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Multimorbidity and healthcare utilization: A register-based study in Denmark

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19 **Abstract**

20 **Background**

21 People with multimorbidity have reduced functional capacity, lower quality of life, and higher
22 mortality rates and use healthcare resources more intensively than healthy people or those with a
23 single chronic condition. The aim of this study was to explore associations between multimorbidity
24 and use of healthcare services and the impact of socioeconomic status on utilization of
25 hospitalizations and bed days.

26 **Methods**

27 The study population included all individuals aged 16 years and older who lived in the Capital
28 Region of Denmark on January 1st, 2012. Data on chronic conditions, use of healthcare services
29 and demographics were obtained from Danish national administrative and health registries. Zero-
30 inflated models were used to calculate anticipated annual use of hospitalizations and bed days.

31 **Findings**

32 The study population comprised 1,397,173 individuals; the prevalence of multimorbidity was 22%.
33 Prevalence was inversely related to educational attainment. For people with multimorbidity,
34 utilization of hospitalizations and bed days increased approximately linearly with the number of
35 chronic conditions. However, a steep increase in utilization of bed days was observed between five
36 and six or more chronic conditions. An educational gradient in hospitalization rates and use of bed
37 days was observed regardless of the number of chronic conditions. Educational attainment was
38 strongly associated with healthcare utilization.

39 **Conclusion**

40 Multimorbidity was associated with a significant increase in utilization of all healthcare services in
41 Denmark. In addition, a socioeconomic gradient was observed in utilization of hospitalizations and
42 bed days.

43

45 **Introduction**

46 Multimorbidity is often defined as the coexistence of two or more chronic conditions in the
47 same person [1, 2]. People with multimorbidity have decreased functional competence [3],
48 lower quality of life [4], higher mortality rates [5] and use healthcare resources more
49 intensively than healthy people or those with just one chronic condition [6]. Most diseases
50 and consequences of poor health are unequally distributed among socioeconomic population
51 groups, and socioeconomic differences are obvious in the prevalence and consequences of
52 multimorbidity [7, 8]. The prevalence of multimorbidity is increasing internationally. The
53 overall prevalence of multimorbidity in Ontario, Canada increased in nearly all age groups,
54 reflecting a 40% total increase between 2003 and 2009 from 17.4% to 24.3% [9]. A study
55 from the Netherlands reported an increase in multimorbidity prevalence from 12.7% to
56 16.2% between 2004 and 2011 [10]. An American study showed that the prevalence of
57 multimorbidity rose between 2000 and 2010 from 22% to 30%, a trend that was most
58 pronounced among people younger than age 65 [11]. Expected continuing increases in the
59 prevalence of multimorbidity are recognized as a major public health and healthcare
60 challenge for modern societies [9].

61 To understand the healthcare challenges associated with multimorbidity, the impact of
62 multimorbidity on healthcare utilization must be carefully assessed [12, 13]. However,
63 detailed knowledge about how multimorbidity affects healthcare utilization is incomplete. A
64 systematic review identified 35 studies investigating relationships between multimorbidity
65 and healthcare utilization, healthcare costs, or both. All included studies showed a positive
66 correlation between multimorbidity and at least one aspect of utilization (physician visits and
67 hospital care) and costs (medications, out-of-pocket spending, and total healthcare costs) for

68 elderly populations [14]. The included studies were from the United States (23), Europe (5),
69 Canada (4), Asia (2), and Australia (1). Many of these study populations were large enough to
70 enable sophisticated statistical analyses, and four were large cross-sectional studies that
71 included 1.13 million to 1.65 million people [15-17]. Regrettably, these large studies had
72 varying inclusion criteria, and none reported sociodemographic data that are necessary for
73 exploring possible associations between multimorbidity, healthcare utilization, and
74 sociodemographic status. Synthesis of the studies was not possible due to ambiguous
75 definitions and measurements of multimorbidity, as well as a multitude of healthcare
76 utilization outcomes.

77 After publication of this systematic review, several large-scale studies [18-22]
78 exploring the relationship between healthcare utilization and the number of chronic
79 conditions demonstrated that additional factors affecting utilization include age [18, 19],
80 gender [18, 19], impaired activities of daily life [20], and socioeconomic status [19].
81 Furthermore, the impact of multimorbidity on healthcare utilization has been shown to differ
82 across individual factors, disease combinations, healthcare systems, and regions [22, 23].

83 The Danish healthcare system is based on universal coverage and principles of free and
84 equal access to healthcare for all citizens. Information on the impact of multimorbidity on
85 healthcare utilization in the Danish healthcare system is sparse. To the best of our knowledge,
86 only a single study to date has demonstrated that hospitalizations, use of bed days and
87 general practitioner (GP) visits, were significantly higher for patients with multimorbidity,
88 compared with those who had no chronic conditions [24].

89 The aim of this study was to explore associations between multimorbidity and
90 healthcare utilization and the impact of socioeconomic status on utilization of hospitalizations and
91 bed days. The structure and content of Danish healthcare registers provide a unique

92 opportunity to quantify how these variables interact [25, 26], which we explored in a large-
93 scale, cross-sectional, regional, register-based population study.

94

95 **Methods**

96 **Study population and data sources**

97 The study population included all individuals aged 16 years and older who lived in the
98 Capital Region of Denmark on January 1st, 2012. The included 1,397,173 individuals
99 represented approximately one-third of the entire Danish adult population. Data on chronic
100 conditions, use of healthcare services, and demographics, including gender, age, and
101 educational attainment, were obtained from Danish national administrative and health
102 registries: the Danish National Patient Registry [27], the Danish National Prescription
103 Registry [28], the Danish National Health Service Registry [29], and The National Diabetes
104 Registry [30]. All data obtained from registries were merged at the level of individuals using
105 their unique social security numbers. However, national registries do not provide data on
106 conditions diagnosed in the primary care sector. In addition to data on diagnoses of chronic
107 conditions available from the secondary healthcare sector, diagnostic algorithms developed
108 by the Research Center for Prevention and Health at Glostrup University Hospital were used
109 to identify primary sector diagnoses of 16 chronic conditions of interest for the entire
110 population (Table 1) [6]. Details about the diagnostic algorithms are provided elsewhere [7].
111 Multimorbidity was defined as two or more chronic conditions occurring simultaneously in
112 the same person.

113

114 **Table 1.** Chronic conditions included in definition of multimorbidity (N = 16)

115	Allergies
116	Hypertension
117	High cholesterol
118	Diabetes (type 1 and type 2)
119	Heart disease
120	Stroke
121	Back pain
122	Joint disease
123	Osteoarthritis
124	Osteoporosis
125	Chronic obstructive pulmonary disease
126	Cancer
127	Dementia
128	Anxiety
129	Long-term use of antidepressants
130	Schizophrenia

131

132 Because data on direct costs could not be linked to the study data, we identified
133 utilization of hospitalizations and bed days, which are among the most expensive services in
134 healthcare, as proxies for direct costs. Socioeconomic status was defined as highest
135 educational achievement and grouped into four categories according to the length of
136 education: none (primary school) (≤ 10 years), short (11-14 years), medium (14-17 years),
137 and long (≥ 17 years) [31]. Finally, we also recorded healthcare utilization for emergency

138 department visits, outpatient visits, GP visits, out-of-hour GP visits, yearly control visits in
139 general practice, and specialist visits during 2012.

140 **Statistical analysis**

141 Descriptive statistics were calculated for gender, age, and educational attainment by
142 the number of chronic conditions. Means for each type of healthcare utilization were
143 calculated. Logistic regression was used to calculate odds ratios (ORs) for healthcare
144 utilization for individuals with multimorbidity versus individuals with none and with one
145 chronic condition. ORs were calculated in both a raw form and adjusted for gender, age, and
146 educational attainment.

147 As cost data was not linked to the present dataset we chose to investigate the effect of
148 socioeconomic status based on the proxies for general healthcare utilization: hospitalizations
149 and bed days. Hospitalizations and bed days were adjusted for emergency visits, out-patient
150 visits GP visits, out-of-hours GP visits, yearly controls in general practice, private specialist
151 visits, number of conditions, age, gender, cohabitation status, education attainment, and
152 employment status.

153 This was accomplished by applying zero-inflated models to both proxies. The models were used to
154 calculate anticipated annual use of hospitalizations and bed days within educational attainment
155 groups, separately for each number of chronic conditions.

156 The decision to use zero-inflated models was prompted by the fact that many individuals do
157 not use bed days or hospitalization [32]. To counter extreme values for some covariates, squared
158 effects of all numerical covariates were included as explanatory variables. For the partial model (1)
159 below, a squared effect of GP visits was not included due to convergence problems. For the partial
160 models of the form (2) below, quadrupled effects of ambulatory visits and out-of-hours GP visits
161 were included. The zero-inflated model was applied as follows.

162 First, the probability p of having at least one bed day/one hospitalization was modeled with
163 a logistic regression model

$$164 \quad \text{logit}(p_i) = \sum_{j=1}^{26} \alpha_j x_{ji}, i = 1, \dots, n, \quad (1)$$

165 where p_i is the probability of one or more hospitalizations or bed days for an individual i and x_j is
166 the j th covariate derived from the specified explanatory variables. Subsequently, numbers of bed
167 days and hospitalizations y were similarly modeled with a log-linear model,

$$168 \quad \log(y_i) = \sum_{j=1}^{29} \beta_j x_{ji} + \varepsilon_i, i = 1, \dots, n_1, \quad (2)$$

169 where $n_1 \leq n$ is the number of individuals with at least one bed day or hospitalization. In the
170 models (2), two observations of bed days and three observations of hospitalizations were omitted as
171 outliers for the analysis of bed days and hospitalizations, respectively.

172 For scenarios in which a specific number of conditions and a specific level of education
173 were assumed, the linear predictors $\hat{\eta} = \sum \hat{\alpha}_j x_j$ and $\hat{\lambda} = \sum \hat{\beta}_j x_j$ were calculated, with all other
174 covariates kept at the empirical mean for the group with the specified number of conditions and
175 level of education. Estimated responses were found as $\hat{y} = \text{logit}^{-1}(\hat{\eta}) \exp(\hat{\lambda} + \hat{\sigma}^2/2)$, where σ^2 is
176 the variance of $\hat{\lambda}$, thus combining models (1) and (2). All analyses were carried out using R
177 software version 3.5.0 (34).

178

179 **Ethics approval:**

180 Approval to conduct the study was obtained from the Danish Data Protection Agency. No informed
181 consent was required.

182

183 **Results**

184 Among 1,397,173 individuals included in the study population, approximately half
185 (720,885; 52%) were women, the majority (927,568; 66%) had none or short education, and
186 the prevalence of multimorbidity was 22% (301,757). Table 2 shows the distribution of
187 gender, age, and educational attainment by the number of chronic conditions. The prevalence
188 of both one and two or more chronic conditions was significantly higher for women than for
189 men. Overall, multimorbidity was highest among individuals 65-84 years old, followed by
190 those who were 45-64 years old. Educational attainment was inversely related to
191 multimorbidity.

192

193

194 **Table 2.** Distributions of the study population (N = 1,397,173) by gender, age, and educational
 195 attainment and number of chronic conditions, N (%)

196

197

		Number of chronic conditions		
		0	1	≥ 2
		N = 809,920	N = 285,496	N = 301,757
200	Gender			
201	Male	418,105 (62)	127,591 (19)	130,592 (19)
202	Female	391,815 (54)	157,905 (22)	171,165 (24)
203	Age in years			
204	16-24	170,486 (86)	25,768 (13)	1,770 (1)
205	25-44	385,540 (77)	89,216 (18)	23,557 (5)
206	45-64	205,947 (48)	111,147 (26)	110,949 (26)
207	65-84	45,529 (19)	53,334 (22)	140,001 (59)
208	>84	2,418 (7)	6,031 (18)	25,480 (75)
209	Education			
210	None (≤ 10 years)	185,347 (53)	69,779 (20)	93,702 (27)
211	Short (11-14 years)	325,241 (56)	123,439 (22)	130,420 (23)
212	Medium (15-16 years)	132,531 (59)	49,576 (22)	41,536 (19)
213	Long (≥ 17 years)	107,578 (65)	34,035 (21)	22,174 (14)
213	Missing	59,233 (72)	8,667 (11)	13,925 (17)

214 Mean rates of healthcare utilization among people with multimorbidity were much
 215 higher than among people with no chronic conditions, by a factor of 1.73 to 9.67, depending
 216 on the type of utilization (Table 3). When comparing people with multimorbidity and those
 217 with one chronic condition, rates of healthcare utilization were 1.44 to 4.00 times higher for

218 those with multimorbidity. In both comparisons, the largest between-group difference was for
 219 yearly control visits in general practice. Unadjusted and adjusted ORs for all types of
 220 healthcare utilization were significantly higher ($p < 0.001$) among people with multimorbidity,
 221 compared with people with zero or one chronic condition. Unadjusted ORs for healthcare
 222 utilization for people with multimorbidity were 1.65 to 11.76 times higher than for people
 223 with no chronic conditions and 1.31 to 3.15 times higher than for people with one chronic
 224 condition (Table 3). Adjusted ORs for healthcare utilization for people with multimorbidity
 225 were 1.86 to 6.70 times higher than for people with no chronic conditions and 1.44 to 2.94
 226 times higher than for people with one chronic condition (Table 3).

227

228 **Table 3.** Mean and odds ratios (ORs) for healthcare utilization among individuals with 0, 1, and ≥ 2
 229 chronic conditions

230

	Number of chronic conditions						
	0	1	≥ 2	≥ 2 vs. 0		≥ 2 vs. 1	
	Mean			Unadjusted OR	Adjusted OR*	Unadjusted OR	Adjusted OR*
Hospitalizations	0.12	0.22	0.51	3.84 (3.80-3.88)	2.78 (2.74-2.83)	2.26 (2.23-2.29)	1.77 (1.75-1.80)
Bed days	0.31	0.82	2.65	3.84 (3.80-3.88)	2.78 (2.74-2.85)	2.26 (2.23-2.29)	1.77 (1.75-1.80)
Emergency visits	0.15	0.18	0.26	1.65 (1.63-1.66)	1.86 (1.83-1.88)	1.39 (1.37-1.41)	1.49 (1.47-1.52)
Outpatient visits	0.91	1.88	3.86	4.83 (4.79-4.87)	3.79 (3.76-3.84)	2.25 (2.23-2.29)	2.03 (2.01-2.05)
General practice visits	4.34	7.39	12.94	8.37 (8.31-8.44)	6.70 (6.64-6.76)	3.15 (3.13-3.18)	2.94 (2.91-2.27)
Out-of-hours general practice visits	0.28	0.38	0.56	1.66 (1.64-1.67)	2.23 (2.19-2.26)	1.31 (1.29-1.32)	1.59 (1.57-1.61)
Yearly control visits in general practice	0.03	0.12	0.29	11.76 (11.58-11.96)	5.66 (5.56-5.77)	2.86 (2.81-2.89)	1.96 (1.93-1.98)
Specialist visits	0.69	1.39	2.09	3.66 (3.63-3.69)	2.36 (2.34-2.39)	1.77 (1.75-1.79)	1.44 (1.43-1.45)

231 *Adjusted for gender, age, and educational attainment

232 Among people with multimorbidity, utilization of hospitalizations increased
233 approximately linearly with the number of chronic conditions. In Fig. 1A, hospitalization rates
234 are indicated with a black line; the reference regression line in red has a slope equal to the
235 mean number of hospitalizations across the number of chronic conditions. The similarity
236 between observed rates and the regression line indicates that each chronic condition
237 corresponded to an average of approximately 0.24 hospitalizations per year. A similar pattern
238 was observed for bed days (Fig. 1B). For people with five or fewer chronic conditions, the
239 utilization of bed days was approximately proportional to the number of conditions. However,
240 between five and six or more chronic conditions, a steep increase in utilization of bed days
241 was observed. Among individuals with six or more chronic conditions, utilization was higher
242 than the mean number of bed days per condition multiplied by the number of conditions.

243

244 **Fig 1.**

245 **1A. Relationship between numbers of chronic conditions and hospitalizations.**

246 The black line indicates the number of hospitalizations by the number of chronic conditions. The
247 red line indicates the mean number of hospitalizations multiplied by the number of chronic
248 conditions.

249 **1B. Relationship between numbers of chronic conditions and bed days.**

250 The black line indicates the number of bed days by number of chronic conditions. The red line
251 represents the mean number of bed days multiplied by the numbers of chronic conditions.

252

253

254 Fig 2 and Fig 3 depict utilization of hospitalization and bed days stratified by
255 educational attainment. An educational gradient in hospitalization rates was observed across

256 one to six or more chronic conditions (Fig 2). Hospitalizations were more frequent in
257 individuals with shorter education, compared with those with longer education. For bed day
258 utilization (Fig 3), individuals with no education exhibited the highest estimated utilization
259 rates, regardless of the number of chronic conditions.

260

261 **Fig 2. Number of chronic conditions associated with the modeled rate of hospitalizations by**
262 **educational attainment levels**

263 Black line, no education; red line, short education; green line, medium education; blue line, long
264 education.

265

266 **Fig 3. Number of chronic conditions associated with the modeled rate of bed days by**
267 **educational attainment**

268 Black line, no education; red line, short education; green line, medium education; blue line, long
269 education.

270

271 **DISCUSSION**

272 This study is the first large-scale, register-based study investigating associations between
273 multimorbidity and utilization of healthcare services in the secondary and primary sectors in
274 Denmark. In this study we were able to obtain a medical diagnosis for all diseased adults in the
275 Capital Region aged 16 and above using algorithmic diagnoses for 16 conditions. This contrasts
276 with studies using register-based diagnoses that only included patients who had had a hospital
277 admission or were affiliated with an outpatient clinic. Although the 16 selected conditions do not
278 represent the full spectrum of chronic disease, they include highly prevalent chronic conditions. A

279 similar study from Scotland [33] included 40 conditions and revealed an age-stratified pattern of
280 prevalence of chronic conditions nearly identical to that of the data reported here [7, 33]. This
281 suggests that the 16 included diagnoses in this study encompass all conditions and combinations of
282 conditions that are predominant at the population level.

283 The prevalence of multimorbidity in our study was 22% [7]. Females had a 10%
284 overrepresentation among individuals with multimorbidity (Table 2). However, in this study the
285 overrepresentation of women among multimorbid individuals cannot be explained by the longevity
286 of women alone: The frequency of multimorbidity within each one-year age group was consistently
287 higher for women than men from 68 years to 100 years of age, the difference increasing with age.
288 This finding is consistent with previous results across healthcare systems and geography [34-36].
289 Eighty percent of the study population and 45% of individuals with multimorbidity were younger
290 than age 65 (Table 2). The study of multimorbidity is often confined to adults aged 65 and up [19,
291 37-39]. However, younger individuals with multimorbidity who survive will age into this group and
292 can be expected to have higher lifelong healthcare utilization. In fact, we observed that, compared
293 to age-similar individuals without chronic conditions, younger multimorbid individuals had a
294 relatively higher rate of bed day utilization than did older individuals with multimorbidity This
295 finding highlights the importance of understanding chronic illness and healthcare utilization of
296 younger multimorbid persons.

297 **Utilization vs. number of conditions**

298 The consistency of increases in healthcare utilization for individuals with multimorbidity,
299 compared to those without chronic conditions, is remarkable (Table 3). The use of all services was
300 higher to a statistically significant degree. Excluding hospitalizations and bed days, the increase in
301 utilization rates for individuals with multimorbidity ranged from 73% (emergency department
302 visits) to 324% (outpatient visits), except for yearly control visits in general practice, which were

303 867% higher. Disregarding the latter due to very low utilization rates, the average increase in
304 healthcare utilization was 180% for individuals with multimorbidity, compared to those with no
305 chronic conditions. The corresponding average increase in utilization rates for multimorbid
306 individuals, compared with those with one chronic disease, was 65%. Unadjusted ORs for
307 healthcare utilization for individuals with multimorbidity, compared with those with no chronic
308 conditions, were all statistically significant and ranged from 1.65 (95% confidence interval [CI],
309 1.63 – 1.66) for emergency department visits and 11.76 (95% CI, 11.58 – 11.96) for yearly control
310 visits. When adjusted for gender, age, and educational attainment, utilization differences were less
311 pronounced, ranging from 1.86 (95% CI, 1.83 – 1.88) for emergency department visits to 6.70 (95%
312 CI, 6.64 – 6.76) for GP visits. A similar but less pronounced pattern was seen when comparing
313 multimorbid individuals to those with one chronic disease (Table 3). These results demonstrate that
314 the impact of multimorbidity on healthcare utilization applies to a range of services and varies
315 relatively little. Healthcare utilization rates were 2-4 times higher than those for people without
316 chronic conditions. The direct relationship between the number of chronic conditions and healthcare
317 utilization is well-documented in the literature [14, 23, 24, 40, 41], but, to the best of our
318 knowledge, the impact of multimorbidity on a broad spectrum of healthcare utilization has not been
319 documented previously.

320 The approximately linear relationship between frequency of hospitalizations and the number
321 of chronic conditions depicted in Fig. 1A also applies to the relationship between bed days and the
322 number of chronic conditions in Fig. 1B for five or fewer conditions. When the number of
323 conditions increases to six or more, the utilization of bed days increases by a factor greater than the
324 impact of a single additional condition. The overall utilization pattern is that each condition
325 corresponds to 0.24 hospitalizations and 0.92 bed days, while the length of each hospitalization is
326 longer for individuals with six or more conditions. The slope of the curve for six or more conditions

327 increases twofold to 1.84 (Fig 1B). The fact that the regression coefficient no longer explains the
328 frequency of bed days per chronic condition leads us to define individuals with six or more
329 conditions as high utilizers; they make up 0.87% of the population but account for 7.29% of bed
330 days. An earlier Danish study found that 5% of the population with chronic conditions accounted
331 for 45% of healthcare expenses [42]. This finding is in line with a large US study that showed that
332 5% of high utilizers accounted for up to 47% of healthcare costs [43]. A recent German study
333 reported two subgroups of high utilizers: the oldest patients who suffered from severe
334 multimorbidity and younger elderly patients with psychiatric or psychosomatic conditions [40].
335 Future research is required to examine characteristics and utilization of the high utilizers identified
336 in this study.

337 Fig 1A shows a decline in utilization between nine and ten or more conditions. A possible
338 explanation is that individuals with a very high disease burden have higher mortality, while those
339 who survive have lower healthcare utilization than expected. Only 43 individuals had ten or more
340 diagnosed conditions, and small sample size effects may also contribute to this finding.

341 **Socioeconomic status**

342 We found that the prevalence of multimorbidity decreased with increasing educational
343 attainment, revealing a pronounced and statistically significant inverse socioeconomic gradient.
344 This is consistent with previous findings [7].

345 To study the impact of multimorbidity on healthcare costs, we adjusted data for proxy costs
346 for different educational attainment groups with varying profiles in terms of age, gender, other
347 healthcare utilization and level of multimorbidity. When adjusted for these effects, as described in
348 the methods statistical section, a clear inverse social gradient in hospitalization utilization appeared
349 (Fig. 2). Adjusted hospitalization utilization decreased as the level of educational attainment
350 increased, generally irrespective of the number of chronic conditions. However, adjusted bed-day

351 utilization revealed a slightly different pattern. An educational gradient no longer appeared; curves
352 for short, medium, and high educational attainment tended to overlap. However, the group with no
353 educational attainment stood out by virtue of higher healthcare utilization than the other. One
354 important feature is that the relative difference between utilization rates for individuals with no
355 education and those in other educational groups appeared close to constant across the number of
356 chronic conditions.

357 In general, the number of hospitalizations decreased with increasing level of educational
358 attainment. For multimorbid individuals, the length of each hospitalization was longer for
359 individuals without any education than for those with at least some education. The reason for this
360 finding is unknown. It may be the case that chronic disease tends to be more severe among
361 individuals without education and that longer hospitalizations are caused by non-chronic conditions
362 not included in our study. In addition, one could posit that different spectra of chronic conditions
363 occur for persons with and without education, but investigation of this supposition will require
364 further research. Other factors affecting the higher healthcare utilization rate observed in people
365 with lower education attainment include lower health literacy levels linked to lower education
366 attainment [44]. Disease burden has been shown to be associated with lower education levels in
367 type 2 diabetes, and this may apply to other chronic conditions [45]. Furthermore, people with none
368 or low educational attainment often has weak social networks and proper discharge to home might
369 demand coordinated preparation that rely, in part, on support from individual's own social support
370 structure [46]. However, we currently lack a well-founded explanation for differences in the two
371 adjusted proxies for general utilization of healthcare services.

372 **Strengths and limitations**

373 The major strength of our study is that it is a large-scale register-based study, including
374 comprehensive information about chronic conditions, healthcare utilization, and educational

375 attainment of the complete population of the Capital Region of Denmark aged 16 years and above.
376 Generally, data from the Danish national registers provide complete information about healthcare
377 system contacts, are of high quality and reliability, and are used extensively in research [25, 47]. As
378 a general population-based study, our findings reflect the actual situation in a real-world setting.
379 Based on register data, our study was free of recall bias and there was no loss of follow up.

380 Several limitations of our study deserve consideration. The necessary use of diagnostic
381 algorithms to identify patients with chronic conditions in the primary healthcare sector is an
382 approximation of actual diagnoses. Although the diagnostic algorithms have been shown to be
383 highly accurate [6], they are not clinically determined by physicians. The study was based on cross-
384 sectional data collected during a single year, and the number of patients with specific chronic
385 conditions may be underestimated [48, 49]. In addition, we were not able to include healthcare
386 services provided in the municipalities. Scarce register data exist for municipality services; existing
387 data are not well defined and thus not useful for research purposes. Inclusion of the data on
388 utilization of community healthcare services would likely have helped to generate a more complete
389 picture of healthcare utilization related to multimorbidity. Finally, 6% of our population did not
390 have information on educational attainment. This information appeared to be missing at random,
391 except for individuals aged 91 years and above; Danish administrative registers only contain
392 information on education for individuals born since 1921 [31]. However, this group contained few
393 individuals, and we estimated the effect of these missing data to be minimal and possible changes in
394 parameter estimates therefore very small.

395 Comparison to other studies on multimorbidity in populations should be performed with
396 care. Varying definitions of multimorbidity (i.e., two or more chronic conditions), included
397 conditions, and data collection methods render comparisons difficult. However, these challenges
398 may be overcome for large studies [33].

399

400 **Conclusion**

401 Multimorbidity is associated with a significant increase in utilization of all healthcare
402 services in Denmark. A socioeconomic gradient was observed in utilization of hospitalizations, and
403 socioeconomic effects in utilization of bed days. A steep increase in the utilization of bed days in
404 patients with six or more chronic conditions suggests a subpopulation of high utilizers that should
405 be explored in further studies.

406

407 **Acknowledgements**

408 We thank Jennifer Green for skillful editing.

409

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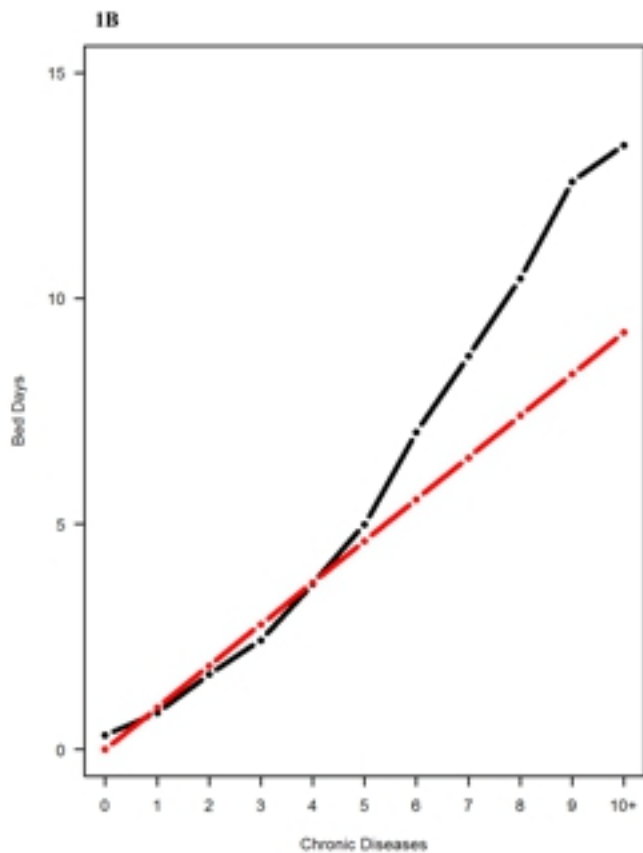
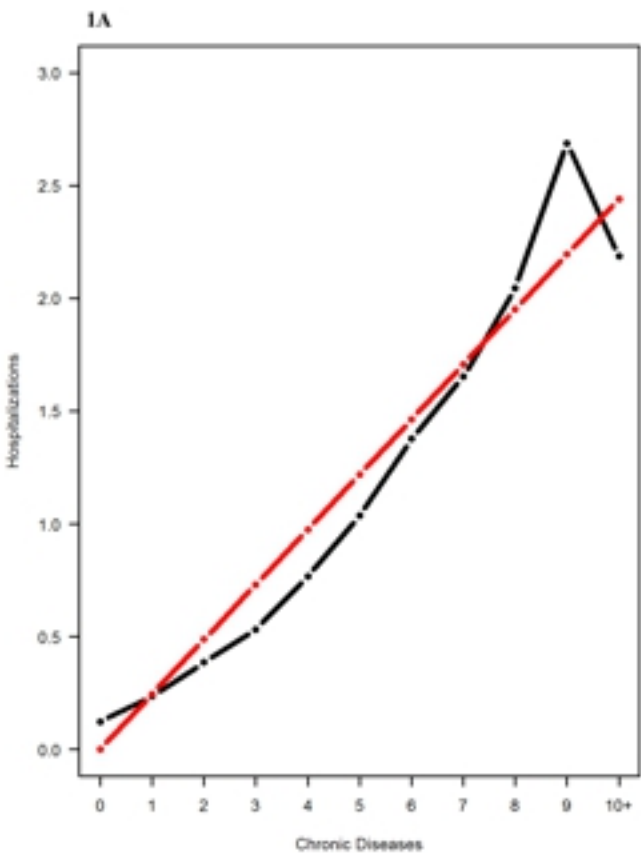


Fig1

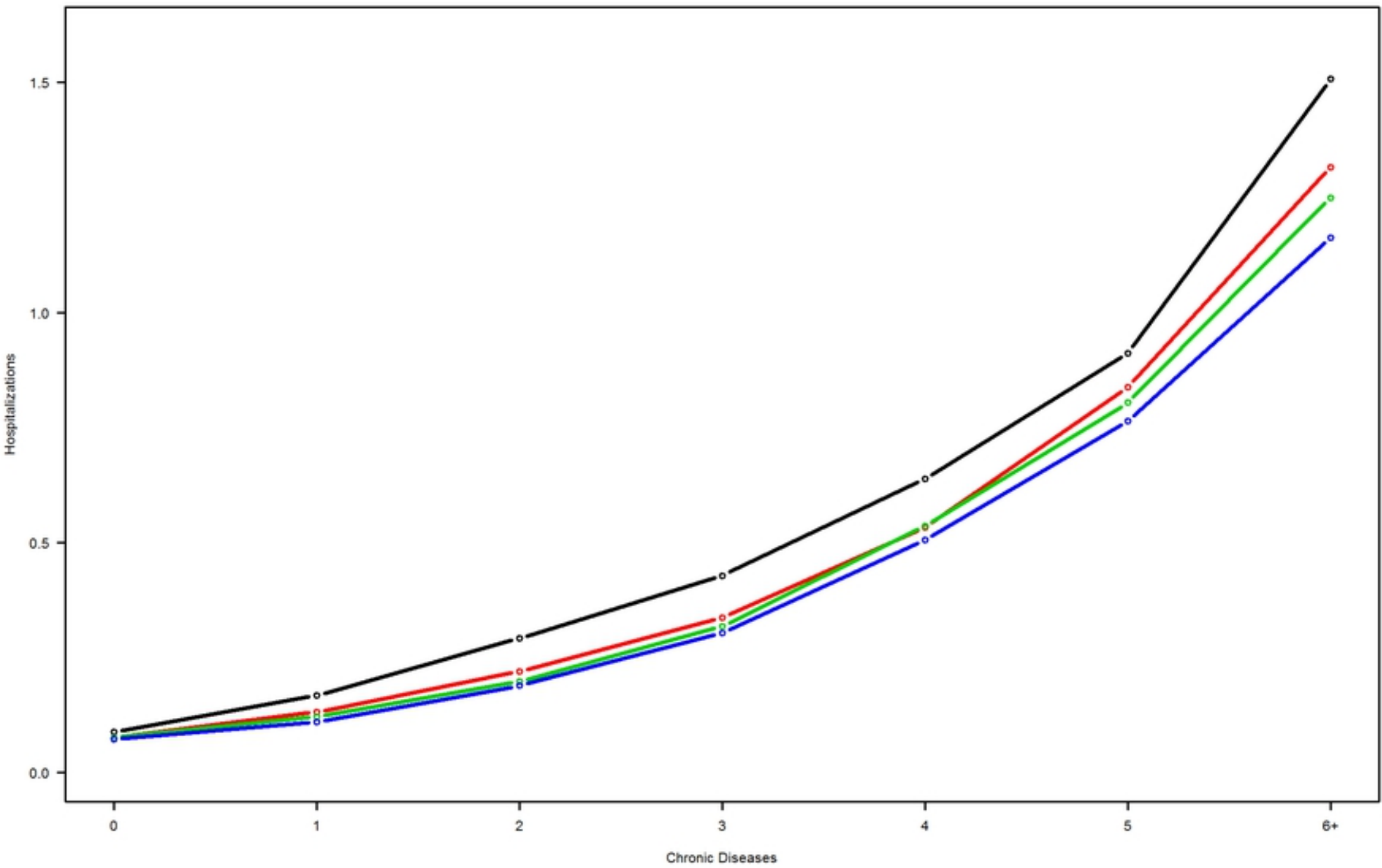


Fig2

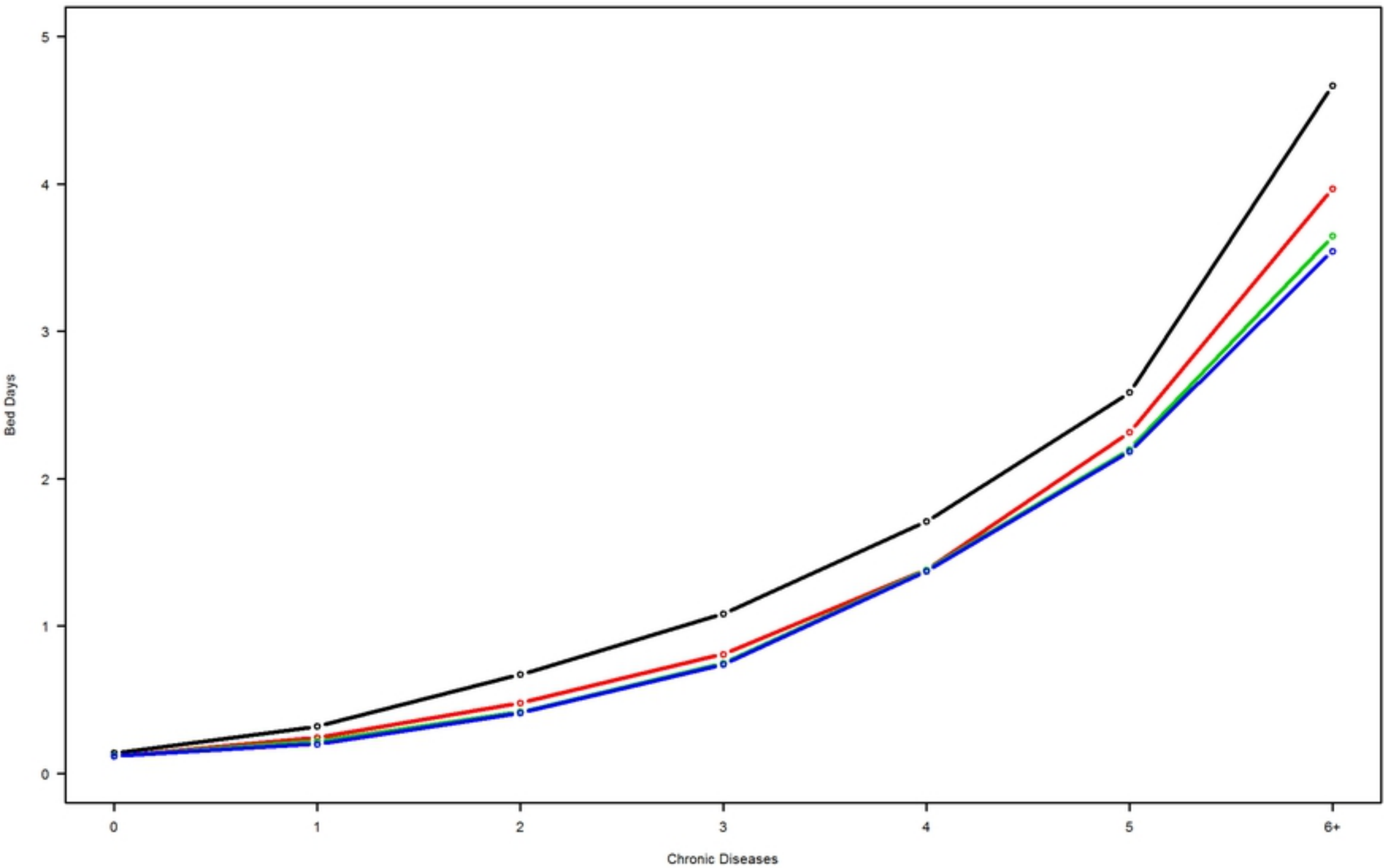


Fig3