Underlying conditions in adults with COVID-19

ORIGINAL ARTICLE

WENCHE NYSTAD

E-mail: wenche.nystad@fhi.no
Department of Chronic Diseases and Ageing
Norwegian Institute of Public Health
She has contributed to the idea, design, quality assurance and
interpretation of results, drafting and revision of the manuscript and has
approved the submitted manuscript version.
Wenche Nystad, PhD, epidemiologist and senior researcher.
The author has completed the ICMJE form and declares no conflicts of
interest.

VIDAR HJELLVIK

Department of Chronic Diseases and Ageing
Norwegian Institute of Public Health
He has contributed to the quality assurance of statistics, analyses,
preparation and interpretation of results, drafting and revision of the
manuscript and has approved the submitted manuscript version.
Vidar Hjellvik, dr. scient., statistician and senior researcher.
The author has completed the ICMJE form and declares no conflicts of
interest.

INGER KRISTIN LARSEN

Registry Department
Norwegian Cancer Registry
She has contributed to the idea, design, quality assurance and
interpretation of results, drafting and revision of the manuscript and has
approved the submitted manuscript version.
Inger Kristin Larsen, PhD, epidemiologist and researcher.
The author has completed the ICMJE form and declares no conflicts of
interest.

INGER ARIANSEN

Department of Chronic Diseases and Ageing
Norwegian Institute of Public Health
She has contributed to the quality assurance of and interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.
Inger Ariansen, PhD, MD and senior researcher.
The author has completed the **ICMJE form** and declares no conflicts of interest.

EYVIND HELLAND

Department of Health Registries
Norwegian Directorate of Health, Trondheim
He has contributed to the quality assurance and facilitation of statistics and analyses, interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.
Eyvind Helland, PhD candidate in psychology, Norwegian University of Science and Technology, and advisor.
The author has completed the **ICMJE form** and declares no conflicts of interest.

KNUT IVAR JOHANSEN

Department of Health Registries
Norwegian Directorate of Health, Trondheim
He has contributed to the interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.
Knut Ivar Johansen, cand. polit. in sociology and head of section.
The author has completed the **ICMJE form** and declares no conflicts of interest.

JOHANNE GULBRANDSEN

Data Delivery Unit
Registry Department
Cancer Registry of Norway
She has contributed to the interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.
Johanne Gulbrandsen, health information scientist and head of section.
The author has completed the **ICMJE form** and declares no conflicts of interest.

HANNE LØVDAL GULSETH

Department of Chronic Diseases and Ageing

Norwegian Institute of Public Health

She has contributed to the idea, interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.

Hanne Løvdal Gulseth, PhD, MD and head of department.

The author has completed the ICMJE form and declares no conflicts of interest.

HELENA NIEMI EIDE

Department of Infection Control and Environmental Health
Norwegian Institute of Public Health

She has contributed to the interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.

Helena Niemi Eide, MPH and MD.

The author has completed the ICMJE form and declares no conflicts of interest.

SIRI E. HÅBERG

Centre for Fertility and Health
Norwegian Institute of Public Health

She has contributed to the idea, design, interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.

Siri E. Håberg, PhD, MD and senior researcher.

The author has completed the ICMJE form and declares no conflicts of interest.

ØYSTEIN KARLSTAD

Department of Chronic Diseases and Ageing
Norwegian Institute of Public Health

He has contributed to the design, preparation and interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version

Øystein Karlstad, PhD, pharmacist and senior researcher.

The author has completed the ICMJE form and declares no conflicts of interest.

INGER JOHANNE BAKKEN

Department of Health Registries
Norwegian Directorate of Health, Trondheim

She has contributed to the idea, design, facilitation of statistics, data analysis, interpretation of results, drafting and revision of the manuscript and has approved the submitted manuscript version.

Inger Johanne Bakken, dr. ing and senior advisor.

BACKGROUND

Cardiovascular diseases, cancer, type-2 diabetes and chronic obstructive pulmonary disease (COPD) were initially noted as the most common diseases among individuals who were hospitalised for COVID-19. However, the evidence base is weak. The objective of this study is to describe how selected diseases were distributed among adults with confirmed COVID-19 (COVID-19 positive tests) and among those hospitalised for COVID-19 compared to the general population.

MATERIAL AND METHOD

We used data from the Norwegian Patient Registry, the Norwegian Registry for Primary Health Care and the Norwegian Surveillance System for Communicable Diseases for adults from the age of 20 and older for the period 1 March 2020–13 May 2020.

RESULTS

Of all those who tested positive for COVID-19, 7 632 (94 %) were aged 20 years or older, and 1 025 (13.4 %) of these had been hospitalised. Among those hospitalised with COVID-19, there was a higher proportion of individuals with cardiovascular diseases (18.3 % versus 15.6 %), cancer (6.9 % versus 5.4 %), type-2 diabetes (8.6 % versus 5.2 %) and COPD (3.8 % versus 2.7 %) than in the general population as a whole after adjusting for age. The proportion of hospitalised patients with asthma, other chronic respiratory disease, cardiovascular disease, ongoing cancer treatment, complications related to hypertension, obesity and overweight, neurological disorders and cardiac and renal failure was also higher than in the general population. There were few differences between persons who had tested positive for COVID-19 and the general population in terms of underlying conditions.

INTERPRETATION

Among those hospitalised for COVID-19, there was a higher proportion of patients with underlying illnesses than in the general population. This may indicate that these patients tend to have a more severe course of disease or that they are more likely to be hospitalised compared to healthy individuals. The results must be interpreted with caution, since the sample of COVID-19 individuals is non-random.

Main findings

Of all individuals who tested positive for COVID-19, altogether 7 632 (94 %) were 20 years of age or older, and of these, 1 025 (13.4 %) had been hospitalised.

Among those hospitalised for COVID-19, there were a larger proportion of individuals with underlying conditions than in the general population after adjusting for age.

There were few differences between persons who had tested positive and the general population in terms of underlying conditions.

COVID-19 is caused by infection with SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2), a coronavirus which rapidly spread to become a global pandemic after the first case was reported in Wuhan in December 2019. At an early stage, the most common conditions among persons who were hospitalised for COVID-19 were non-communicable diseases such as cardiovascular disease, cancer, diabetes and chronic respiratory diseases (1). At the start of the outbreak, advanced age was also identified as an important risk factor for a severe disease progression (2, 3). The clinical picture of COVID-19 is wide-ranging. Some will not notice any symptoms, while a minority will develop serious illness with pneumonia and a need for hospitalisation, possibly intensive care.

Younger people tend to have a milder disease course than older persons, and are less often hospitalised for COVID-19 (4). It has been debated whether chronic diseases independently increase the risk of severe illness or whether the presence of such diseases reflects the fact that those who develop a severe disease tend to be older (4). Norway has had limited testing capacity, and authorities have been particularly alert to persons with underlying diseases. These may thus be overrepresented among persons who are tested for COVID-19. We still have little knowledge about the degree to which various conditions, age and sex may account for a severe disease course with COVID-19 infection. The objective of this study is to describe the distribution of various conditions among persons with a confirmed COVID-19 infection and among patients hospitalised for COVID-19 compared to the general population.

Material and method

In this study we have used data from the Norwegian Patient Registry (NPR), the Norwegian Registry for Primary Health Care (KPR) (5), the Norwegian Surveillance System for Communicable Diseases (MSIS) in the Norwegian Institute of Public Health, and the Person Registry (the Norwegian Health Network's version of the National Population Registry).

The Norwegian Patient Registry is an administrative database that contains activity data from all government-funded hospitals and outpatient clinics from 2008 onwards. Reporting to the registry is mandatory and provides the basis for specialist health care reimbursements. The registry contains identities and ICD-10 codes (International Classification of Diseases, 10th revision). The Norwegian Registry for Primary Health Care, established in 2016, holds reimbursement claims sent to the government administration from therapists in the primary health service. The ICPC-2 coding system (International

Classification for Primary Care, 2nd edition) is used in reimbursement claims. The Norwegian Surveillance System for Communicable Diseases receives notifications about confirmed SARS-CoV-2 infections from microbiological laboratories. The Person Registry was used to identify the study population to persons who were resident in Norway as of 1 March 2020.

The Norwegian Directorate of Health was provided with data on all individuals who had tested positive for SARS-CoV-2 in a polymerase chain reaction test (PCR) in the period 1 March 2020–13 May 2020. These data were linked to data from the Norwegian Patient Registry and the Norwegian Registry for Primary Health Care with the aid of a project-specific serial number shared by the three registries. Retrievals and linking of data and facilitation of statistics were undertaken with the aid of the database tool SQL Server Management Studio (SSMS, Microsoft) and the R statistics tool (6).

Population data were retrieved from Statistics Norway's website (population statistics per 1 January 2020, persons aged 20 years or older).

Ethics

The facilitation of statistics complies with the regulations for the registries in question, since the objectives of this study were monitoring and health security. Staff of the Norwegian Directorate of Health had no access to personal registration numbers or any other characteristics that could identify individuals. Staff of the Norwegian Institute of Public Health only had access to aggregated data in a tabular format.

Definitions

Diseases and conditions that could lead to an increased risk of a severe disease course COVID-19 were defined on the basis of knowledge about COVID-19 trajectories from other countries, the infection risk for influenza and the course of illnesses, as well as treatments and possible effects on the immune system (2). For some chronic diseases we used all available past data, while for others we went seven or five years back in time, depending on knowledge about the course of the disease (Tables 1 and 2). We included a large number of diseases, because monitoring and emergency preparedness were the main objective of this study, and there was little knowledge about COVID-19. Cancer patients in active treatment were included as a separate group, because many patients still go for regular follow-ups after primary cancer treatment and therefore remain registered in the Norwegian Patient Registry with a diagnostic code for cancer.

Table 1

Definitions of diseases and conditions used in the study

Disease/condition	ICD-10	ICPC-2
Diabetes[1]	E10, E11	T89, T90
Diabetes type 1[1]	E10	T89
Diabetes type 2[1]	E11	T90

Disease/condition	ICD-10	ICPC-2
Asthma[1]	J45, J46	R96
Chronic obstructive pulmonary disease from 40 years[1]	J43, J44	R95
Other chronic pulmonary disease[1]	J41, J42, J47, J84, J98	
Cancer[2]	C00–C97, D32–33, D35.2–35.4, D42–43, D44.3–44.5, D45–47	
Cardiovascular diseases[3]	I00–I99, G45, H34	K74–80, K82–83, K85–87, K89–92
Stroke[3]	G45, I60–I61, I63–I64 (except I63.6), I69	K89, K90–K91
Ischaemic heart disease[3]	I20–I25	K76
Atrial fibrillation[3]	I48	K78
Cardiac failure[3]	I50, I11.0, I13.0, I13.2, I42	K77
Hypertension[2]	I10	K86
Complications of hypertension[2]	I11–I13, I15	K87
Obesity[2]	E66	T82
Overweight[2]		T83
Hypercholesterolaemia[2]	E78	T96
Dementia[1]	F00–F03, G30, G31.0, G31.8, G31.2	
Hip fracture[1]	S72.0, S72.1, S72.2	
Renal failure[1]	N18.3–N18.5	
Gastric ulcer and diseases of the biliary tract[2]	K80, K81, K83, K25, K26, K27	
Neurological disorders[1]	G12, G20–21, G30–32, G35, G40–41, G70–73	
Cerebral palsy[1]	G80–G83	
Transplantation[1]	Z94.0–Z94.4, Z94.8	
Immunological failure[1]	D80–D84	
Rheumatological diseases[1]	M05–M09	L88
Inflammatory bowel disease[1]	K50, K51, K52	D94
Biological drugs[4]	4AA23, 4AA24, 4AA26, 4AA33, 4AA34, 4AB02, 4AB06, 4AC07	
Alcohol-related illness[1]	F10, G62.1, G72.1, I42.6, K29.2, K70.0–K70.4, K70.9, K86.0, O35.4, P04.3, Q86.0	P15–P16

Disease/condition	ICD-10	ICPC-2
Other diagnosis related to psychoactive substance use[1]	F11–F19	P18–P19
Serious mental disorder[1]	F20–29, F30–31, F32.3, F33.3	P72–P73, P98
Other mental disorder[1]	F32 (except F32.3), F33 (except F33.3), F34–F39, F40–F48	P01–P06, P74–85

[1]All available historic data for the period 2008–19 in the Norwegian Patient Registry (ICD10 codes) and July 2016–March 2020 in the Norwegian Registry for Primary Health Care (ICPC2 codes) as far back in time as possible.

[2]Last five years.

[3]Last seven years.

[4]Biological drugs administered in hospital, identified from procedure codes in the Norwegian Patient Registry (used e.g. for multiple sclerosis, rheumatological diseases, ulcerative colitis, Crohn's disease, psoriasis and spondylitis).

Table 2

Definitions of diseases and conditions and proportion in the population aged 20 years and older, among those who tested positive for COVID-19 and among those hospitalised for COVID-19. Number and proportion in per cent. For the COVID-19 groups, the proportions are age-adjusted and shown with a 95 % confidence interval.

Disease/condition	Population (N = 4 118 831) n (%)	COVID-19 test positives (N = 7 632) n (% [95 % CI])	COVID-19 hospitalised (N = 1 025) n (% [95 % CI])
Diabetes[1]	242 592 (5.9)	468 (6.3 [5.8–6.9])	157 (9.4 [8.0–11.0])
Type 1 diabetes[1]	30 007 (0.7)	44 (0.6 [0.4–0.8])	7 (0,6 [0,3–1,3])
Type 2 diabetes[1]	212 585 (5.2)	424 (5.7 [5.2–6.3])	150 (8,6 [7,3–10,1])
Asthma[1]	225 169 (5.5)	515 (6.8 [6.3–7.5])	127 (11.5 [9.7–13.7])
Chronic obstructive pulmonary disease (COPD) from 40 years[1]	111 493 (2.7)	161 (2.3 [2.0–2.7])	67 (3.8 [3.0–4.8])
Other chronic pulmonary disease[1]	13 554 (0.3)	34 (0.5 [0.3–0.7])	13 (0.8 [0.5–1.4])
Cancer[2]	224 018 (5.4)	421 (5.8 [5.2–6.3])	127 (6.9 [5.8–8.3])
treated during the last 6 months	23 277 (0.6)	40 (0.6 [0.4–0.8])	16 (1,0 [0,6–1,6])
treated during the last 3 months	10 599 (0.3)	20 (0.3 [0.2–0.4])	11 (0,7 [0,4–1,3])

Disease/condition	Population (N = 4 118 831) n (%)	COVID-19 test positives (N = 7 632) n (% [95 % CI])	COVID-19 hospitalised (N = 1 025) n (% [95 % CI])
Cardiovascular disease[3]	644 443 (15.6)	1 233 (16.4 [15.5–17.4])	333 (18.3 [16.4–20.3])
Stroke[3]	94 766 (2.3)	190 (2.5 [2.2–2.9])	49 (2,4 [1,8–3,2])
Ischaemic heart disease[3]	159 355 (3.9)	278 (3.7 [3.3–4.2])	94 (4,5 [3,7–5,5])
Atrial fibrillation[3]	132 491 (3.2)	270 (3.5 [3.1–3.9])	91 (3,9 [3,2–4,8])
Cardiac failure[3]	63 552 (1.5)	136 (1.7 [1.4–2.0])	60 (2,6 [2,0–3,3])
Hypertension[2]	578 867 (14.1)	977 (13.4 [12.5–14.2])	251 (14,4 [12,7–16,3])
Complications of hypertension[2]	43 419 (1.1)	88 (1.2 [1.0–1.5])	32 (1,6 [1,2–2,3])
Obesity[2]	68 047 (1.7)	120 (1.5 [1.3–1.8])	26 (2.8 [1.9–4.2])
Overweight[2]	56 781 (1.4)	105 (1.3 [1.1–1.6])	24 (2.6 [1.8–3.9])
Hypercholesterolaemia[2]	28 756 (0.7)	64 (0.9 [0.7–1.1])	11 (0.7 [0.4–1.3])
Dementia[1]	15 190 (0.4)	107 (1.3 [1.1–1.6])	9 (0.4 [0.2–0.7])
Hip fracture[1]	7 659 (0.2)	19 (0.2 [0.1–0.4])	6 (0.2 [0.1–0.6])
Renal failure[1]	23 196 (0.6)	67 (0.9 [0.7–1.1])	37 (1.7 [1.3–2.4])
Gastric ulcer and diseases of the biliary tract [2]	41 846 (1.0)	88 (1.1 [0.9–1.4])	21 (1.5 [1.0–2.4])
Neurological disorders[1]	73 178 (1.8)	197 (2.6 [2.3–3.0])	42 (3.0 [2.2–4.0])
Cerebral palsy[1]	10 204 (0.2)	13 (0.2 [0.1–0.3])	5 (0.5 [0.2–1.1])
Transplantation[1]	6 921 (0.2)	22 (0.3 [0.2–0.4])	12 (0.9 [0.5–1.6])
Immunological failure[1]	3 054 (0.1)	17 (0.2 [0.1–0.4])	8 (0.7 [0.4–1.5])
Rheumatological diseases[1]	86 720 (2.1)	157 (2.1 [1.8–2.5])	35 (2.5 [1.8–3.5])
Inflammatory bowel disease[1]	56 206 (1.4)	95 (1.3 [1.0–1.5])	22 (2.0 [1.3–3.0])
Biological drugs[4]	17 849 (0.4)	24 (0.3 [0.2–0.5])	6 (0.6 [0.3–1.4])
Alcohol-related illness[1]	71 592 (1.7)	79 (1.0 [0.8–1.3])	11 (1.0 [0.6–1.9])
Other diagnosis related to psychoactive substance use[1]	69 574 (1.7)	72 (0.9 [0.8–1.2])	15 (2.0 [1.2–3.4])
Serious mental disorder[1]	79 363 (1.9)	91 (1.2 [1.0–1.4])	17 (1.8 [1.1–2.9])
Other mental disorder[1]	1 070 244 (26.0)	1 827 (23.6 [22.5–24.7])	259 (27.0 [23.9–30.5])

[1]All available historic data for the period 2008–19 in the Norwegian Patient Registry (ICD10 codes) and July 2016–March 2020 in the Norwegian Registry for Primary Health Care (ICPC2 codes) as far back in time as possible.

[2]Last five years.

To define diseases we used data from the Norwegian Patient Registry for the period 2008–19 (ICD-10 codes; principal and secondary diagnoses) and from the Norwegian Registry for Primary Health Care (ICPC-2 codes) for the period July 2016–March 2020 (Table 1). For all persons registered with at least one contact with one or more of these conditions as a principal or secondary diagnosis and who had not died or emigrated as of 1 March 2020, dummy variables (yes/no) were created for each of these conditions.

The information on hospitalisations for COVID-19 is based on data on completed hospital care episodes that are reported monthly to the Norwegian Patient Registry (the period January–April 2020). The periods vary somewhat, because of the national procedures for reporting hospitalisations to the Norwegian Patient Registry and the availability of data in the project. We defined hospitalisation for COVID-19 as a positive test for COVID-19 and a hospitalisation with the diagnostic code U07.1 (COVID-19, virus identified), B34.2 (coronavirus infection, unspecified) or B97.2 (coronavirus as cause of diseases classified elsewhere).

Statistical analyses

The analyses included all persons aged 20 or older in the total population, among all those who have tested positive for COVID-19 and among all those who have been hospitalised for COVID-19.

The proportion of persons who have been registered with each condition in the three populations is reported in percentages. We present results for all conditions for men and women combined and in 20-year age groups (20–39 years, 40–59 years, 60–79 years and 80 years and older). For the largest groups of diseases (cardiovascular diseases, cancer, type 2 diabetes and COPD) we also present results for men and women separately and in 20-year age groups among persons aged 40 years and older, because the proportion with these diseases is low in the age group 20–39 years.

The proportion with each condition among those who had tested positive or had been hospitalised for COVID-19 is adjusted for sex and age and presented with a 95 % confidence interval. The age adjustment was made with the aid of the *ageadjust.indirect* function in the R package Epitools, with the population divided into five-year age groups as reference (6). This function also estimates the confidence interval.

Results

The population aged 20 years and older encompassed 4 118 831 persons, of whom 65 % were 40 years or older. Furthermore, 8 125 persons were registered as having tested positive for COVID-19 in the period 1 March–13 May 2020 according to the Norwegian Surveillance System for Communicable Diseases. Of these, 7 632 (94 %) were 20 years or older, and 5 046 (66 %) were 40 years or older. In the period from January through April 2020, altogether 1 025 (13.4 %) of those who were registered as having tested positive for COVID-19 and aged 20 years and older had been hospitalised for COVID-19, and of these, 905 (88 %) were 40 years or older. They had been hospitalised for eight days on average, the median hospitalisation time was six days, and the longest hospitalisation time was 50 days.

Among all those hospitalised, a total of 333 (18.3 %) were registered with a cardiovascular disease, 127 (6.9 %) with cancer, 150 (8.6 %) with type 2 diabetes and 67 (3.8 %) with COPD (these percentages are adjusted for sex and age). The proportions were higher than in the population as a whole (Table 2).

When looking in detail at the largest disease groups distributed by sex and age among those aged 40 years and older, we observed that the proportion of patients hospitalised for cardiovascular diseases, cancer, type 2 diabetes and COPD increased with age (Figure 1). The same tendency can be seen in the general population (Figure 1) and in the group who tested positive for COVID-19 (data not shown). Among those hospitalised for COVID-19, several age groups had a higher proportion of these four diseases than the population as a whole, among women and men alike (Figure 1). However, the figures are small with wide confidence intervals. The proportion of individuals hospitalised with one of these diseases in the age group 40 years and older was 31.3 %, while the proportion with two was 16.9 %, with three 2.8 % and four 0.4 % (not adjusted for age). There were only minor differences between women and men, and the proportion of patients hospitalised with multiple diseases increased with age (data not shown).
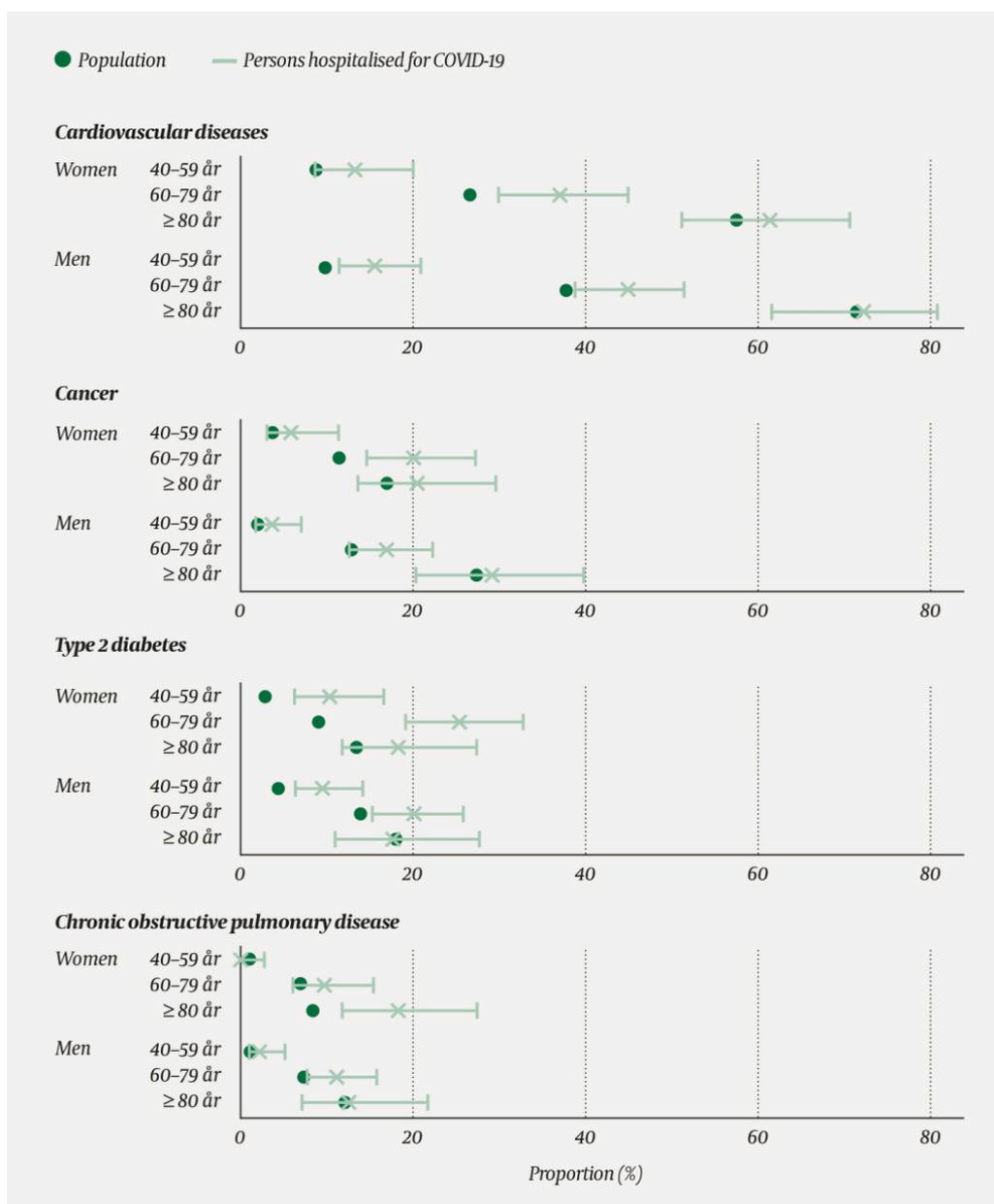
Figure 1 Proportion with cardiovascular disease, cancer, type 2 diabetes and chronic obstructive pulmonary disease in the age group 40 years or older in the total population (N = 2 676 532) and among patients hospitalised for COVID-19 (N = 905), distributed by sex and 20-year age intervals. Cross = proportion among patients hospitalised for COVID-19 shown with a 95 % confidence interval. Closed dot = proportion in the population as a whole.

The proportion with underlying diseases and conditions, for both sexes combined in the age group 20 years and older, shows that individuals hospitalised with COVID-19 are distributed over a number of conditions (Table 2). That is also the case for the total group of individuals with a positive test (COVID-19 test positives). Among those hospitalised, there are a larger proportion of individuals with active cancer treatment in the last six and three month, asthma, other chronic pulmonary disease, cardiovascular diseases, cardiac failure, complications of hypertension, obesity, overweight, renal failure and neurological disorders than in the general population as a whole (Table 2).

The distribution by age groups among those hospitalised for COVID-19 is shown in Figures 2–5. Among the oldest patients, there are more people with cancer in active treatment in the last three months than in the general

population as a whole (Figure 2). In this age group, the proportion with dementia who tested positive to COVID-19 is higher than in the general population (data not shown), but not among the group of hospitalised patients (Figure 2). Moreover, we can see that the proportion with type 1 diabetes, asthma, other pulmonary diseases, cancer, cardiac failure, obesity and renal failure is higher than in the general population in the age group 60–79 years (Figure 3). In the age group 40–59 years, the proportion with type 2 diabetes, asthma, atrial fibrillation, cardiac and renal failure, complications of hypertension, overweight, gastric ulcer and diseases of the biliary tract is higher than in the general population (Figure 4), while the proportion with asthma, cardiovascular diseases, stroke and neurological disorders is higher in the age group 20–39 years than in the general population (Figure 5). It should be noted that the figures are small, and this is reflected in their confidence intervals.
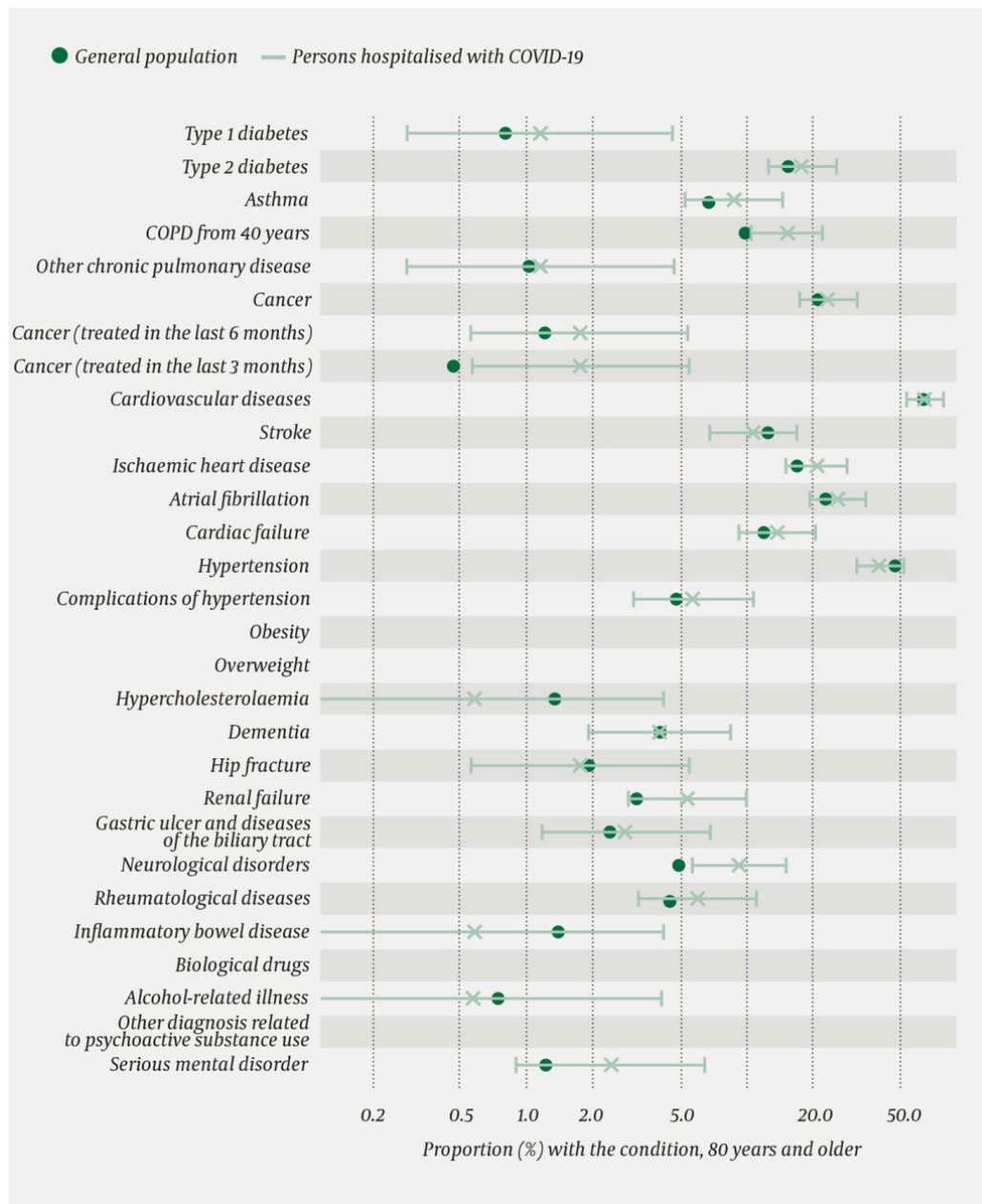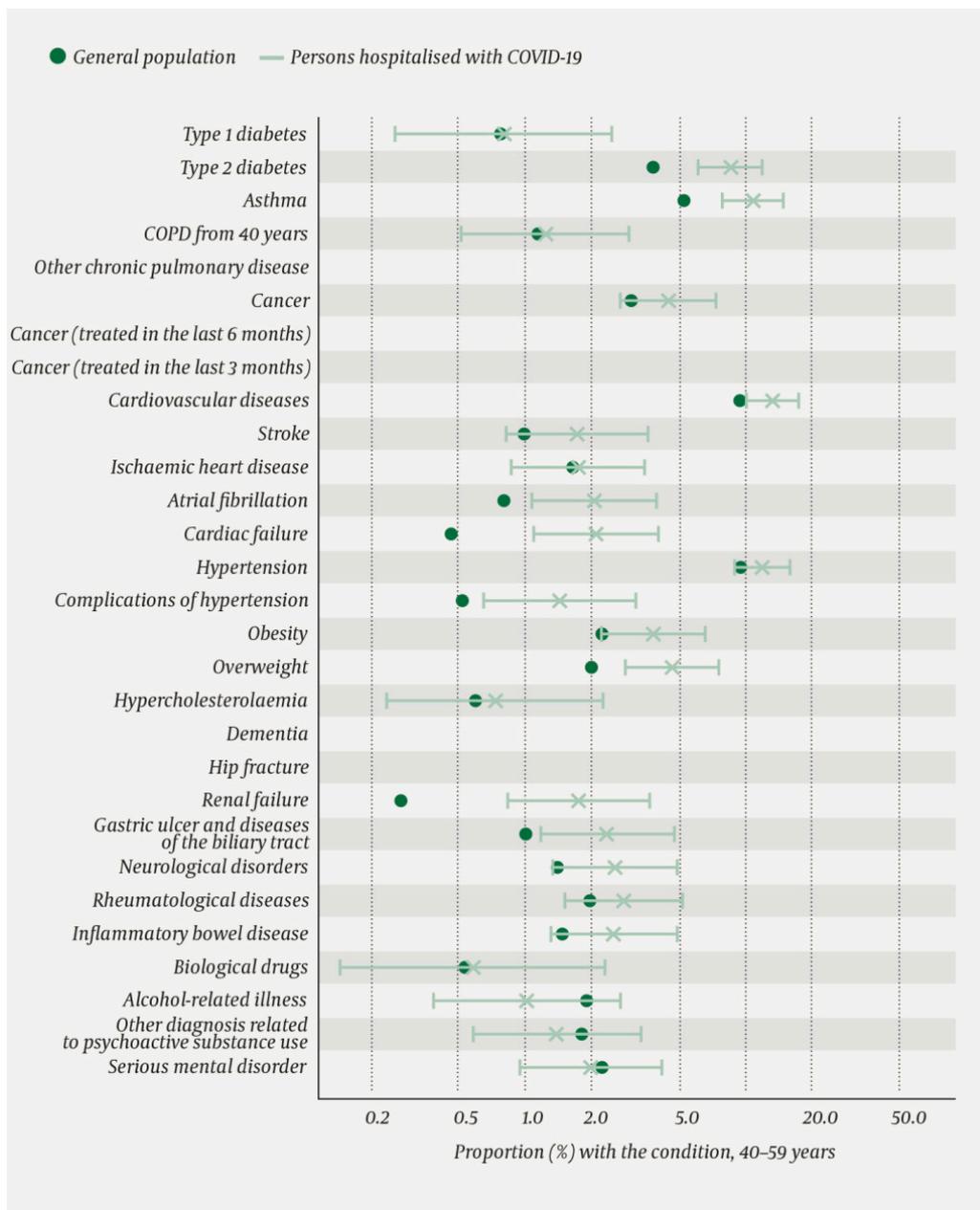

Figure 2 Proportion with the different diseases/conditions in the age group 80 years and older in the general population (N = 230 710) and among patients hospitalised for COVID-19 (N = 172). Conditions with a prevalence of ≥ 0.5 % in the general population or > 1 % among those hospitalised in the age group in question are shown. Cross =
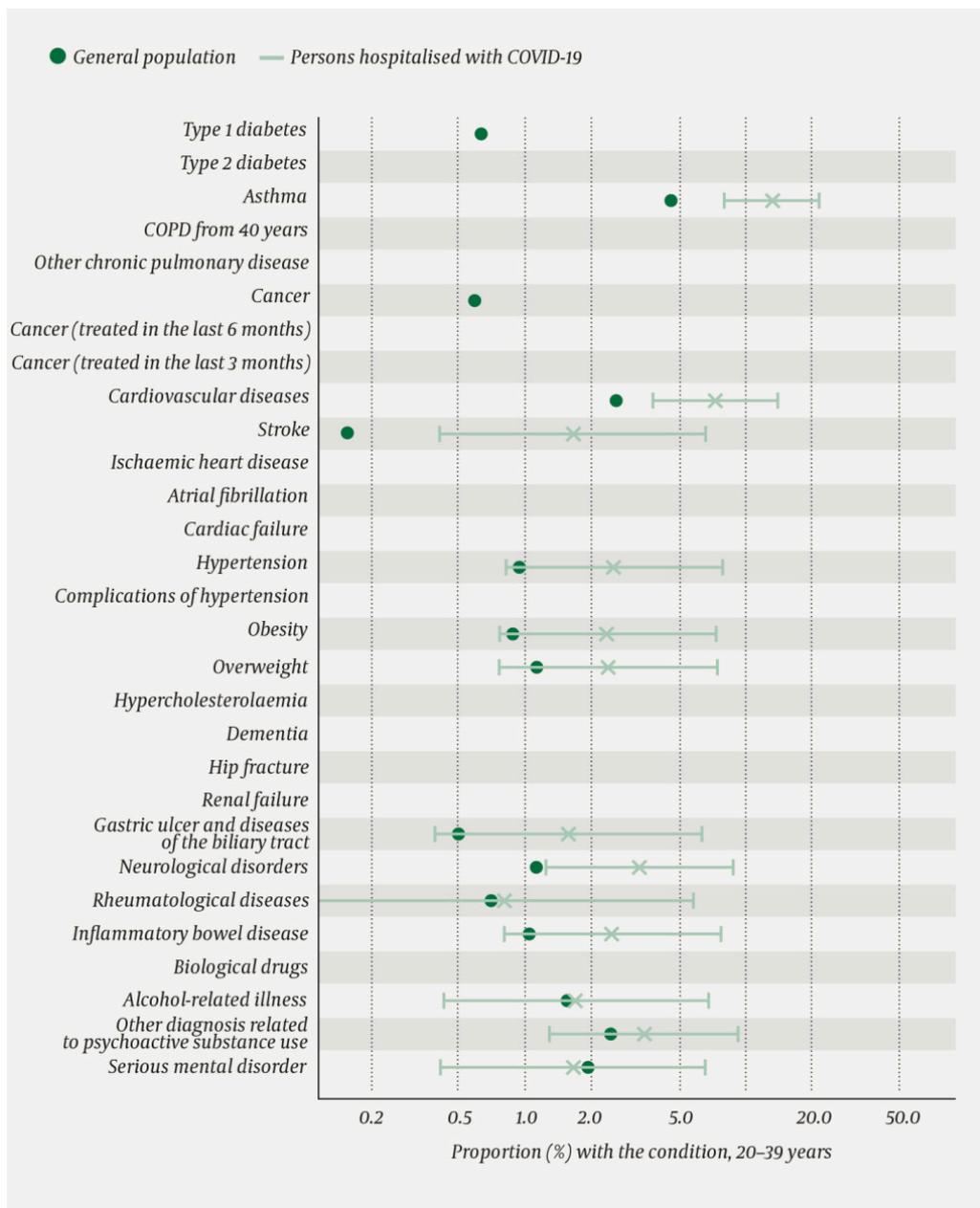
proportion among patients hospitalised for COVID-19, with a 95 % confidence interval. Closed dot = proportion in the general population. Logarithmic scale on the x axis.
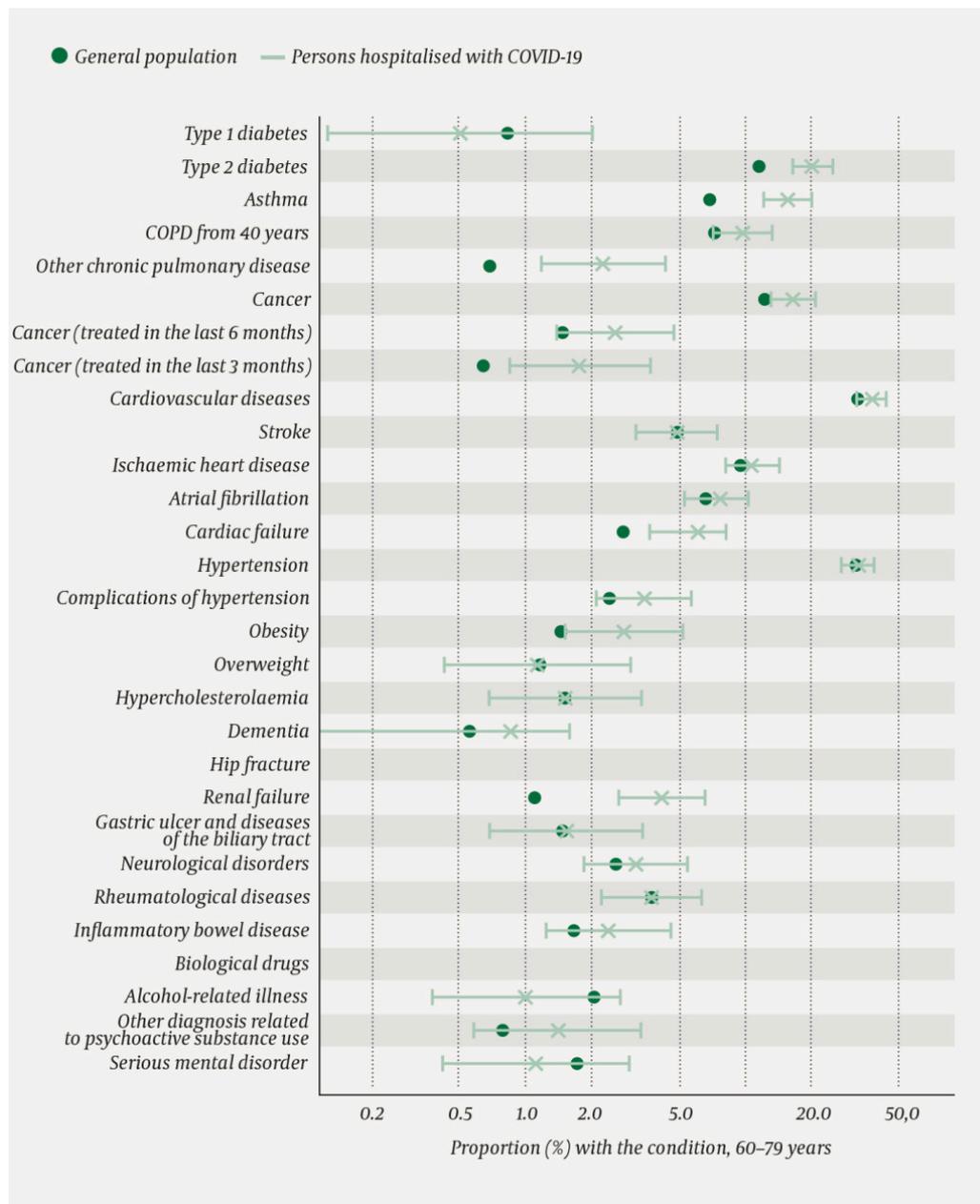
Figure 3 Proportion with the different diseases/conditions in the age group 60–79 years in the general population (N=1 018 329) and among patients hospitalised for COVID-19 (N = 379). Conditions with a prevalence of ≥ 0.5 % in the general population or > 1 % among those hospitalised in the age group in question are shown. Cross = proportion among patients hospitalised for COVID-19, with a 95 % confidence interval. Closed dot = proportion in the general population. Logarithmic scale on the x axis.

Figure 4 Proportion with the different diseases/conditions in the age group 40–59 years in the general population (N = 1 427 493) and among patients hospitalised for COVID-19 (N = 354). Conditions with a prevalence of ≥ 0.5 % in the general population or > 1 % among those hospitalised in the age group in question are shown. Cross = proportion among patients hospitalised for COVID-19, with a 95 % confidence interval. Closed dot = proportion in the general population. Logarithmic scale on the x axis.

Figure 5 Proportion with the different diseases/conditions in the age group 20–39 years in the general population (N = 1 442 299) and among patients hospitalised for COVID-19 (N = 120). Conditions with a prevalence of ≥ 0.5 % in the general population or > 1 % among those hospitalised in the age group in question are shown. Cross = proportion among patients hospitalised for COVID-19, with a 95 % confidence interval. Closed dot = proportion in the general population. Logarithmic scale on the x axis.

Discussion

Among hospitalised adults registered with COVID-19 there was a higher proportion of patients with various underlying conditions than in the population as a whole. The clinical picture changes with age. We found a tendency towards a higher proportion registered with non-communicable diseases such as cardiovascular diseases, cancer, type 2 diabetes and COPD than in the general population in many age groups, among both women and

men. There was little difference in the prevalence of registered conditions between persons who had tested positive for COVID-19 and the general population.

Currently there is little research evidence as to whether persons with specific underlying diseases and conditions are at a higher risk of a serious course of COVID-19 (7). In most previous studies, the analyses are based on population groups where there might be a selection to be tested for SARS-CoV-2 and to be hospitalised with COVID-19 (8, 9). This might influence the results (7, 10).

Advanced age alone, or the presence of multiple diseases, is associated with a severe course of COVID-19 (7). However, it is difficult to determine whether the increased risk of developing severe disease after COVID-19 is due to the presence of multiple diseases or whether it is a reflection of the fact that older persons with these diseases are often hospitalised as a precautionary measure.

It is difficult to distinguish between these factors in our project as well. Being hospitalised for COVID-19 may in itself be an expression of the disease severity. We did, however, observe that even though the length of the hospitalisation period may reflect the severity of the COVID-19 infection, some patients also died during or shortly after a short stay in hospital. It will thus be difficult to rate the illness severity among hospitalised patients exclusively based on the length of their stay or use of intensive care.

Analyses of individual diseases have pointed out that cardiovascular diseases, cancer, diabetes and COPD are overrepresented among persons who developed severe disease after COVID-19, although the findings are not entirely unambiguous across the studies (4). For example, in a study by Petrilli et al., chronic pulmonary diseases are not overrepresented among hospitalised patients (11). For other diseases, such as diabetes, the findings are more consistent across studies and well as with our own findings. A Danish non-peer reviewed study by Riley et al. shows that the proportion with diabetes is higher among adults with a serious course of COVID-19 (10). We have little knowledge of how the diseases are distributed by age and sex among hospitalised patients when compared to the general population. Our data therefore have value despite the small and non-random nature of the data material, which needs to be interpreted with caution.

The proportion of hospitalised persons with multiple diseases such as cardiovascular diseases, cancer, type 2 diabetes and COPD increases with age and can explain part of the difference between age groups. It is interesting to note that among the oldest – 80 years and older – we find that compared to the general population, a higher proportion of those who tested positive to COVID-19 are registered with dementia, while the proportion with dementia among patients hospitalised with COVID-19 is not higher than in the general population. This may partly be due to the Norwegian testing procedures, whereby people who are at higher risk, including elderly nursing home residents with dementia, may have been tested more frequently, but perhaps not hospitalised to the same extent.

The strength of this registry study lies in its inclusion of the entire Norwegian population aged 20 years and older. This means that we have shown how the proportion of the population with the large disease groups of cardiovascular

diseases, cancer, type 2 diabetes and COPD are distributed by sex and age among persons who have tested positive or been hospitalised for COVID-19. This is important when assessing the potential effects of pandemics that can affect persons in these large disease groups. We included separate analyses for cancer patients who were undergoing active treatment, since we can assume that they will be more vulnerable than other cancer patients. The proportion of patients undergoing treatment for cancer was also higher among those hospitalised for COVID-19 than in the general population.

A registry study will include non-validated data. Here, this does not apply to the definition of the patient group, since one of the strengths of our study is the high degree of correspondence between the Norwegian Surveillance System for Communicable Diseases and the coding in the Norwegian Patient Registry for hospitalised patients. As regards all the listed diseases, on the other hand, non-validated data will be included. Validation of data from the Norwegian Patient Registry may, for example, show that 'suspicion of a disease' has been coded as 'the disease'. Furthermore, we have insufficient knowledge about the quality of the Norwegian Registry for Primary Health Care, since it was established relatively recently. Overestimation of disease prevalence is generally likely in registry studies without validation, and this is a weakness. Unfortunately, the project had no data on multimorbidity for all the diseases. This means that an individual can be affected by more than one disease, in the same way as the general population with which the hospitalised patients are compared.

Follow-up times vary between the different registries. The Norwegian Patient Registry contains information on completed hospital care episodes, and consequently we have no data on those who were hospitalised in late April/early May. Access to data on currently hospitalised patients could have further strengthened the study. This group is likely to have encompassed a proportion with long hospitalisation periods and a more serious disease course may assume, however, that this weakness of the study will have little effect on the results, since this group is small. The regulations stipulate that the code for COVID-19 infection should not be used as a main diagnosis. In the hospital data, it is thus impossible to distinguish between patients who have been admitted for COVID-19 and patients who have been diagnosed with COVID-19 during hospitalisation for other conditions.

Because of the Norwegian testing strategies in the spring of 2020, the likelihood of being tested was higher for a person with an underlying disease than for an otherwise healthy person with the same symptoms. If many people have had COVID-19 without being tested, this could weaken the findings in our study. The majority of these would then most likely be in the group of 'otherwise healthy' persons, and we would have expected an overrepresentation of chronically ill patients among those who had tested positive. This seems however not to be the case.

With access to data about those who tested negative for COVID-19 we could have estimated the degree of selection caused by the testing strategies. Many of those who were first confirmed to have COVID-19 were fit and healthy ski tourists, and this may also have served to reduce the proportion of chronically ill persons among those who tested positive. A person with an underlying

disease will also tend to be hospitalised with milder symptoms than an otherwise healthy person. We know that during the influenza pandemic caused by the A(H1 N1) virus in 2009–2010, the likelihood of hospitalisation was higher among persons with type 2 diabetes than among the general population, while the disease severity and complications was not any higher (12). The weaknesses of observation studies that use non-random material, as in parts of this study, and how this affects the results have been described in a number of recently published articles (8, 9, 13).

The objective of this study was to describe how different diseases were distributed among persons with confirmed COVID-19 and among patients hospitalised for COVID-19 when compared to equivalent figures for the general population. The main purpose has been to contribute to monitoring and emergency preparedness. Having such an overview is important in order to follow the development in Norway further. Linking registry data with personal data that include all persons tested for COVID-19 and where the group that tested positive to COVID-19 is not selected, could have helped answer questions about the risk of being infected with or hospitalised for COVID-19, and thus provided more evidence about the underlying causes of the development of severe disease.

The article has been peer reviewed.

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