

# Supplemental Material

This appendix has been provided by the authors to give readers additional information about their work.

**Supplement to:**

BMI in early adulthood is associated with severe COVID-19 later in life – a prospective cohort study of 1.5 million Swedish men

Josefina Robertson, Martin Adiels, Lauren Lissner, Kirsten Mehlig, Agnes af Geijerstam, Martin Lindgren, Magnus Gisslén, Elin Ekblom Bak, Annika Rosengren, Maria Åberg

## Supplemental Material

# BMI in early adulthood is associated with severe COVID-19 later in life – a prospective cohort study of 1.5 million Swedish men

### Running title:

BMI in youth and severe COVID-19

### Authors:

Josefina Robertson<sup>1,2,3</sup>, MD, PhD; Martin Adiels<sup>4</sup>, PhD; Lauren Lissner<sup>2</sup>, MD, PhD; Kirsten Mehlig<sup>2</sup>, PhD; Agnes af Geijerstam<sup>2</sup>, MD; Martin Lindgren<sup>3,4</sup>, MD, PhD; Magnus Gisslén<sup>1,3</sup>, MD, PhD; Elin Ekblom Bak<sup>5</sup>, PhD; Annika Rosengren<sup>3,4</sup>, MD, PhD; Maria Åberg<sup>2,6</sup>, MD, PhD.

### Affiliations:

<sup>1</sup>Department of Infectious Diseases, Institute of Biomedicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

<sup>2</sup>School of Public Health and Community Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

<sup>3</sup>Region Västra Götaland, Sahlgrenska University Hospital, Gothenburg, Sweden

<sup>4</sup>Department of Molecular and Clinical Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

<sup>5</sup>The Swedish School of Sport and Health Sciences, Department of Physical Activity and Health, Stockholm, Sweden

<sup>6</sup>Region Västra Götaland, Regionhälsan, Gothenburg, Sweden

### Corresponding author

Josefina Robertson, Department of Infectious Diseases, Sahlgrenska University Hospital, SE-416 85, Gothenburg, Sweden  
Email: josefina.robertson@gu.se

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## Supplemental tables

**Table S1.** List of included principal diagnoses among cases with COVID-19 (U07.1 or U07.2) as a secondary diagnosis in the National Patient Register (n = 272).

Included categories	ICD-codes
<b>COVID-related symptoms</b>	
Cough	R05
Abnormalities of breathing	R06
Pain in throat and chest	R07
Other symptoms and signs involving the circulatory and respiratory system	R09
Dizziness and giddiness	R42
Fever of other or unknown origin	R50
Headache	R51
Malaise and fatigue	R53
Syncope and collapse	R55
<b>Upper and lower respiratory tract infections</b>	
Acute nasopharyngitis	J00
Acute tonsillitis	J03
Acute upper respiratory infections of multiple and unspecified sites	J06
Influenza due to other identified influenza virus	J10
Other viral pneumonia	J128
Viral pneumonia, unspecified	J129
Pneumonia due to <i>Streptococcus pneumoniae</i>	J13
Bacterial pneumonia, not elsewhere classified	J15
Pneumonia due to other specified infectious organisms	J168
Pneumonia in diseases classified elsewhere	J17
Pneumonia, unspecified organism	J18
Unspecified acute lower respiratory infection	J22
Coronavirus infection, unspecified	B342
Other viral infections of unspecified site	B348
Viral infection, unspecified	B349
Coronavirus as the cause of diseases classified elsewhere	B972
Other and unspecified infectious diseases	B99
<b>Respiratory disorders</b>	
Pulmonary embolism	I26
Acute respiratory distress syndrome	J80
Pulmonary edema	J81
Pleural effusion not elsewhere classified	J90
Respiratory failure, not elsewhere classified	J96
Respiratory disorders in diseases classified elsewhere	J99
<b>Obstructive Airway Diseases</b>	
Acute bronchitis due to other specified organisms	J208
Acute bronchitis, unspecified	J209
Acute bronchiolitis due to other specified organisms	J218
Acute bronchiolitis, unspecified	J219
Other chronic obstructive pulmonary disease	J44

Asthma	J45
<b>Cardiac diseases</b>	
Viral carditis	B332
Chronic ischemic heart disease	I25
Acute pericarditis	I30
Pericarditis in diseases classified elsewhere	I32
Acute myocarditis, unspecified	I40
Myocarditis in diseases classified elsewhere	I41
Atrial fibrillation and flutter	I48
Heart failure	I50
Abnormalities of heart beat	R00
<b>Kidney disorders</b>	
Acute kidney failure	N17
Chronic kidney disease	N18
Unspecified kidney failure	N19
<b>Electrolyte disorders</b>	
Other disorders of fluid, electrolyte and acid-base balance	E87

**Table S2.** Diagnostic codes for preexisting comorbidities from the International Classification of Diseases (ICD).

<b>Diagnosis</b>	<b>ICD-8</b>	<b>ICD-9</b>	<b>ICD-10</b>
Cancer	140–209	140–208	C00–97
Chronic obstructive pulmonary disease	490–492	490–492, 496	J40–44
Coronary heart disease	410–414	410–414	I20–25
Diabetes mellitus	250	250	E10–14
Heart failure	427.00, 427.10	428	I50
Hypertension	401–405	401–405	I10–15
Obesity	-	278	E66

**Table S3.** Odds ratios (OR) and 95% confidence intervals (CI) for severe COVID-19 by body mass index (BMI) category in 1,551,670 young Swedish men born 1950-1987.

	OR (95% CI)	
	Model 1 <sup>a</sup>	Model 2 <sup>a</sup>
<b>COVID-19 (admitted to hospital, n = 4,315)</b>		
BMI 15–18.5	1.05 (0.93–1.20)	1.06 (0.93–1.20)
BMI 18.5–20 (reference)	1	1
BMI 20–22.5	1.08 (0.99–1.18)	1.06 (0.97–1.16)
BMI 22.5–25	1.29 (1.17–1.42)	1.19 (1.08–1.31)
BMI 25–30	1.83 (1.64–2.05)	1.52 (1.36–1.70)
BMI ≥30	2.36 (1.96–2.83)	1.68 (1.39–2.02)
Age in 2020, years	1.05 (1.05–1.05)	1.04 (1.03–1.04)
Hypertension <sup>b</sup>		1.82 (1.66–1.98)
Diabetes mellitus type 1 <sup>b</sup>		1.43 (1.05–1.95)
Diabetes mellitus type 2 <sup>b</sup>		1.96 (1.79–2.15)
Coronary heart disease <sup>b</sup>		0.94 (0.82–1.07)
Heart failure <sup>b</sup>		1.92 (1.62–2.26)
<b>COVID-19 (admitted to an intensive care unit, n = 729)</b>		
BMI 15–18.5	1.31 (0.97–1.78)	1.31 (0.97–1.78)
BMI 18.5–20 (reference)	1	1
BMI 20–22.5	1.13 (0.90–1.41)	1.10 (0.88–1.38)
BMI 22.5–25	1.57 (1.23–2.00)	1.44 (1.13–1.84)
BMI 25–30	2.54 (1.94–3.32)	2.04 (1.56–2.68)
BMI ≥30	3.87 (2.58–5.79)	2.61 (1.73–3.93)
Age in 2020, years	1.07 (1.07–1.08)	1.06 (1.05–1.07)
Hypertension <sup>b</sup>		1.93 (1.58–2.35)
Diabetes mellitus type 1 <sup>b</sup>		0.41 (0.10–1.66)
Diabetes mellitus type 2 <sup>b</sup>		2.15 (1.75–2.64)
Coronary heart disease <sup>b</sup>		0.66 (0.47–0.93)
Heart failure <sup>b</sup>		1.45 (0.96–2.20)
<b>COVID-19 (requiring high-flow nasal oxygen therapy, n = 849)</b>		
BMI 15–18.5	1.10 (0.82–1.46)	1.10 (0.83–1.47)
BMI 18.5–20 (reference)	1	1
BMI 20–22.5	1.04 (0.85–1.28)	1.02 (0.83–1.25)
BMI 22.5–25	1.47 (1.19–1.84)	1.34 (1.08–1.67)
BMI 25–30	2.11 (1.64–2.70)	1.67 (1.30–2.15)

BMI $\geq$ 30	2.95 (1.95–4.30)	1.94 (1.30–2.90)
Age in 2020, years	1.07 (1.06–1.07)	1.05 (1.04–1.06)
Hypertension <sup>b</sup>		1.76 (1.45–2.13)
Diabetes mellitus type 1 <sup>b</sup>		1.46 (0.72–2.93)
Diabetes mellitus type 2 <sup>b</sup>		2.36 (1.95–2.86)
Coronary heart disease <sup>b</sup>		0.92 (0.69–1.23)
Heart failure <sup>b</sup>		1.77 (1.23–2.53)
<b>Death due to COVID-19<sup>c</sup> (n = 224)</b>		
BMI 15–18.5	1.42 (0.89–2.27)	1.44 (0.90–2.30)
BMI 18.5–20 (reference)	1	1
BMI 20–22.5	0.83 (0.56–1.22)	0.80 (0.54–1.18)
BMI 22.5–25	1.16 (0.75–1.79)	0.99 (0.64–1.53)
BMI 25–30	3.01 (1.95–4.65)	2.10 (1.34–3.27)
BMI $\geq$ 30	2.91 (1.23–6.87)	1.50 (0.63–3.59)
Age in 2020, years	1.16 (1.14–1.18)	1.13 (1.11–1.16)
<b>COVID-19 among individuals younger than 55 years of age (admitted to hospital, n = 1,675)</b>		
BMI 15–18.5	1.06 (0.84–1.35)	1.06 (0.84–1.35)
BMI 18.5–20 (reference)	1	1
BMI 20–22.5	1.09 (0.93–1.27)	1.08 (0.92–1.26)
BMI 22.5–25	1.44 (1.22–1.70)	1.39 (1.18–1.63)
BMI 25–30	2.07 (1.73–2.47)	1.83 (1.53–2.19)
BMI $\geq$ 30	2.66 (2.07–3.42)	2.02 (1.56–2.61)
Age in 2020, years	1.08 (1.07–1.08)	1.07 (1.06–1.07)
<b>COVID-19 among individuals without any cardiovascular comorbidity (admitted to hospital, n = 2,968)</b>		
BMI 15–18.5	1.03 (0.88–1.21)	-
BMI 18.5–20 (reference)	1	-
BMI 20–22.5	1.11 (1.00–1.24)	-
BMI 22.5–25	1.27 (1.13–1.43)	-
BMI 25–30	1.67 (1.45–1.92)	-
BMI $\geq$ 30	2.07 (1.62–2.65)	-
Age in 2020, years	1.04 (1.04–1.05)	-
<b>COVID-19 (admitted to hospital, n = 4,315), using the US CDC BMI percentiles<sup>d</sup></b>		



BMI 15–18	0.85 (0.74-0.99)	0.79 (0.66-0.95)
BMI 18–24.5 (reference)	1	1
BMI 24.5–27.5	1.46 (1.33-1.60)	1.30 (1.16-1.47)
BMI 27.5–59.2	2.08 (1.86-2.34)	1.88 (1.62-2.19)

<sup>a</sup> Model 1 is adjusted for test center and age in 2020. Model 2 is further adjusted for preexisting comorbidities (before January 1, 2020) including coronary heart disease, heart failure, hypertension, and diabetes mellitus type 1 and 2.

<sup>b</sup> Preexisting comorbidities before January 1, 2020.

<sup>c</sup> Firth’s biased reduction method was used to model COVID-19 deaths.

<sup>d</sup> Categorization by US Centers for Disease Control and Prevention (CDC) BMI percentiles.

**Table S4.** Descriptive data of 4,315 patients with severe COVID-19 leading to hospital admission divided by the first and second wave of the pandemic in 2020 in Sweden.

	<b>COVID-19<sup>a</sup> before Sep 1, 2020, n = 2564 (59%)</b>	<b>COVID-19<sup>a</sup> after Sep 1, 2020, n = 1751 (41%)</b>	<b>p-value</b>
Age at conscription, years (SD)	18.4 (0.8)	18.5 (0.9)	p = ns
Height at conscription, m (SD)	179.3 (6.9)	179.5 (7.0)	p = ns
Weight at conscription, kg (SD)	71.6 (11.9)	71.9 (12.5)	p = ns
BMI at conscription, kg/m <sup>2</sup> (SD)	22.3 (3.4)	22.0 (3.1)	p = ns
Systolic blood pressure at conscription, mmHg (SD)	127.8 (10.9)	128.0 (10.8)	p = ns
Diastolic blood pressure at conscription, mmHg (SD)	68.9 (9.6)	68.6 (9.6)	p = ns
Age in 2020, years (SD)	56.2 (8.9)	56.6 (8.7)	p = ns
<b>Comorbidities<sup>a</sup>, n (%)</b>			
Any comorbidity	924 (36.0)	649 (37.1)	p = ns
Coronary heart disease	161 (6.3)	103 (5.9)	p = ns
Heart failure	109 (4.3)	58 (3.3)	p = ns
Hypertension	530 (20.7)	352 (20.1)	p = ns
Diabetes mellitus type 1 <sup>b</sup>	14 (0.6)	27 (1.5)	p < 0.01
Diabetes mellitus type 2 <sup>b</sup>	396 (15.4)	294 (16.8)	p = ns
Cancer	3969 (2.6)	95 (5.4)	p = ns
Chronic obstructive pulmonary disease	157 (6.1)	66 (3.8)	p = ns
Obesity diagnosis	117 (4.6)	70 (4.0)	p = ns
<b>Outcomes, n (%)</b>			
COVID-19 admitted to an ICU <sup>c</sup>	564 (22)	165 (9)	p < 0.001
COVID-19 requiring high-flow nasal oxygen therapy in hospital <sup>a</sup>	559 (22)	290 (17)	p < 0.001
Death due to COVID-19 <sup>d</sup>	162 (6)	14 (0.8)	p < 0.001

*SD, standard deviation; BMI, body mass index; ICU, intensive care unit.*

<sup>a</sup> Diagnoses received from the National Patient Register.

<sup>b</sup> Diagnoses received from the National Diabetes Register until 2016 and from the National Patient Register from 2016.

<sup>c</sup> Diagnoses received from the Intensive Care Register.

<sup>d</sup> Diagnoses received from the Cause of Death Register.

**Table S5.** Descriptive data of 151,603 conscripts with additional information on BMI in middle age [mean age 45.2 (10.1) years] through the Health Profile Institute (HPI) AB.

	All conscripts in the HPI, n = 151,603 (100%)	No COVID-19 admitted to hospital, n = 151,226 (99.8%)	COVID-19 admitted to hospital <sup>a</sup> , n = 377 (0.2%)	p-value
Age at conscription, years (SD)	18.3 (0.6)	18.3 (0.6)	18.4 (0.8)	p < 0.01
Height at conscription, m (SD)	179.5 (6.5)	179.5 (6.5)	180.3 (7.2)	p < 0.05
Weight at conscription, kg (SD)	70.3 (10.4)	70.3 (10.4)	71.6 (11.3)	p < 0.05
BMI at conscription, kg/m <sup>2</sup> (SD)	21.8 (2.9)	21.8 (2.9)	22.0 (3.1)	p = ns
BMI in middle age, kg/m <sup>2</sup> (SD)	26.1 (5.6)	26.1 (5.6)	27.9 (6.1)	p < 0.001
Systolic blood pressure at conscription, mmHg (SD)	128.5 (10.9)	128.5 (10.9)	127.5 (10.5)	p = ns
Diastolic blood pressure at conscription, mmHg (SD)	67.2 (9.8)	67.2 (9.8)	67.4 (9.5)	p = ns
Age in 2020, years (SD)	52.5 (9.3)	52.5 (9.3)	56.1 (8.0)	p < 0.001
<b>Comorbidities<sup>a</sup>, n (%)</b>				
Any comorbidity	20028 (13.2)	19924 (13.2)	104 (27.6)	p < 0.001
Coronary heart disease	3586 (2.4)	3569 (2.4)	17 (4.5)	p < 0.05
Heart failure	867 (0.6)	861 (0.6)	6 (1.6)	p < 0.05
Hypertension	9223 (6.1)	9172 (6.1)	51 (13.5)	p < 0.001
Diabetes mellitus type 1 <sup>b</sup>	788 (0.5)	786 (0.5)	2 (0.5)	p = ns
Diabetes mellitus type 2 <sup>b</sup>	6049 (4.0)	6011 (4.0)	38 (10.1)	p < 0.001
Cancer	3991 (2.6)	3969 (2.6)	22 (5.8)	p < 0.001
Chronic obstructive pulmonary disease	1072 (0.7)	1060 (0.7)	12 (3.2)	p < 0.001
Obesity diagnosis	1473 (1.0)	1464 (1.0)	9 (2.4)	p < 0.05
<b>Outcomes, n (%)</b>				
Admitted to an ICU <sup>c</sup>	58 (0.04)	0 (0)	58 (15.4)	p < 0.001
Requiring high-flow nasal oxygen therapy <sup>a</sup>	79 (0.05)	0 (0)	79 (21.0)	p < 0.001

Death <sup>d</sup>	10 (0.01)	0 (0)	10 (2.7)	p < 0.001
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*SD, standard deviation; BMI, body mass index; ICU, intensive care unit*

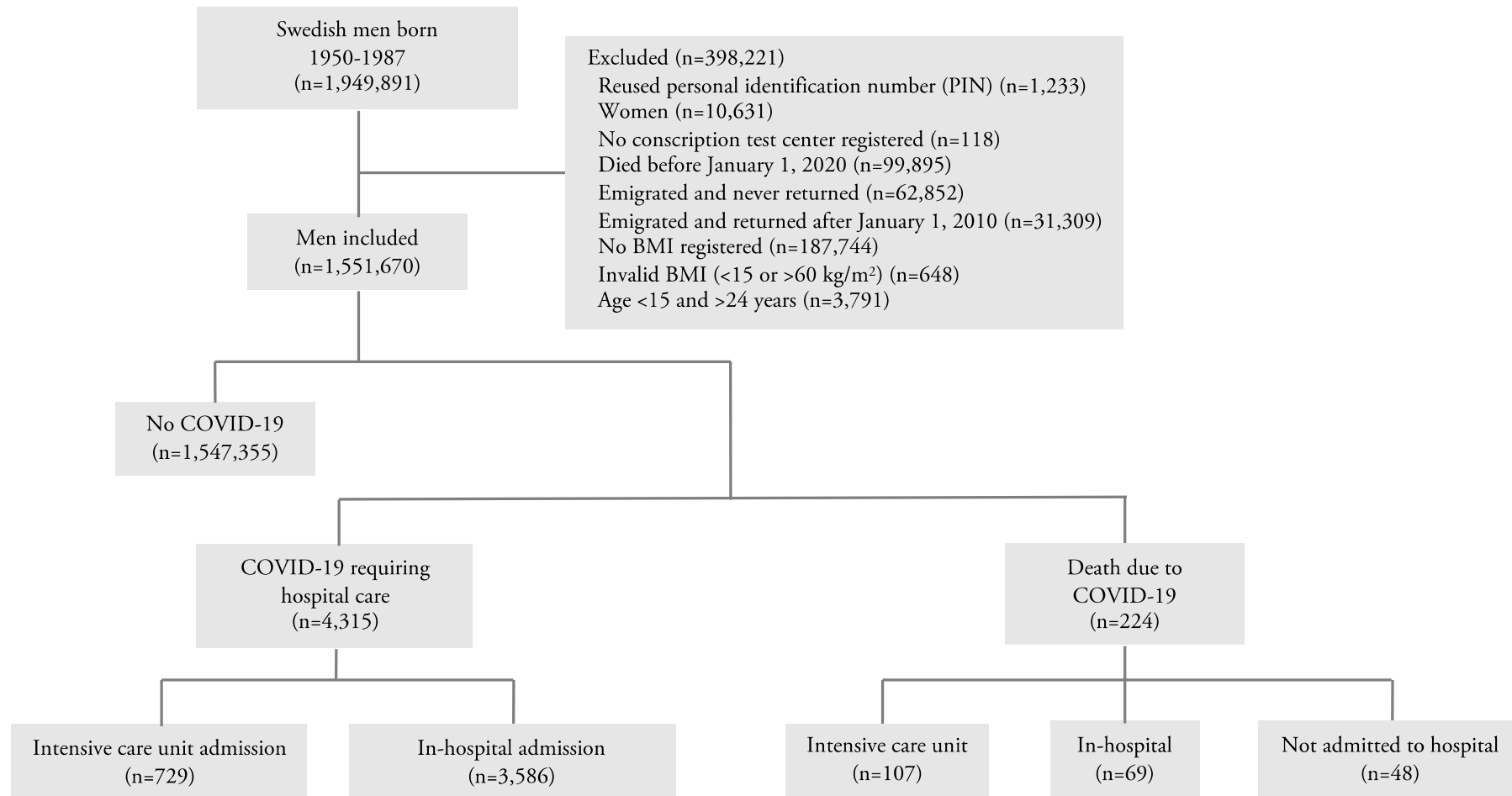
<sup>a</sup> Diagnoses received from the National Patient Register.

<sup>b</sup> Diagnoses received from the National Diabetes Register until 2016 and from the National Patient Register from 2016.

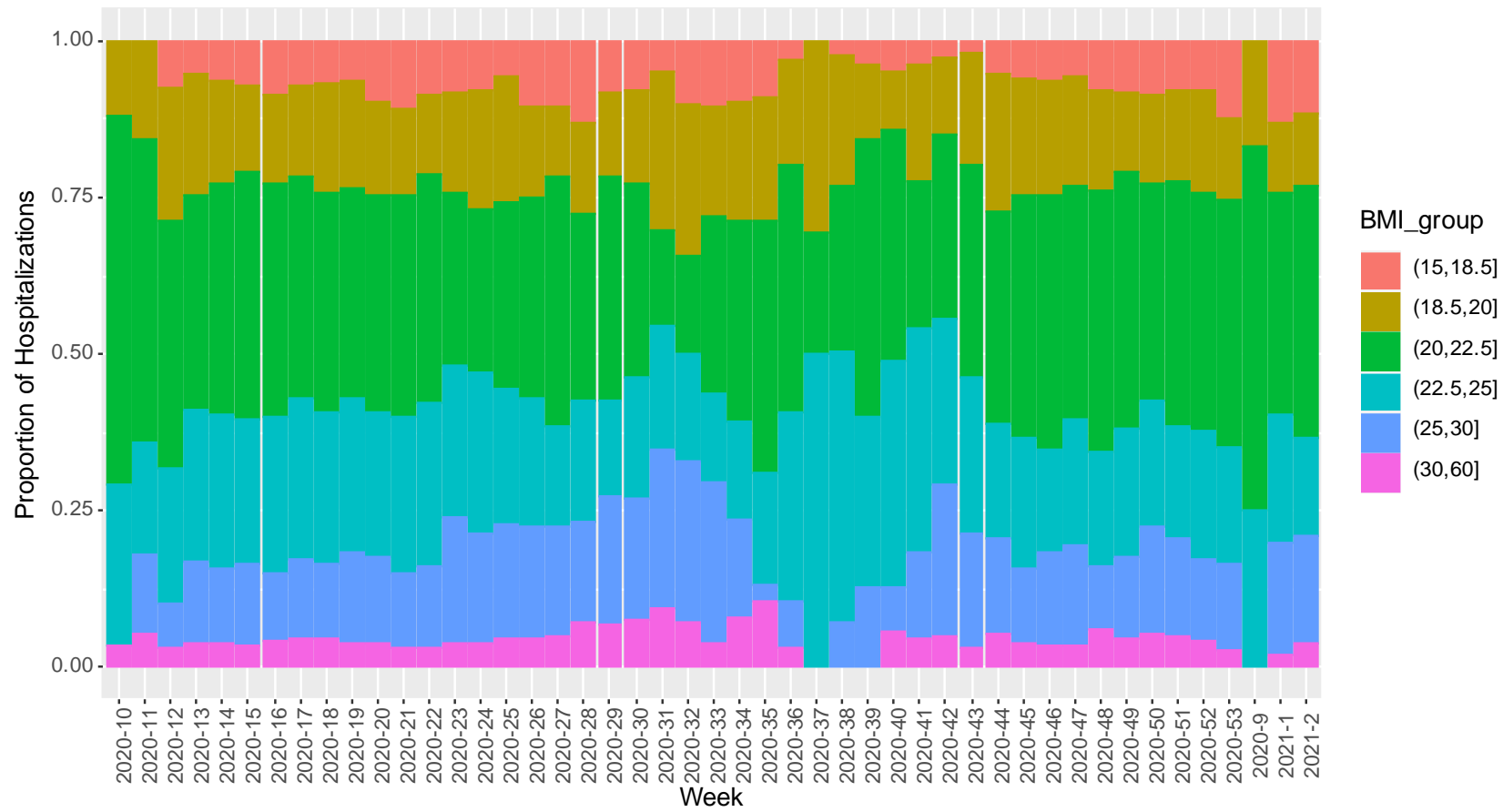
<sup>c</sup> Diagnoses received from the Intensive Care Register.

<sup>d</sup> Diagnoses received from the Cause of Death Register.

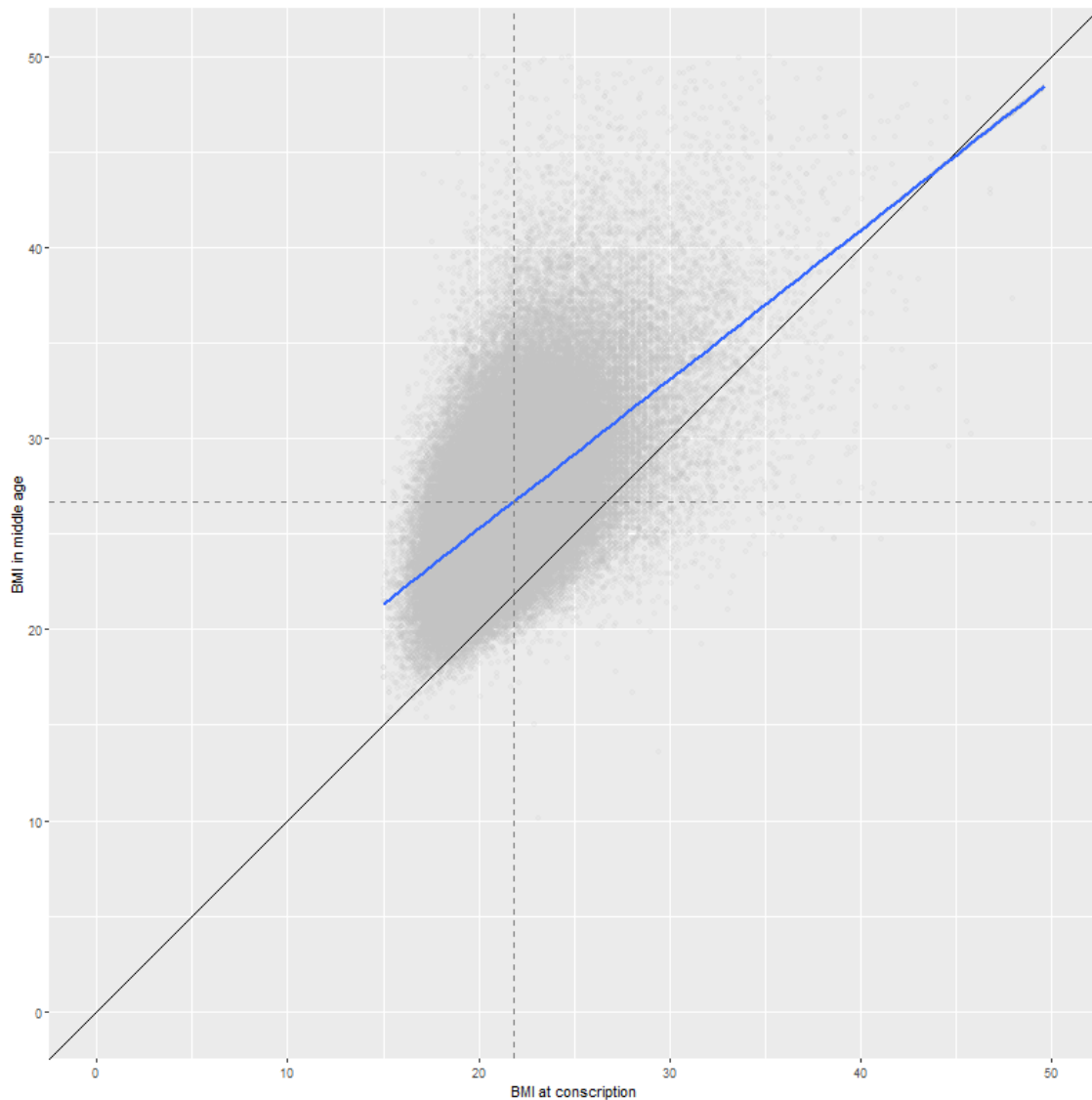
## Supplemental figures



**Figure S1.** Flowchart of included and excluded men.



**Figure S2.** Proportions of BMI groups in hospitalized patients with COVID-19 by week during the pandemic in 2020.



**Figure S3.** Correlation between body mass index (BMI) at conscription [mean age 18.3 (SD 0.6) years] and at measurement in middle age [mean age 45.2 (SD 10.1) years] through the Health Profile Institute (HPI) AB for 151,603 Swedish conscripts. Mean BMI at conscription was 21.8 (2.9) kg/m<sup>2</sup> and in middle age 26.1 (5.6) kg/m<sup>2</sup> (vertical and horizontal dotted lines). The slope of the regression line (blue) was 0.79 indicating that the increase in BMI was lower, on average, in men who were more obese at conscription. Adjusted R<sup>2</sup> was 0.3.