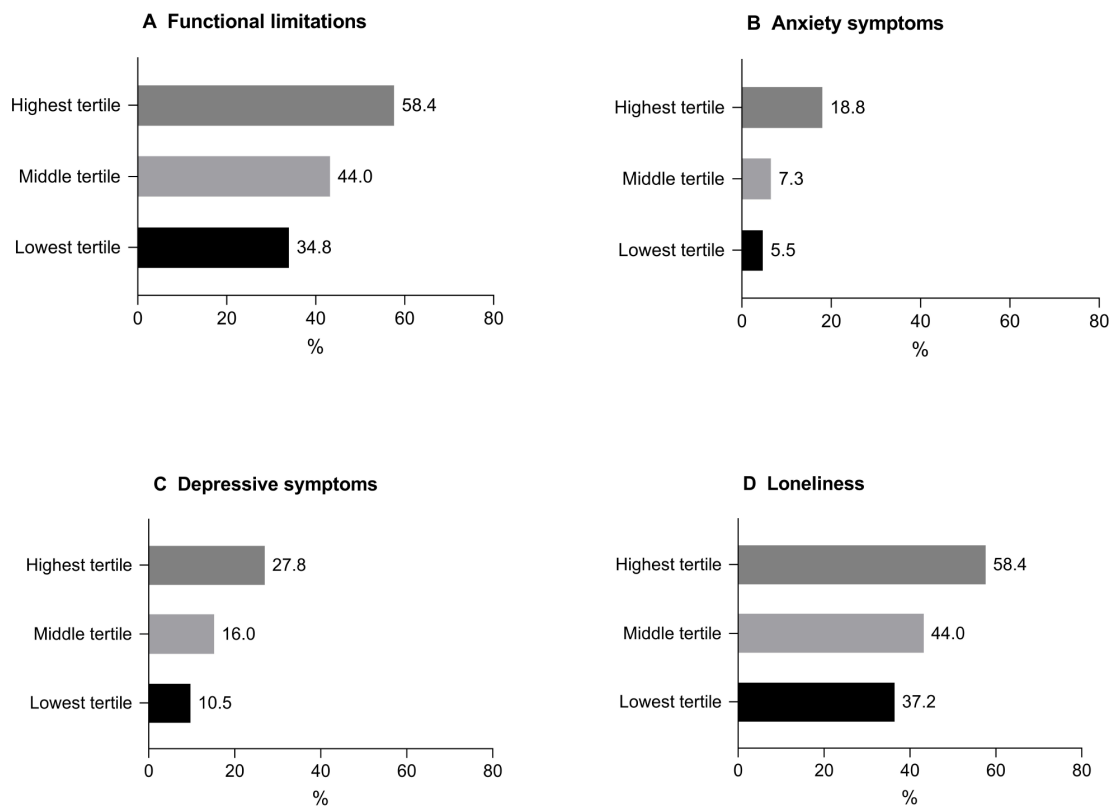


**Figure 1** Distribution of the COVID-19 exposure index.

**Statistical analysis**

First, we described the demographic characteristics of the study population. Next, descriptive statistics of the exposure index were calculated, such as mean, median and range. The distribution of the exposure index was

presented with a histogram. Furthermore, we showed characteristics of the study population stratified by categories of the exposure index. For the latter, we divided the exposure index scores into tertiles, because there are no established cut-points. This approach is also helpful to gain insight into the potential dose–response relationship between the exposure index scores and various domains of functioning. Finally, we looked at associations between the exposure index and outcomes. We first explored the correlations between the continuous scores of these variables (online supplemental table 1), and then we performed logistic regression analyses to study associations between the exposure index tertiles and functional limitations, anxiety, depression and loneliness. Three models were fitted: a crude model, a model adjusted for age, sex, partner status, educational level and region and a model additionally adjusted for prepandemic functioning (prepandemic values of each outcome, measured in 2018–2019). The latter was done to control for reverse causation, that is, the possibility that people with worse prepandemic functioning had a higher likelihood of experiencing COVID-19 adversity and having higher exposure index scores. In the 2018–2019 LASA wave, all functional indicators were defined in the same way and assessed with the same instruments as in the LASA COVID-19 study, as described above. All analyses were done in SPSS V.26 and statistical significance was set at  $p < 0.05$ .



**Figure 2** Various domains of functioning by COVID-19 exposure index tertiles: functional limitations (A), anxiety symptoms (B), depressive symptoms (C) and loneliness (D). Note: Functional limitations=mild or severe limitations (yes); anxiety symptoms=Hospital Anxiety and Depression Scale - Anxiety subscale $\geq 8$ ; depressive symptoms=Center for Epidemiologic Studies Depression Scale-10 $\geq 10$ ; loneliness=De Jong Gierveld Loneliness Scale $\geq 3$ .

## RESULTS

The characteristics of the study sample are displayed in [table 2](#). The majority of the sample was women (53%), with partner (74%) and higher educated (55%). The largest proportion of the sample was aged between 70 and 79 years (43.8%) and lived in the Amsterdam region (43.7%).

In the current sample, the distribution of the COVID-19 exposure index was slightly skewed to the right ([figure 1](#)). The mean exposure index score was 0.20 (SD 0.103), with a range from 0 to 0.63. The median was 0.20 (IQR: 0.13–0.27). Although scores were slightly lower among respondents who sent back their questionnaire in August–September 2020 compared with those who filled out the questionnaire in June or July (24.8% vs 33.7% of each group were in the highest tertile), these differences were not statistically significant. Assessment mode (written, digital, telephone) was not associated with exposure index score (online supplemental table 2). [Table 1](#) shows the prevalence of the items included in the exposure index, ranging from <1% (hospital admission or intensive care unit admission of respondent because of COVID-19) to 73% (respondent experienced moderate or strong impact of not being able to visit bars, restaurants and/or shops during the COVID-19 pandemic). [Table 2](#) shows the characteristics of the study sample stratified by tertiles of the exposure index. COVID-19 exposure index scores were higher among women (57.3% of highest tertile vs 43.4% of lowest tertile) and in the southern region of the Netherlands (29.6% of highest tertile vs 19.5% of lowest tertile). No statistically significant differences in exposure index scores were observed for age categories, partner status and educational level.

[Figure 2](#) shows the prevalence of functional limitations, anxiety symptoms, depressive symptoms and loneliness by tertiles of the COVID-19 exposure index. For all indicators, functioning was worse in those with scores in the highest tertiles of the exposure index. This was further confirmed in logistic regression analyses, in both crude and adjusted models ([table 3](#) and [figure 3](#)). In models adjusted for age, sex, partner status, educational level and region, people in the middle and highest tertile of the exposure index were more likely to have functional limitations (OR middle tertile: 1.61, 95% CI 1.15 to 2.26; OR highest tertile: 3.15, 95% CI 2.23 to 4.43), depressive symptoms (OR middle tertile: 1.59, 95% CI 1.01 to 2.50; OR highest tertile: 3.28, 95% CI 2.15 to 5.03) and loneliness (OR middle tertile: 1.84, 95% CI 1.35 to 2.50; OR highest tertile: 2.63, 95% CI 1.93 to 3.60) compared with people in the lowest tertile. For anxiety symptoms, only those in the highest tertile had a significantly higher probability of the outcome compared with the lowest tertile (OR: 3.84, 95% CI 2.25 to 6.55). Further adjusting for prepandemic levels of functioning in the final model did not change the results: people in the highest tertile of the exposure index were more likely to report functional limitations (OR: 2.24; 95% CI: 1.48 to 3.38), anxiety symptoms (OR: 3.14; 95% CI: 1.82 to 5.44), depressive

symptoms (OR: 2.49; 95% CI: 1.55 to 4.00) and loneliness (OR: 2.97; 95% CI: 2.08 to 4.26) than those in the lowest tertile. A full overview of all covariate effects of all models as well as explained variance (Nagelkerke R<sup>2</sup>, crude models ranging from 4.5% to 6.9% and fully adjusted models ranging from 10.6% to 50.5%) is shown in online supplemental table 3). In sensitivity analyses, we additionally adjusted the analyses on depressive symptoms for loneliness and vice versa. This additional adjustment did not change the results (online supplemental table 4).

## DISCUSSION

Using data from the LASA COVID-19 study in the Netherlands, collected just after the first wave of the pandemic, we developed an index to measure older adults' exposure to the COVID-19 pandemic, and we studied associations of this index with various indicators of functioning. Our results revealed that older people with higher exposure index scores showed worse functioning across various domains, even after adjustment for prepandemic levels of functioning. This was observed in physical, mental and social domains, suggesting that the groups who experienced the greatest consequences from the COVID-19 situation also experienced relatively poor health and well-being across the board.

One previous publication described the development of a questionnaire to measure the impact of the COVID-19 pandemic on daily lives of older adults in the USA.<sup>18</sup> However, this publication does not contain any data. Therefore, our study is unique, and the findings cannot directly be compared with previous work. To determine whether exposure index scores are low or high, a comparison with older adults in other countries or at later time points during the pandemic is necessary. We have studied variation within our study sample and did not observe differences in exposure index scores by age and educational level. This indicates that during the first wave of the pandemic different demographic groups in the Dutch older population experienced a similar impact of COVID-19 and related governmental measures in daily life. In previous studies, socioeconomic differences in COVID-19-related morbidity and mortality have been reported in several countries.<sup>31 32</sup> Our exposure index is a rather broad measure, not only covering COVID-19-related morbidity and mortality, which might explain the absence of an association with educational level. However, we did observe differences in exposure index scores by sex and region. Women are usually more socially active and provide more often informal care than men, and may have experienced stronger effects of governmental social distancing measures. The higher scores among LASA respondents in the south of the Netherlands were expected, since the southern regions were the epicentre of the Dutch COVID-19 outbreak in 2020.<sup>21</sup>

The findings of this study have practical implications, among others for health policy-makers. It is of utmost importance to know to what extent the COVID-19

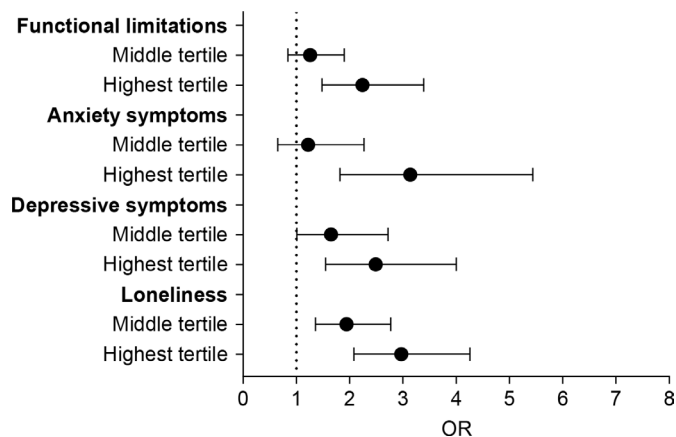
**Table 3** Logistic regression analyses: associations between the COVID-19 exposure index and various domains of functioning

	Functional limitations		Anxiety symptoms		Depressive symptoms		Loneliness	
	n/N	OR (95% CI)	n/N	OR (95% CI)	n/N	OR (95% CI)	n/N	OR (95% CI)
Crude model								
COVID-19 exposure index								
Lowest tertile	125/359	1.00 (ref.)	20/361	1.00 (ref.)	38/362	1.00 (ref.)	136/366	1.00 (ref.)
Middle tertile	159/361	1.47 (1.09 to 1.94)*	26/355	1.35 (0.74 to 2.46)	57/356	1.63 (1.05 to 2.52)*	181/357	1.74 (1.29 to 2.34)*
Highest tertile	206/353	2.62 (1.94 to 3.55)*	66/351	3.95 (2.34 to 6.67)*	98/352	3.29 (2.19 to 4.95)*	212/357	2.47 (1.83 to 3.34)*
Adjusted for covariates†								
COVID-19 exposure index								
Lowest tertile	125/359	1.00 (ref.)	20/361	1.00 (ref.)	38/362	1.00 (ref.)	136/366	1.00 (ref.)
Middle tertile	159/361	1.61 (1.15 to 2.26)*	26/355	1.31 (0.71 to 2.42)	57/356	1.59 (1.01 to 2.50)*	181/357	1.84 (1.35 to 2.50)*
Highest tertile	206/353	3.15 (2.23 to 4.43)*	66/351	3.84 (2.25 to 6.55)*	98/352	3.28 (2.15 to 5.03)*	212/357	2.63 (1.93 to 3.60)*
Adjusted for prepandemic functioning‡								
COVID-19 exposure index								
Lowest tertile	115/325	1.00 (ref.)	20/329	1.00 (ref.)	35/330	1.00 (ref.)	124/333	1.00 (ref.)
Middle tertile	146/333	1.26 (0.84 to 1.93)	24/328	1.22 (0.65 to 2.27)	52/329	1.65 (1.01 to 2.72)*	166/329	1.94 (1.36 to 2.77)*
Highest tertile	190/326	2.24 (1.48 to 3.38)*	60/324	3.14 (1.82 to 5.44)*	86/325	2.49 (1.55 to 4.00)*	196/330	2.97 (2.08 to 4.26)*

\*Statistically significant  $p < 0.05$ ; functional limitations=mild or severe limitations (yes); anxiety symptoms=Hospital Anxiety and Depression Scale - Anxiety subscale  $\geq 8$ ; depressive symptoms=Center for Epidemiologic Studies Depression Scale-10  $\geq 10$ ; loneliness=De Jong Gierveid Loneliness Scale  $\geq 3$ .

†Adjusted for sex, age, partner status, educational level and region.

‡Additionally adjusted for prepandemic (2018–2019) functioning (functional limitations, anxiety symptoms, depressive symptoms or loneliness); n/N=number of positive outcomes/total N of the COVID-19 index tertile.



**Figure 3** Fully adjusted associations between the COVID-19 exposure index tertiles and various domains of functioning in logistic regression analyses. Note: Error bars show the 95% CI; lowest tertile=reference group; all associations are adjusted for sex, age, partner status, educational level, region and prepandemic (2018–2019) functioning (functional limitations, anxiety symptoms, depressive symptoms or loneliness).

pandemic and related governmental measures affect daily functioning of older adults, positively or negatively. However, it is also important to take into account that there might be great variation within the older population with regard to experienced impact of the pandemic. The exposure index as created in the current study helps to capture this variation and may especially be useful to identify persons for whom targeted interventions are needed to improve or maintain functioning across various domains during the pandemic. This will contribute to improved health and well-being of older adults and may also help to develop health policy responses in future pandemics. For example, to prevent adverse effects on social functioning, strategies may be developed to maintain social contact during a pandemic.<sup>33</sup>

This was—to our knowledge—the first study to comprehensively measure the exposure to the COVID-19 pandemic among older adults. Where previous studies mainly focused on isolated indicators of exposure such as infections,<sup>13–16</sup> we created a more elaborated measure which summarised the consequences of the pandemic on everyday life. Our approach reveals that great heterogeneity exists within the older population in terms of impact of the pandemic on levels of functioning. Other strengths of the current study include the use of data from a large sample of older adults in the Netherlands, with indicators of functioning that covered multiple domains. However, the study also has limitations. First, our results should be interpreted with caution. Because of the cross-sectional design of the study, we have to be careful with drawing conclusions on the direction of the observed associations. We partly addressed this by controlling the analyses on the associations between the COVID-19 exposure index and various indicators of functioning for prepandemic functioning. This adjustment was needed because it is possible that people who already had health problems before the

pandemic have a higher chance to experience changes in healthcare or homecare, and therefore score higher on the COVID-19 exposure index. However, it is still possible that levels of functioning partly determine how people respond to certain items included in the exposure index. For example, mental health problems may result in a more negative evaluation of the impact of the pandemic on daily life. Ancillary analyses (online supplemental table 5) showed that prepandemic functioning (2018–2019), in particular functional limitations and depressive symptoms, predicted higher exposure index scores (2020). Second, our data covered the first wave of the pandemic in the Netherlands. We do not know to what extent these findings are generalisable to later stages of the pandemic and to other geographical areas. This will become more clear when follow-up data from the LASA study become available, as well as data from cohort studies in older populations across Europe, such as the Survey of Health, Ageing and Retirement in Europe (SHARE).<sup>34–35</sup> Third, we created the exposure index with an existing dataset, so we were limited to variables available in this dataset. We missed consequences of the pandemic in some domains, such as concerns regarding the COVID-19 situation, worries regarding one's own health, the quality of sleep, mood and the experience of COVID-19 ageism.<sup>18–36–38</sup> Fourth, all the measures included in this study are based on self-report. For some items included in the exposure index, additional information from more objective sources such as medical records would have been helpful, especially with regard to details on COVID-19 infection, symptoms and test results. Fifth, in the current study, there were different assessment modes, including completion of the questionnaire by postal mail, via internet, or a telephone interview. Even though we did not observe differences in exposure index scores by assessment mode, we cannot exclude that the observed differences between respondents were partially caused by a mode effect.<sup>39</sup> Finally, selection effects may limit the generalisability of our findings. Although the participation rate of the LASA COVID-19 study was rather high, we might have missed people in our sample with more severe COVID-19 infections or certain COVID-19 risk groups. Therefore, the total exposure index score as well as the prevalence of some items in the exposure index, such as COVID-19 infection and related hospitalisation, could be an underestimation. Furthermore, LASA is an ongoing longitudinal study from which participants drop-out for various reasons. Refresher cohorts are added to the study every 10 years, but loss to follow-up may still have resulted in a selection of relatively healthy survivors.<sup>20</sup>

There is a growing body of research exploring the effects of COVID-19 infection on morbidity and mortality in older adults.<sup>40–43</sup> An increasing number of studies also has been investigating the impact of the COVID-19 pandemic on older adults' levels of functioning in daily life, such as mental health, loneliness, lifestyle and well-being.<sup>5–25–44</sup> Yet, it is still unknown what the effects of the pandemic will be in the long term. When monitoring



levels of functioning of older adults over time and comparing them to pre-pandemic functioning, it is challenging to disentangle ageing effects from changes that are due to the pandemic, which are period effects. There are statistical approaches available to distinguish ageing effects from period effects,<sup>45 46</sup> but these require multiple measurements over an extended time period before, during and after the pandemic. The index that was developed in the current study could make the comparison of functional trajectories across groups with different COVID-19 exposure easier and does not require the availability of long-term pre-pandemic data. Therefore, an important direction of future research is to study associations between COVID-19 exposure and levels of functioning in the long term. Another question that remains unanswered, and that could be addressed in future research, is whether the COVID-19 exposure index itself changes over time. By repeatedly measuring the exposure index, patterns in COVID-19 exposure and the impact of cumulative exposure may be revealed. For example, it is possible that during the pandemic—in certain domains (eg, healthcare provision, lifestyle or the work situation)—the impact of COVID-19 decreases due to adaptation processes or possible that people feel less restricted and more safe because of increasing vaccination rates. Lastly, the COVID-19 exposure index is not intended as a fixed measure. It may need to be updated according to the stage of the pandemic, or it may need to be adapted for specific purposes. For example, in its current form, it could be too long for use in practice. Therefore, future research may also focus on reducing the number of items of the index, without losing too much information for a specific goal of using the index (eg, case finding or outcome prediction) and matching the stage of the pandemic (eg, in a later stage, the experience of multiple COVID-19 infections and long COVID-19 complaints may become more important).<sup>47</sup> Another possibility would be to distinguish subdomains of the exposure index in future studies, so that interventions could be targeted more easily, because not all older adults experience adversity across all domains covered by the index.

## CONCLUSION

We developed a COVID-19 exposure index using data from older adults participating in the LASA study in the Netherlands. We found that, just after the first wave of the pandemic, exposure was relatively higher among women and in the southern region of the Netherlands. Moreover, older adults with higher scores on the index reported worse functioning in the physical, mental and social domain. Our index may provide a more comprehensive and sensitive measure of COVID-19 exposure than measuring exposure based on infection alone. When monitoring functioning of older adults over time, the use of indexes such as ours enables the identification of people for whom targeted interventions are needed to

maintain or improve functioning across various domains, during the pandemic or post pandemic.

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