Disability and cardiovascular disease among young adults

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Disability and cardiovascular disease among young adults

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ABSTRACT

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Background: Cardiovascular disease (CVD) exhibits concerning trends among young adults globally, with risk factors like physical inactivity and obesity on the rise. In addition, limited research has explored the relationship between disability and CVD in the young adult population. This study aims to investigate the association between disability and CVD risk in young adults in Korea.

Methods: From a nationwide health screening database, we obtained data on 120,287 individuals with disability from 7,711,487 eligible participants, aged between 20 and 39 years, who underwent health screening between 2009 and 2014. Disability was categorized into four types: external, internal, developmental, and mental disabilities. We performed 1:10 exact matching of the disability population with the general population based on age, sex, and index year without replacement for each type of disability. The total of four matched cohorts was 1,323,157. Stratified Cox proportional hazard regression was used to evaluate the overall and type-specific risk for premature CVD in comparison to the corresponding matched general population. Premature CVD includes myocardial infarction, stroke, heart failure, and cardiovascular death. The index date was defined as the earliest

examination date during the cohort enrollment period and followed-up until any CVD event, death, or the end of observation (December 31, 2020), whichever came first. In addition, sensitivity analyses were conducted as follows: (1) the analytic sample was expanded to the total eligible population (N=7,711,487); (2) disability and no disability groups were weighted using propensity score; (3) E-values were calculated and the robustness of our findings was assessed; and (4) the competing risk was treated with the sub-distribution hazard function. Moreover, the healthcare utilization and relative importance of risk factors were additively considered.

Results: As a result, individuals with disabilities showed a higher prevalence of lower socioeconomic status, higher comorbidities, poorer biometric measures, and physical inactivity. The prevalence of smoking and at-risk drinking was lower in the disability group when considering the higher proportion of the male sex and older age in this group. The fully adjusted hazard ratios (95% confidence interval) were 1.34 (1.25–1.44), 2.45 (1.81–3.31), 2.50 (2.12–2.96), and 1.58 (1.16–2.15) for external, internal, developmental, and mental disabilities, respectively. Additionally, the severity and duration of disability were gradually associated with the CVD risk across all types of disability. In end-specific sub-outcome analyses, some associations were not statistically significant possibly due to the fact that the small number of events and risks for stroke, heart failure, and cardiovascular deaths was higher in the disability group in comparison to the general population. We conducted various sensitivity analyses and reassured the consistent findings. Additive analyses using explained relative risk revealed an overall similarity in the association of well-known risk factors with CVD between the general population and individuals with disabilities. However, there were heterogeneous patterns within each disability type.

Conclusion: Disability was associated with a greater risk of CVD across all disability types. However, the strength of association and underlying risk factors should be understood based on disability types. In young adults with disabilities, both disability-related issues and the subsequent CVD risk should be addressed.

Key words : disability; cardiovascular diseases; young adult; modifiable factors

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I. INTRODUCTION

1. Cardiovascular disease among young adults

Despite extensive efforts, there has been a global stagnation or increase in the burden of cardiovascular disease (CVD) in recent years.[1,2] The higher prevalence of CVD with advancing age has prompted a specific emphasis on older populations as a target of relevant research and preventive measures.[3-5] Notably, the deterioration of cardiovascular-related risk factors, such as physical inactivity and obesity are significant among younger age groups.[6] Furthermore, predisposing conditions for CVD, such as hypertension, are also on the rise among the younger population.[6] In addition, the treatment and control rates for patients with hypertension are at their lowest in young adults aged 20–39 years compared to other age groups.[7] Young patients who do not adhere to antihypertensive drugs demonstrate a 1.6-fold higher risk of CVD development.[8] Consequently, on a global scale, CVD among young adults, including heart failure (HF), exhibits either a stalling or increasing trend.[9,10] To effectively address this trend, it is imperative to focus on CVD prevention among young adults and to identify vulnerable populations, including young adults with disabilities in particular.

2. Young adults with disabilities

Previous research demonstrated that life expectancy has increased globally, and there has been a concurrent rise in the number of years lived with disability before reaching older age.[11-13] According to the World Health Organization (WHO), over 1.3 billion individuals have significant disabilities, which account for 16% of the global population.[14] In Korea, 2.6 million individuals were officially registered as individuals with disability in 2022, which constitutes 5.2% of the Korean population.[15] Among them, approximately 300,000 were young adults with disabilities, aged between 20 and 39 years, representing 13% of the total population with disabilities.

Disability in the younger population should be understood differently from that of the older population. Although general health conditions may be better in younger individuals than their older counterparts, treatment adherence and lifestyle factors may show unfavorable patterns, including lower medication adherence and risks of smoking and drinking.[6,7,16] Moreover, the leading causes of years lived with disability vary with age. Notably, older adults with disabilities have more functioning limitations and comorbid conditions attributable to metabolic risks, which can be associated with the aging process to a certain extent.[14] In contrast, disability at a younger age is largely attributable to behavioral risks, including smoking, alcohol use, and dietary risks.[17]

Disabilities, although mostly prevalent in later stages of life, can manifest at any age. For younger individuals, it costs the prolonged years lived with a disability while increasing the economic burden and elevating additional risks for other diseases. The cost of early-

onset disability aggravates the lifetime economic burden in young individuals. For instance, the estimated annual financial burden from traumatic spinal cord injury at age 35 years amounts to $2.67 billion in Canada, comprising $1.57 billion in indirect costs and $1.10 billion in direct costs.[18] Moreover, individuals with disabilities show a higher prevalence of other diseases besides a causative disease or injury of disability.[19-22] From a broader perspective, this double burden potentially leads to increased healthcare demand in the future. Previous studies elucidate the profound impact of comorbidities or secondary conditions among people with disabilities on public health. In patients with disabilities, preventable hospitalization and mortality significantly increased as the number of comorbid chronic conditions increased.[23-25] Therefore, it is essential to assess the risk for secondary conditions and implement timely interventions among younger cohorts.

Despite its potential impact on public health, relevant research on long-term disabilities among young adults has often been overlooked by researchers and policymakers.[26,27] Moreover, collecting longitudinal data on younger cohorts can cause several hindrances for the following reasons: (1) the young adult age group is associated with many age-normative transitional events, such as going to college, joining the military, commencing work, or getting married, which can impede active study participation; (2) young individuals exhibit high mobility, changing their place of residence or occupation; and (3) monetary incentives may not be relatively compelling for those with considerable discretionary income.[26-28] Given the extended duration of disability and the corresponding rise in secondary risks, efforts should be made to address the underexplored domain of research on young individuals with disabilities.

3. Disability and cardiovascular health

The definition of disability has evolved to encompass not only individual health conditions but also cultural, environmental, and political elements.[29] The WHO has proposed a comprehensive model called the International Classification of Functioning Disability and Health.[29,30] Beyond the limitations of body functions and structures, the complex interplay between health conditions and contextual factors results in disability, which cannot be solely defined by the International Classification of Diseases (ICD).[30] However, the prevailing approach to disabilities and health has primarily emphasized medical aspects of a causative disease or injury, such as acute treatment or medical rehabilitation.[27] Consequently, individuals with disabilities, and chronic and stable dysfunction status, have not received adequate attention as active participants in health promotion and disease prevention efforts.[27,29] In addition, a considerable body of research on associations between CVD and disability has deemed disability as the adverse outcome of CVD.[31-34] Few studies on secondary conditions following disability have narrowly focused on specific dysfunctions resulting from particular diseases. A study reviewed the research on disability that investigated secondary conditions and was published between 1980 and 2017. Of the included 19 research papers, 10 were devoted to spinal cord injury.[19,35] Moreover, the higher prevalence of disability and CVD in older individuals has driven academic interest primarily toward the population aged 65 years and older, with some studies including the middle-aged population.[36-39]

Despite diverse research settings and definitions of disabilities, substantial evidence indicates a close association between disabilities and poorer health beyond the underlying conditions that caused the disability.[40] Some studies conducted in the United States have

demonstrated a higher prevalence of unfavorable health behaviors among individuals with disabilities, such as sedentary lifestyles, physical inactivity, and tobacco use.[41-43] Moreover, males with disabilities were more likely to be underweight in comparison to those without disabilities, while females with disabilities showed increased odds ratios of both being underweight and obese.[44]

A study conducted in Korea revealed that disability was associated with non-communicable diseases, such as hypertension and diabetes, with odds ratios of 1.34 (95% confidence interval (CI), 1.15–1.56) and 1.51 (1.28–1.79), respectively.[45] Moreover, individuals with disabilities were more likely to be in suboptimal health conditions than those without disabilities. For instance, chronic pain, lower bone mineral density, and depressive symptoms were more prevalent in those with disabilities and associated with cardiovascular risk,.[46-50] A large body of literature has shown strong associations between disability and all-cause mortality; individuals having disabilities in hearing, vision, motor function, and mental health were at an elevated risk of mortality among the middle-aged and older populations.[51-55] Recently, the mortality risk in younger individuals was elucidated in a study with participants aged between 25 and 44 years.[56]

In the context of CVD, disability was associated with cardiac and cerebrovascular diseases, with odds ratios of 1.49 (1.18–1.87) and 4.00 (3.22–4.96), respectively.[45] A longitudinal study conducted in Korea that followed-up participants for 10 years confirmed the risk of CVD incidence; a fully adjusted hazard ratio was 2.89 (2.41–3.46) for cardiovascular events and 2.03 (1.78–2.31) for cardiovascular death.[57] However, it only includes middle-aged and older adults over 40 years, and the risk in the younger age group remains unclear.

4. Objective of the study

We considered disability in individuals not only as an adverse consequence of a specific disease or injury to treat but also as a subpopulation that particularly requires tailored clinical guidance and public health intervention. We hypothesized that young adults aged between 20 and 39 years with disabilities would exhibit a higher incidence of CVD than their counterparts without disabilities, and the risks would vary according to the disability type. Hence, the primary objective of this study is to investigate the hypothesis and identify the possible associations between disability and CVD in the young population of Korea, after accounting for well-known risk factors. The analyses included an assessment of overall and type-specific CVD risks according to disability attributes, such as severity, duration, and subtypes of disability.

II. MATERIALS AND METHODS

1. Data source

The National Health Insurance Service (NHIS) is the single provider of public health insurance in Korea that provides universal health coverage to the entire Korean population.[58] It established the National Health Information Database (NHID) by archiving the users' sociodemographic details, claim data for medical service use with information on diagnosis using the International Classification of Diseases, 10th Revision (ICD-10), and results from national health screening programs.[59,60] With ethics approval from the researchers' institutional review board and a review by the NHIS committee, de-identified data was provided to researchers (NHIS-2023-1-317). The details for the NHID are described elsewhere.[8,58,61] Using the unique identification number system, the NHID was linked with the information on disability of the Korean National Disability Registration System (KNDRS), an official disability registration system.

2. Study population

We identified all young adults aged between 20 and 39 years who received health examinations during the cohort enrollment period between January 1, 2009, and December 31, 2014 (N= 8,370,832). Based on predetermined criteria, we excluded 78,954 participants with a history of myocardial infarction (MI), stroke, or HF using outpatient and inpatient records. We excluded those with incomplete information on disability, including type, severity, and registration date (N= 1,656); and other covariates, such as age, sex, income, residence area, body mass index (BMI), blood pressure, fasting glucose, total cholesterol, smoking, drinking, and physical activity (N= 578,561). A total of 174 individuals registered

with a disability due to heart disease were also excluded since preexisting cardiac dysfunction may hinder evaluating the association between disability and CVD.

Among the eligible 7,711,487 individuals, we identified 120,287 with a disability and 7,591,200 individuals of the general population without any disability. We created a matched general cohort by conducting the exact matching of 10 individuals from the general population, considering age, sex, and the index year, to each individual with a disability using sampling without replacement.[62] As a result, 1,323,157 participants with (N= 120,287) and without disability (N= 1,202,870) were included in the primary analyses (Figure 1). The total eligible population of 7,711,487 individuals was also used for the sensitivity analyses.

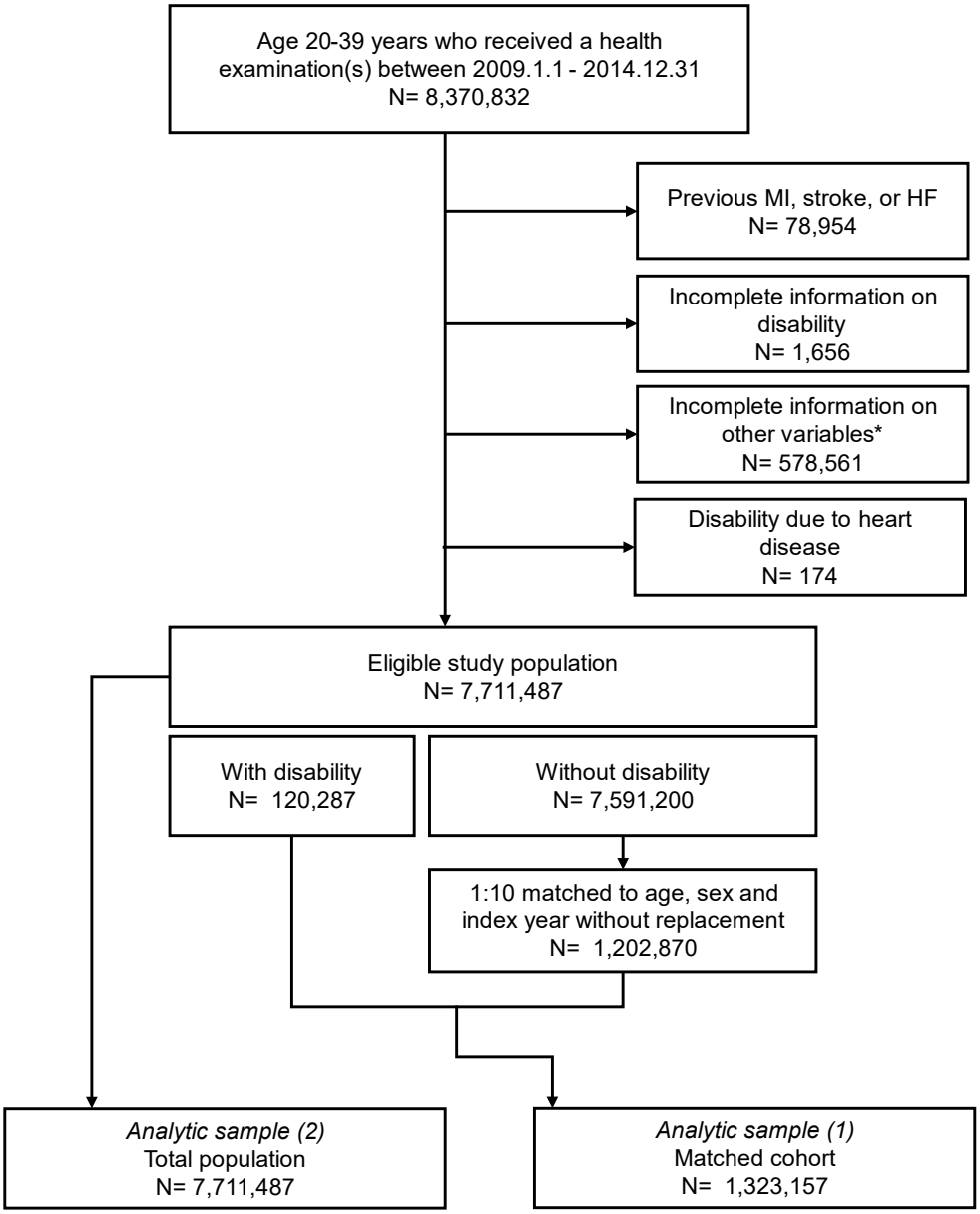

Figure 1. Flowchart of the inclusion and exclusion criteria
* Other variables included age, sex, income, residence area, body mass index, blood pressure, fasting glucose, total cholesterol, smoking, drinking, and physical activity. HF, heart failure; MI, myocardial infarction.

3. Measurement and key variables

A. Disability

Disability was defined as an individual officially registered as having a disability in the KNDRS based on the index date. The index date was determined as the date of the first health examination during the cohort enrollment period from January 1, 2009, to December 31, 2014. Disability encompasses four types of dysfunctions: external physical, internal physical, developmental, and mental disabilities.[63] This classification was medically based and legally specified in the Act on Welfare of Persons with Disabilities.[64] As each type of disability may have distinct characteristics, we divided disability into four groups according to the type and analyzed them.

We examined the overall risk of disabilities in CVD development and the type-specific risk according to severity, duration, and subtype of disability within each group. First, the severity of disability was determined by the KNDRS committee, which comprised medical specialists, using the type-specific criteria. It comprises six grades, from Grade 1 (most severe) to Grade 6 (least severe). Developmental and mental disabilities can only be registered for Grades 1 to 3. It is noted that the existing grading system has been reorganized and divided into two grades since 2019: mild (Grades 4, 5, and 6) and severe (Grades 1, 2, and 3). Since this study identified disability before 2014, the analyses utilized both grading systems. Second, the disability duration was calculated as the period between the disability registration and index dates. Last, the four groups encompass 15 subtypes (Table 1). External disability comprises six subtypes of impairment involving extremities, vision, hearing, and the like. Internal disability includes six subtypes resulting from dysfunctions of internal organs such as renal, cardiac, hepatic, and respiratory diseases.

Developmental disability has two subtypes: intellectual impairment and autism. Mental disability refers to one subtype characterized by severe psychiatric disorders such as schizophrenia, schizoaffective disorder, bipolar disorder, and recurrent depressive disorder.

Table 1. The 4 types and 15 subtypes of disabilities

Type	Subtype	Description
External	Physical	Impairments such as amputation disorders, joint disorders, impaired motor function, and deformities
	Brain	Complex impairments resulting from brain injury
	Visual	Visual impairments, visual field deficits
	Hearing	Hearing impairments, balance function disorders
	Language	Language, speech, and communication disorders
	Facial	Facial abnormalities, atrophy, hypertrophy, and other deformities
Internal	Renal disease	Undergoing dialysis treatment or having received a kidney transplant
	Heart disease	Significant limitations in daily life due to severe cardiac dysfunction
	Liver disease	Significant limitations in daily life due to chronic and severe liver dysfunction
	Respiratory disease	Significant limitations in daily life due to chronic and severe respiratory dysfunction
	Ostomy	Significant limitations in daily life due to enterostomy and urostomy
	Epilepsy	Significant limitations in daily life due to chronic and severe epilepsy
Developmental	Intellectual	An intelligence quotient (IQ) of 70 or below
	Autism	Autism spectrum disorders
Mental	Mental	Schizophrenia, schizoaffective, bipolar, and recurrent depressive disorder

B. Other variables

Covariates were selected a priori, based on previous literature indicating their correlations with CVD in general populations.[65,66] Age was determined by calculating the difference between the birth and index dates. The insurance premiums were divided into quartiles and used as a proxy for household income. Urbanicity of residential areas was categorized into metropolitan, urban, and rural areas. Data on BMI, blood pressure, fasting glucose, total cholesterol, and lifestyle factors, including smoking, alcohol consumption, and physical activity, were obtained from the results of the national health examination on the index date. Details of variables from the national health examination are available elsewhere.[58] BMI, systolic blood pressure, and total cholesterol were used as continuous variables while fasting glucose was depicted as a categorical variable; less than 100 mg/dL, between 100 and 125 mg/dL, and higher than 126 mg/dL. Smoking (never, past, or current), alcohol consumption (none, 1–2 times/week, or ≥3 times/week), and physical activity (none, 1–2 days/week, or ≥3 days/week) were self-reported. Charlson comorbidity index (CCI) was determined using outpatient and inpatient claims data within 3 years before the index date.[67]

C. Cardiovascular outcomes and follow-up periods

The primary outcome was a composite CVD event, which was defined as the earliest hospitalization due to MI (ICD-10: I21–I23), stroke (I60–I64), HF (I50), or death from cardiovascular causes (I00–I99) on or before December 31, 2021 (Table 2). The index date was regarded as the date when each participant took the first health examination during the cohort enrollment period, from January 1, 2009, to December 31, 2014 (Figure 2). The follow-up period was individually calculated as the duration between the index date and

the last day of observation. The last day of observation was determined by the earliest of the following: the occurrence of any CVD event, death from other causes, or the conclusion of the observation period (December 31, 2021), whichever event happened first. In cases where a participant experienced multiple events during the follow-up period, only the first event was considered the primary outcome in the main analysis. These events were assessed individually for sub-outcome analyses specific to each endpoint (MI, stroke, HF, and cardiovascular death). All the observed CVD events occurred before the age of 55 and were defined as premature CVD.

Table 2. Definitions of cardiovascular outcomes

Outcome	Definition	ICD-10
Primary outcome		
Cardiovascular event	Any occurrence of myocardial infarction, stroke, heart failure, or cardiovascular death	-
Sub-outcome		
Myocardial infarction	Earliest admission from myocardial infarction as the primary diagnosis after the index date	I21-I23
Stroke	Earliest admission from stroke as the primary diagnosis after the index date	I60-I64
Heart failure	Earliest admission from heart failure as the primary diagnosis after the index date	I50
Cardiovascular death	Death recorded as cardiovascular death based on the underlying cause of death certificate	I00-I99

ICD-10, International Classification of Diseases, 10th revision

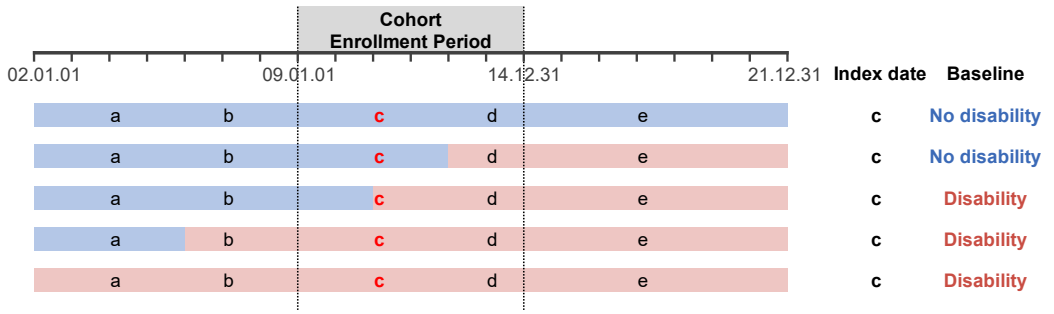

Figure 2. Examples of determination of index date and disability status
The date of the first health examination during the enrollment period was individually defined as the index date, and the disability status was determined on the index date.

4. Statistical analyses

A. Descriptive analyses

We conducted a comparison of sociodemographic, lifestyle-related, and biomedical factors between two groups: individuals with disabilities and those without disabilities. Furthermore, we compared the four groups categorized by disability type with the general population without a disability in two ways: first, comparing with the entire general population, and second, comparing with each matched general cohort respective to each type of disability. Statistical tests were employed to conduct these comparisons: t-tests, analysis of variance (ANOVA), and chi-square tests as appropriate.

B. The risk for cardiovascular disease in disability

The Kaplan-Meier method was employed to estimate the cumulative incidence of cardiovascular events based on the presence, duration, and type of disability. While

external and internal disabilities ranged from grade 1 to 6, developmental and mental disabilities are categorized as severe (Grades 1, 2, 3); therefore, the estimation by severity was made within each disability type. The log-rank test assessed the statistical significance of differences in survival curves between each disability (no disability) and reference groups. In addition, we performed the zero proportional hazards (ZPH) test to evaluate the violation of the proportional hazard assumption, along with graphical inspections.

Using the extended Cox proportional hazards models, the overall and type-specific risks for CVD were obtained. The overall risk of disability was estimated using the total of the matched general cohorts without disabilities as the reference. Meanwhile, given the distinct types of disability, we separately analyzed the association between disability attributes and CVD within each type– external, internal, developmental, and mental disabilities. The reference group was the respective matched general cohort to each disability type. The hazard ratios (HRs) and 95% CIs for CVD events associated with disability attributes (severity, duration, and subtype of disability) were calculated using stratified Cox proportional hazards models, in which the 1:10 matched pairs were considered as the same strata.[68] The primary analyses employed cause-specific hazard function, and competing events (non-cardiovascular deaths) were treated as censored observations.

In addition to the unadjusted model (matched on age, sex, and index year), multiple adjusted models were made. Model 1 was adjusted for income and urbanicity; Model 2 was an extended version of Model 1 with further adjustments for BMI, systolic blood pressure, fasting glucose, total cholesterol, and CCI; Model 3 was further adjusted for lifestyle-related factors such as smoking, drinking, and physical activity.

In the endpoint-specific analyses, sub-outcomes, such as MI, stroke, HF, and cardiovascular death were evaluated as separate outcomes. If a participant experienced multiple CVD events, the first event was counted as the outcome in the primary analyses, while all events were treated as distinct outcomes in the endpoint-specific sub-outcome analyses.

C. Sensitivity analyses

Sensitivity analyses were conducted to confirm the consistency and robustness of findings from the main analyses. First, the identical analyses were repeated for the total eligible population (N= 7,711,487). While the primary analyses assessed the association of disability with CVD using the respective matched general cohort as the reference group, sensitivity analyses used all eligible individuals without disabilities.

Second, we applied overlap weighting using propensity score (PS) to balance the participant characteristics in the disability and no disability groups, thereby adjusting for measured confounding factors.[69] The PS for having disabilities was computed through logistic regressions, given the individual's characteristics (age, sex, income, urbanicity, BMI, systolic blood pressure, fasting glucose, total cholesterol, CCI, smoking, drinking, and physical activity). Subsequently, weights were determined using overlap weighting, particularly advantageous in the presence of extreme tails by emphasizing participants with the most overlap.[70] We assigned weights to each individual as 1–PS in the disability group and as PS in the no-disability group.[70] Thereafter, the balance of covariates was diagnosed by comparing standardized differences before and after the weighting process.[71] The

stratified Cox regression analyses in the primary analyses were repeated using these weights.

Third, we assessed the robustness of the observed associations in the primary analyses using the concept of E-value. We quantified the minimum strength of association that unmeasured confounders would need to have with both disability (exposure) and CVD (outcome) to nullify the observed associations in the fully adjusted model (Model 3) from the primary analyses.[72] The E-value formula in this study was $HR + sqrt[HR \times (HR - 1)]$ for point estimates and $LL + sqrt[LL \times (LL - 1)]$ for the limit of the CIs closest to null.[72,73]

Last, the Fine-Gray sub-distribution hazard model, another method to treat the competing risk, was additionally used. While the cause-specific function employed in the primary analyses was defined as the instantaneous rate of occurrence of CVD events in participants without prior-events, the sub-distribution hazard function in sensitivity analyses represented estimates in participants who were either currently event-free or had previously experienced a competing event.[74,75]

All analyses used SAS version 9.4 (SAS Institute Inc, Cary, NC) and R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) software.

D. Additive considerations

(A) The consideration of healthcare utilization

Furthermore, we took into consideration the aspect of healthcare utilization as it was expected to differ between the population with disability and the general population,

potentially affecting our research findings. However, previous studies highlighted that in research using electronic health record (EHR) data, healthcare utilization is often influenced by both exposure and outcome, acting as a collider.[76] Therefore, we did not include adjustments for healthcare utilization in the main analyses but incorporated them into additional analyses. The number of outpatient visits and hospitalization days were separately tallied for participants within 1 year from the index date.

(B) Risk factors in each type of disability

Variables in adjusted models were selected based on previously described CVD risk determinants in general populations. However, considering less evidence in the disability population, risk factors were assessed within each type of disability in two manners.

The estimated explained relative risk (ERR), denoted as R^2, quantified the contribution of a subset of covariates to the explained risk estimate of the full model.[77] It was derived based on entropy loss functions using full, null, and degenerative models.[77] The detailed statistical methodologies are provided elsewhere.[77-79] In this study, the explained relative risks reflected the strength of association of each covariate with CVD within five distinct groups, namely matched general cohort and external, internal, developmental, and mental disability groups. Thereby, the relative importance of covariates can be evaluated in each type of disability. We established the full multivariate Cox proportional hazards model (Model 3: matched on age, sex, and index year and adjusted for income, urbanicity, BMI, systolic blood pressure, fasting glucose, total cholesterol, CCI, smoking, drinking, and physical activity). In addition, separate null density models excluding each variable from the full model were made. The explained relative risk for each covariate was derived from the logarithmic mean of the full minus null model, ranging from 0 to 1. The higher value

indicates the greater effect of a variable on the estimate in the full model.[77] For the estimation of the ERR, covariates were used as continuous or binary categorical variables. Age, systolic blood pressure, BMI, total cholesterol, CCI, and fasting glucose were continuous variables as analyzed in this study. On the other hand, categorical variables were re-classified as binary categorical variables: current smoking, the lowest income brackets (Q1), female sex, physical inactivity (none), rural residence, and at-risk drinking (≥3 days/week).

5. Ethics statement

The study protocol was approved by the Institutional Review Board of Severance Hospital at Yonsei University College of Medicine, Seoul, Korea (IRB no. 4-2022-1143). Informed consent was waived, as this retrospective study used deidentified data managed by the NHIS (NHIS-2023-1-317).

III. RESULTS

1. Description of the study population

In the total eligible population before matching, significant differences in baseline characteristics were observed between those with and without disability (Appendix 1). The disability population had a higher proportion of males (78.0%) and a higher prevalence of individuals in the lowest income brackets (40.4%) compared to the general population (male 57.9%; the lowest income 22.6%). Individuals with disabilities were likely to reside in urban or rural areas rather than metropolitan areas, and they also exhibited a higher comorbidity level as measured by the CCI. Systolic and diastolic blood pressure, as well as BMI, fasting glucose levels, and total cholesterol levels, were also observed to be significantly higher in the disability group. Among lifestyle factors, the disability group appeared to have a higher prevalence of current smoking, at-risk drinking, and physical inactivity.

However, when conducting exact matching on age, sex, and index year, the unhealthier behaviors in the disability group reversed, implying that the higher proportion of males drove the higher prevalence of current smoking and at-risk drinking. Individuals with disabilities were less likely to smoke or drink frequently (Table 3).

Table 3. Baseline characteristics of the matched cohort sample by disability (N =1,323,157)

Variables	No Disability (N = 1,202,870)	Disability (N = 120,287)	p-value
Age, y	33 [28-36]	33 [28-36]	1.000
Sex			1.000
Female	264,390 (22.0)	26,439 (22.0)	
Male	938,480 (78.0)	93,848 (78.0)	
Household income quartile			< 0.001
Q4, highest	206,190 (17.1)	11,806 (9.8)	
Q3	373,905 (31.1)	27,811 (23.1)	
Q2	376,354 (31.3)	32,123 (26.7)	
Q1, lowest	246,421 (20.5)	48,547 (40.4)	
Residential area			< 0.001
Metropolitan	559,379 (46.5)	48,817 (40.6)	
Urban	563,839 (46.9)	59,610 (49.6)	
Rural	79,652 (6.6)	11,860 (9.9)	
Charlson comorbidity index			< 0.001
0	792,416 (65.9)	69,790 (58.0)	
1	233,421 (19.4)	25,131 (20.9)	
2	105,533 (8.8)	13,864 (11.5)	
≥3	71,500 (5.9)	11,502 (9.6)	
Systolic blood pressure, mmHg	119.9 ± 13.2	120.2 ± 13.8	< 0.001
Diastolic blood pressure, mmHg	75.1 ± 9.5	75.5 ± 9.8	< 0.001
Body mass index, kg/m^2	23.7 ± 3.6	23.9 ± 4.1	< 0.001
Fasting glucose, mg/dL	92.6 ± 18.9	93.5 ± 22.2	< 0.001
Total cholesterol, mg/dL	187.8 ± 35.2	185.5 ± 36.5	< 0.001
Tobacco smoking			< 0.001
Never	516,549 (42.9)	61,396 (51.0)	
Past	153,200 (12.7)	13,109 (10.9)	
Current	533,121 (44.3)	45,782 (38.1)	
Alcohol consumption			< 0.001
None	390,614 (32.5)	56,770 (47.2)	
1-2 times/week	636,892 (53.0)	47,588 (39.6)	
≥3 times/week	175,364 (14.6)	15,929 (13.2)	
Physical exercise			< 0.001
None	547,931 (45.6)	59,187 (49.2)	
1-2 times/week	427,003 (35.5)	36,946 (30.7)	
≥3 times/week	227,936 (19.0)	24,154 (20.1)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

When the types of disability were categorized, sociodemographic, biomedical, and lifestyle factors varied across the four groups (Table 4). The group with external disability had a higher proportion of males (81.4%), and a relatively lower number of comorbidities. This group also exhibited a higher prevalence of current smoking and frequent drinking compared to other groups. The group with internal disability had more comorbidities and higher blood pressure compared to other groups. The group with developmental disability consisted of younger participants even in young adults aged between 20 and 39. Moreover, in both developmental and mental disabilities, the proportion of individuals from lower income brackets was notably high, exceeding 80%, with a higher percentage residing in rural areas. While the prevalence of current smoking and at-risk drinking was relatively low in these groups, there was a higher proportion of individuals displaying physical inactivity. In particular, the group with a mental disability had a higher BMI. The comparisons between each disability type and the respective matched cohort are shown in Appendix 2.

Table 5 represents the disability-related attributes of 120,287 individuals with disabilities. External disability was the most common type of disability, accounting for 76.1%, with physical impairments being the predominant subtype within this category. Internal disability was associated with a shorter duration of disability, while renal impairments included persons receiving kidney transplants or hemo- or peritoneal dialysis for more than 3 months, which constituted the majority within this group. Developmental disability accounted for 18.4% of disability and showed the longest duration of disability.

Table 4. Baseline characteristics of the matched cohort sample by the type of disability

Variables	Type of disability								p-value
	External (N = 91,500)		Internal (N = 2,733)		Developmental (N = 22,084)		Mental (N = 3,970)		
Age, y	34 [29-37]		34 [30-37]		28 [23-34]		35 [32-38]		< 0.001
Sex									< 0.001
Female	17,027	(18.6)	805	(29.5)	7,060	(32.0)	1,547	(39.0)	
Male	74,473	(81.4)	1,928	(70.6)	15,024	(68.0)	2,423	(61.0)	
Household income quartile									< 0.001
Q4, highest	10,690	(11.7)	314	(11.5)	665	(3.0)	137	(3.5)	
Q3	26,016	(28.4)	681	(24.9)	891	(4.0)	223	(5.6)	
Q2	29,141	(31.9)	719	(26.3)	1,874	(8.5)	389	(9.8)	
Q1, lowest	25,653	(28.0)	1,019	(37.3)	18,654	(84.5)	3,221	(81.1)	
Residential area									< 0.001
Metropolitan	38,143	(41.7)	1,191	(43.6)	7,947	(36.0)	1,536	(38.7)	
Urban	45,570	(49.8)	1,331	(48.7)	10,896	(49.3)	1,813	(45.7)	
Rural	7,787	(8.5)	211	(7.7)	3,241	(14.7)	621	(15.6)	
Charlson comorbidity index									< 0.001
0	52,650	(57.5)	628	(23.0)	14,207	(64.3)	2,305	(58.1)	
1	19,546	(21.4)	913	(33.4)	4,039	(18.3)	633	(15.9)	
2	10,530	(11.5)	538	(19.7)	2,212	(10.0)	584	(14.7)	
≥3	8,774	(9.6)	654	(23.9)	1,626	(7.4)	448	(11.3)	
Systolic blood pressure, mmHg	121.0	±13.6	123.0	±15.9	116.9	±13.8	117.4	±13.5	< 0.001
Diastolic blood pressure, mmHg	76.0	± 9.8	77.4	±11.0	73.5	± 9.7	74.0	± 9.6	< 0.001
Body mass index, kg/m^2	24.0	± 3.9	23.1	± 4.0	23.2	± 4.6	25.3	± 4.6	< 0.001
Fasting glucose, mg/dL	93.9	±22.0	95.0	±26.4	91.1	±21.6	96.9	±25.0	< 0.001
Total cholesterol, mg/dL	188.8	±36.1	181.3	±37.2	172.5	±35.0	184.9	±38.5	< 0.001
Tobacco smoking									< 0.001
Never	37,791	(41.3)	1,561	(57.1)	19,585	(88.7)	2,459	(61.9)	
Past	11,795	(12.9)	565	(20.7)	499	(2.3)	250	(6.3)	
Current	41,914	(45.8)	607	(22.2)	2,000	(9.1)	1,261	(31.8)	
Alcohol consumption									< 0.001
None	32,722	(35.8)	1,873	(68.5)	18,922	(85.7)	3,253	(81.9)	
1-2 times/week	43,735	(47.8)	722	(26.4)	2,555	(11.6)	576	(14.5)	
≥3 times/week	15,043	(16.4)	138	(5.1)	607	(2.8)	141	(3.6)	
Physical exercise									< 0.001
None	42,153	(46.1)	1,281	(46.9)	13,429	(60.8)	2,324	(58.5)	
1-2 times/week	30,475	(33.3)	870	(31.8)	4,685	(21.2)	916	(23.1)	
≥3 times/week	18,872	(20.6)	582	(21.3)	3,970	(18.0)	730	(18.4)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

Table 5. Disability attributes among participants with a disability

Type of disability	Total, N (%)	Severity		Duration, median year [interquartile range]
		Mild, N (%)	Severe, N (%)	
External disability	91,500 (76.1)	70,535 (58.6)	20,965 (17.4)	7 [4-10]
Physical	63,583 (52.9)	52,240 (43.4)	11,343 (9.4)	6 [3-9]
Brain injury	3,486 (2.9)	1,338 (1.1)	2,148 (1.8)	7 [5-9]
Visual	14,421 (12.0)	12,800 (10.6)	1,621 (1.4)	7 [4-9]
Hearing	8,378 (7.0)	3,125 (2.6)	5,253 (4.4)	9 [6-12]
Language	1,207 (1.0)	785 (0.7)	422 (0.4)	8 [4-10]
Facial	425 (0.4)	247 (0.2)	178 (0.2)	5 [3-6]
Internal disability	2,733 (2.3)	1,671 (1.4)	1,062 (0.9)	4 [2-7]
Renal disease	1,462 (1.2)	788 (0.7)	674 (0.6)	5 [2-8]
Respiratory disease	96 (0.1)	10 (-)	86 (0.1)	4 [2-6]
Liver disease	137 (0.1)	120 (0.1)	17 (-)	4 [2-6]
Ostomy	373 (0.3)	352 (0.3)	21 (-)	2 [1-3]
Epilepsy	665 (0.6)	401 (0.3)	264 (0.2)	5 [3-7]
Developmental disability	22,084 (18.4)	-	22,084 (18.4)	9 [6-12]
Intellectual	21,130 (17.6)	-	21,130 (17.6)	9 [6-12]
Autism	954 (0.8)	-	954 (0.8)	7 [5-10]
Mental disability	3,970 (3.3)	-	3,970 (3.3)	5 [3-8]
Total	120,287 (100.0)	72,206 (60.0)	48,081 (40.0)	7 [4-10]

2. Kaplan-Meier survival curves

Using the Kaplan-Meier method, the overall cumulative incidence of CVD events was plotted by the presence, duration, and type of disability (Figure 3). Overall, the cumulative incidence of CVD was greater in the disability group than in the no-disability group. Although the 95% CIs were partly overlapped, the Kaplan-Meier survival curves showed a higher cumulative incidence in the following order: internal, mental, external, and developmental disabilities, and the general population. The longer-lasting disability exhibited a higher estimate than its counterparts.

The type-specific estimates were plotted by presence, severity, and duration of disability within each disability type (Figure 4, Figure 5, Figure 6, Figure 7). As developmental and mental disabilities were associated exclusively with ‘severe’ grades, the estimates were plotted based on another grading system (Grades 1, 2, and 3). Cumulative incidence was higher in the disability group than in the no-disability group across all disability types and increased by severity in a dose-response manner.

In sub-outcome analyses, consistent findings were observed in terms of stroke, HF, and cardiovascular death, except for MI (Appendix 3).

We confirmed that the proportional hazard assumption was not violated by graphical inspections and the additional ZPH test. The log-rank test showed the statistical significance of differences in survival curves between groups across all disability attributes.

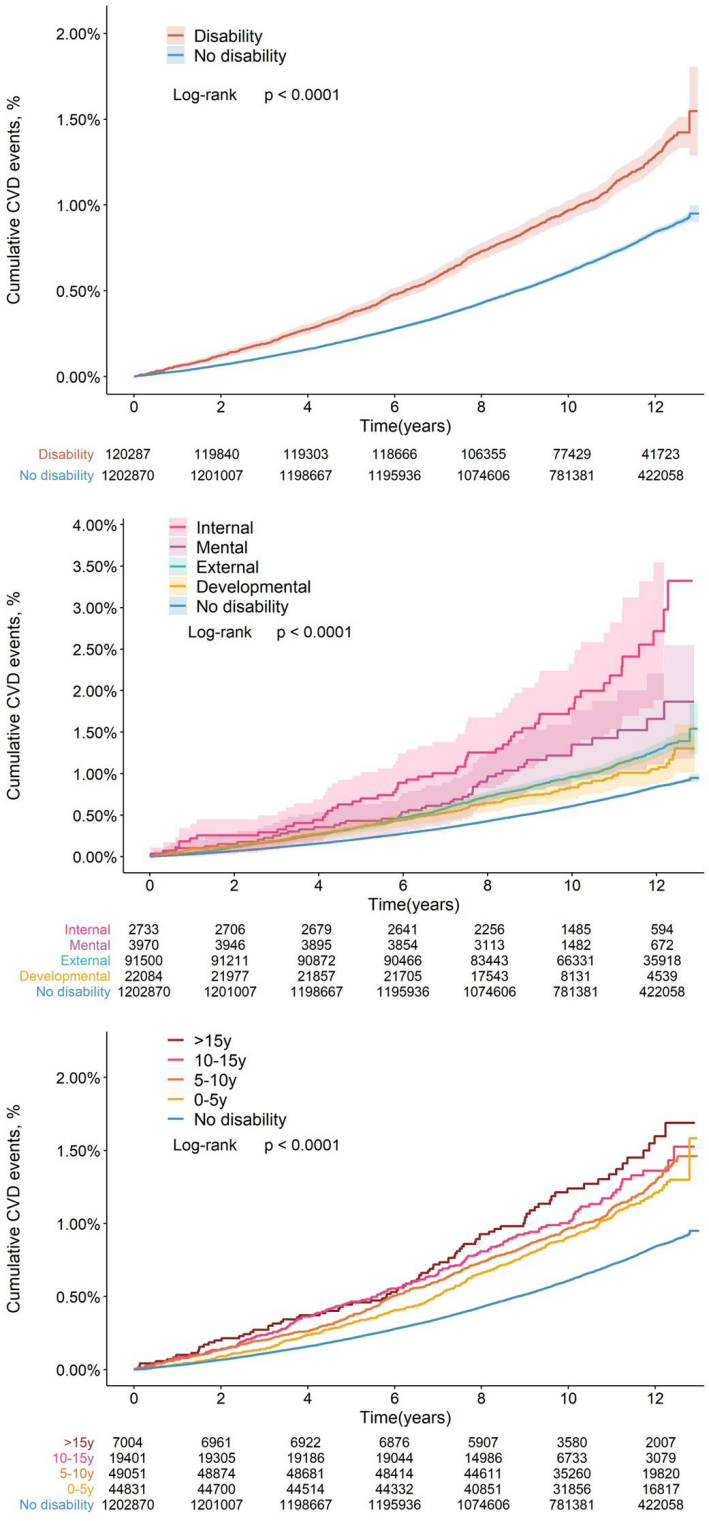

Figure 3. Overall cumulative incidence of cardiovascular event according to the presence, type, and duration of disability

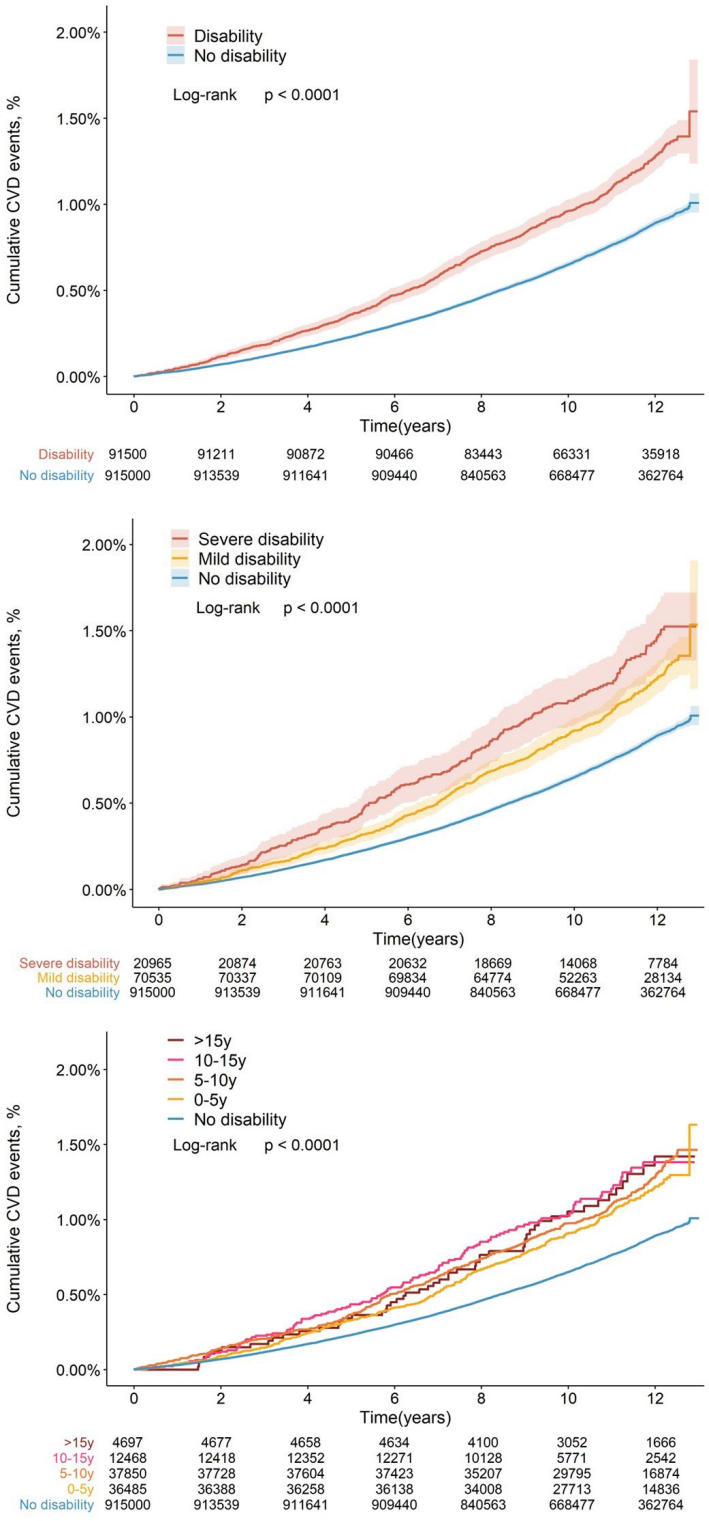

Figure 4. Cumulative incidence of cardiovascular event in external disability according to the presence, severity, and duration of disability

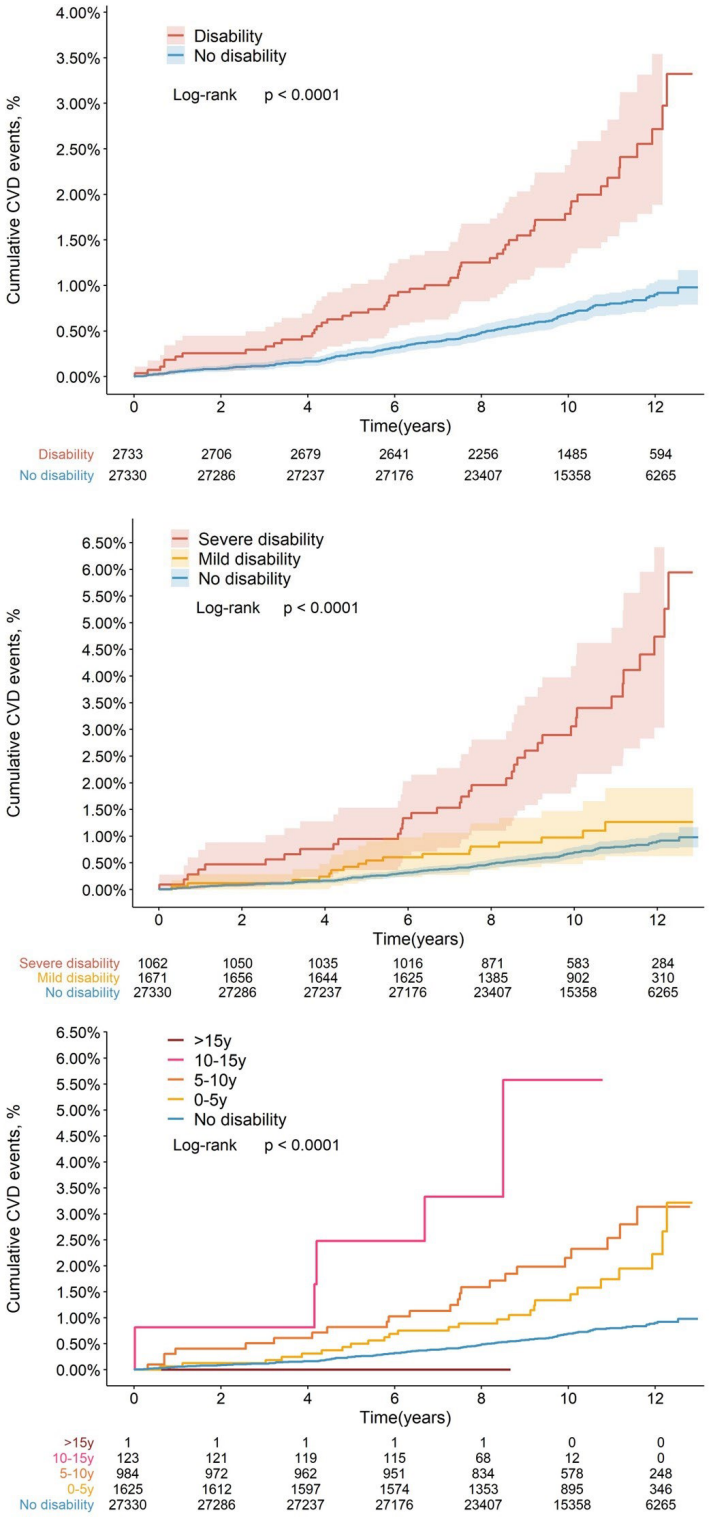

Figure 5. Cumulative incidence of cardiovascular event in internal disability according to the presence, severity, and duration of disability

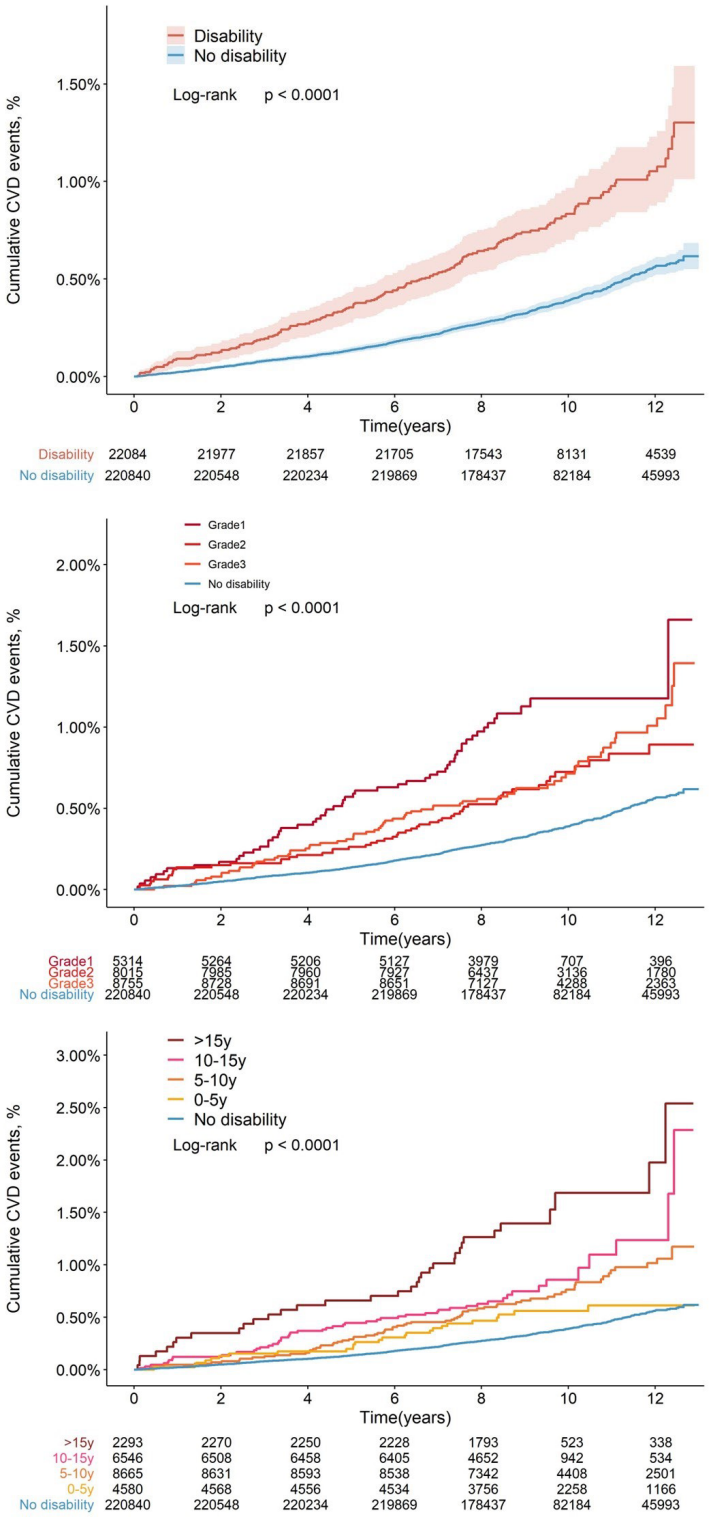

Figure 6. Cumulative incidence of cardiovascular event in developmental disability according to the presence, severity, and duration of disability

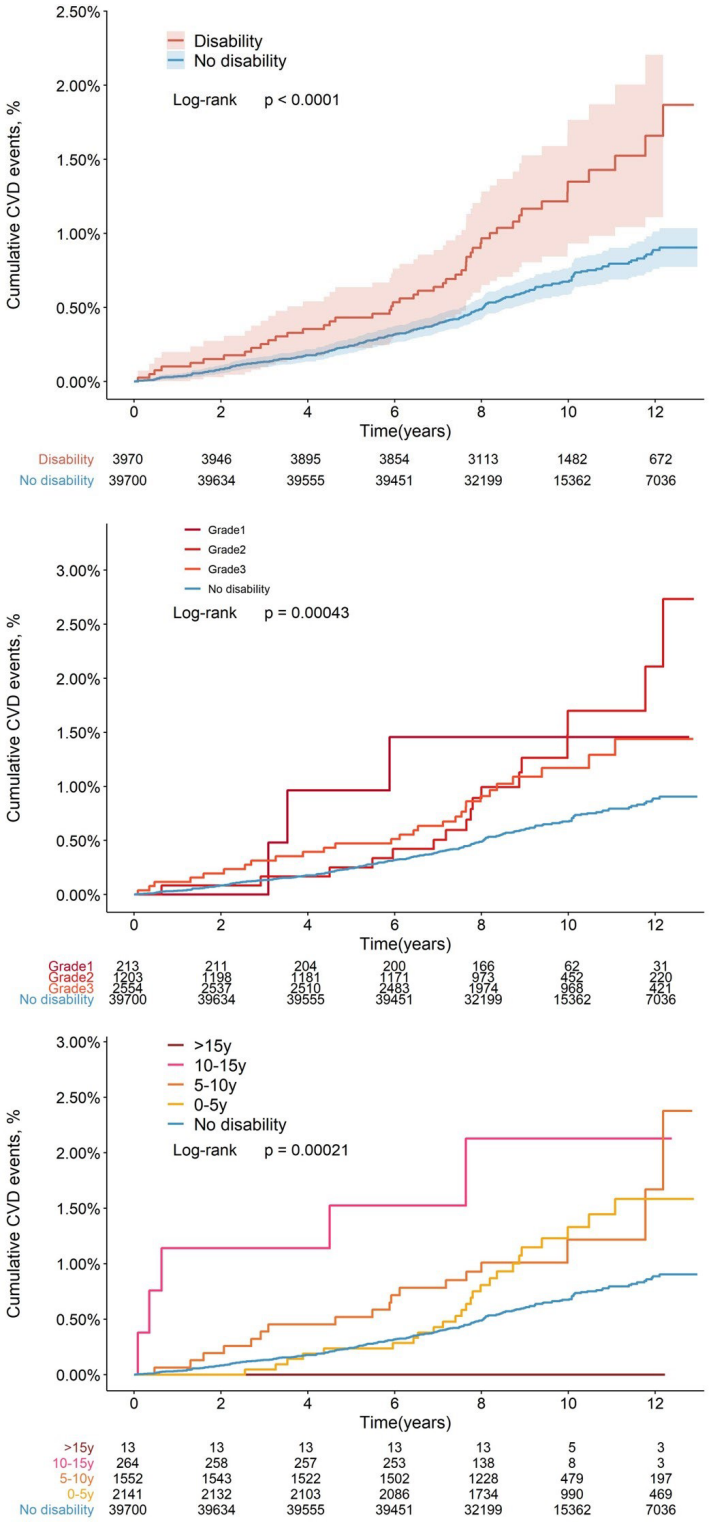

Figure 7. Cumulative incidence of cardiovascular event in mental disability according to the presence, severity, and duration of disability

3. The overall risk in the total and each type of disability

Table 6 shows the overall risk for CVD development for the total and each type of disability in the matched cohort sample. Model 1 was adjusted for income and urbanicity, Model 2 was further adjusted for BMI, systolic blood pressure, fasting glucose, total cholesterol, and CCI, and Model 3 was fully adjusted including smoking, drinking, and physical activity. The HR and 95% CIs of having disabilities were 1.58 (1.49–1.68) for the unadjusted model, 1.49 (1.40–1.58) for Model 1, 1.43 (1.35–1.52) for Model 2, and 1.44 (1.35–1.53) for the fully adjusted Model 3, in comparison to the absence of disabilities.

In each matched cohort, the CVD risk of each type of disability was compared to the respective matched group without a disability. The unadjusted HR and 95% CIs were 1.42 (1.33–1.51) for external, 5.33 (4.00–7.11) for internal, 2.37 (2.03–2.76) for developmental, and 3.17 (2.35–4.27) for mental disabilities. Adjustments for sociodemographic and biomedical factors decreased the strengths of associations; however, further adjustments for lifestyle factors slightly increased the estimates. In Model 3, the fully adjusted risk was 1.34 (1.25–1.44) for external, 2.45 (1.81–3.31) for internal, 2.50 (2.12–2.96) for developmental, and 1.58 (1.16–2.15) for mental disabilities.

Table 6. The overall cardiovascular disease (CVD) risk in the total and each disability type

Type	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
Total disability							
No disability	8,201	12,621,752	65.0	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	1,292	1,256,516	102.8	1.58 (1.49-1.68)	1.49 (1.40-1.58)	1.43 (1.35-1.52)	1.44 (1.35-1.53)
External disability							
No disability	6,915	9,856,921	70.2	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	1,010	981,896	102.9	1.42 (1.33-1.51)	1.40 (1.31-1.50)	1.34 (1.25-1.44)	1.34 (1.25-1.44)
Internal disability							
No disability	190	274,898	69.1	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	54	26,877	200.9	5.33 (4.00-7.11)	2.92 (2.19-3.90)	2.34 (1.73-3.15)	2.45 (1.81-3.31)
Developmental disability							
No disability	839	2,111,403	39.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	180	210,201	85.6	2.37 (2.03-2.76)	1.93 (1.64-2.26)	2.21 (1.88-2.61)	2.50 (2.12-2.96)
Mental disability							
No disability	257	378,530	67.9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	48	37,542	127.9	3.17 (2.35-4.27)	1.59 (1.18-2.15)	1.62 (1.19-2.21)	1.58 (1.16-2.15)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

4. The type-specific risk by disability attributes

We assessed the type-specific risk of CVD according to the severity, duration, and subtypes of disability within each disability type, compared to their respective matched general cohorts.

There were 70.2 CVD incidents per 100,000 person-years among those without disabilities who were exact-matched to the external disability group (Table 7). After full adjustments for sociodemographic, biomedical, and lifestyle factors, severe disability showed a higher risk of CVD (HR, 1.89; 95% CI, 1.64-2.17) than mild disability (HR, 1.22; 95% CI, 1.13-1.32). When evaluated by the six grading severity levels, we found a significant gradual association with CVD (p for trend = 0.050) (Figure 8). The association with CVD risk gradually increased as the disability duration increased in external disability (p for trend = 0.022). The major subtype, physical impairment, had 1.32 HR (95% CI, 1.22–1.43), while facial impairment had no significance due to the small number of events.

The matched individuals without disabilities to those with internal disability showed 69.1 CVD incidents per 100,000 person-years (Table 8). In Model 3, severe internal disability displayed a 3.73 times higher risk of CVD incidence (95% CI, 2.22–6.29) than those without it, whereas the HR for mild disability was not statistically significant (HR, 1.43; 95% CI, 0.82–2.48). Nevertheless, there was a significant increasing trend in the association between the six grading severity levels and CVD (p for trend = 0.022).

Among individuals without disabilities matched to the developmental disability group, there were 39.7 CVD events per 100,000 person-years (Table 9). It was evident that developmental and mental disabilities were registered as severe disability (Grades 1–3). Grade 3 developmental disability exhibited a higher risk compared to lower grades and no-disability; however, a gradual association was not statistically confirmed (p for trend =

0.346). In contrast, participants with longer durations of disability demonstrated a significantly elevated risk (p for trend = 0.010). The fully adjusted HRs were 2.79 (95% CI, 2.23–3.49) for intellectual impairment and 2.98 (0.95–9.36) for autism.

Among the general cohort matched to the mental disability group, there were 67.9 CVD incidents per 100,000 person-years (Table 10). The adjusted HRs were 1.45 (95% CI: 1.00–2.10) for Grade 3, 2.07 (1.28–3.35) for Grade 2, and 2.43 (0.78–7.55) for Grade 1. Additionally, the estimates were 1.63 (0.99–2.67) for 0–5 years, 1.49 (0.84–2.66) for 5–10 years, and 2.45 (0.83–7.22) for 10–15 years. However, the statistical significance of an increasing risk trend was not observed concerning the severity and duration of disability.

Table 7. The cardiovascular disease (CVD) risk of external disability compared to the matched general cohort using the stratified Cox regression analysis

Disability attributes	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	6,915	9,856,921	70.2	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Severity							
Mild	751	760,814	98.7	1.36 (1.26-1.46)	1.30 (1.21-1.41)	1.24 (1.15-1.34)	1.22 (1.13-1.32)
Severe	259	221,082	117.2	1.94 (1.70-2.22)	1.79 (1.57-2.05)	1.81 (1.58-2.09)	1.89 (1.64-2.17)
Severity, grade							
Grade 6	460	470,506	97.8	1.33 (1.21-1.47)	1.29 (1.17-1.42)	1.21 (1.10-1.34)	1.19 (1.07-1.31)
Grade 5	181	183,463	98.7	1.36 (1.17-1.59)	1.31 (1.12-1.53)	1.23 (1.05-1.45)	1.22 (1.04-1.44)
Grade 4	110	106,845	103	1.46 (1.19-1.78)	1.36 (1.12-1.67)	1.39 (1.13-1.71)	1.41 (1.14-1.73)
Grade 3	145	102,320	141.7	2.17 (1.81-2.60)	2.02 (1.68-2.42)	1.97 (1.63-2.37)	1.96 (1.63-2.37)
Grade 2	66	81,583	80.9	1.46 (1.13-1.90)	1.35 (1.04-1.76)	1.45 (1.11-1.89)	1.56 (1.19-2.04)
Grade 1	48	37,179	129.1	2.22 (1.62-3.05)	2.02 (1.47-2.77)	2.07 (1.49-2.89)	2.32 (1.66-3.24)
Duration							
0-5y	386	396,254	97.4	1.40 (1.26-1.56)	1.37 (1.23-1.53)	1.30 (1.17-1.45)	1.29 (1.15-1.44)
5-10y	439	415,131	105.7	1.52 (1.38-1.69)	1.44 (1.30-1.59)	1.39 (1.26-1.55)	1.38 (1.24-1.53)
10-15y	132	121,390	108.7	1.49 (1.24-1.79)	1.39 (1.16-1.68)	1.34 (1.11-1.63)	1.36 (1.13-1.65)
>15y	53	49,121	107.9	1.47 (1.10-1.96)	1.36 (1.01-1.82)	1.34 (0.99-1.82)	1.42 (1.05-1.93)
Subtype							
Physical	755	686,215	110	1.48 (1.37-1.60)	1.42 (1.31-1.53)	1.34 (1.24-1.45)	1.32 (1.22-1.43)
Brain injury	46	35,079	131.1	2.33 (1.69-3.21)	2.11 (1.53-2.91)	2.57 (1.84-3.58)	2.76 (1.98-3.86)
Visual	131	153,162	85.5	1.30 (1.08-1.56)	1.24 (1.03-1.49)	1.18 (0.97-1.42)	1.20 (0.99-1.45)
Hearing	65	90,012	72.2	1.37 (1.06-1.78)	1.30 (1.00-1.68)	1.35 (1.03-1.77)	1.44 (1.10-1.88)
Language	12	12,975	92.5	1.61 (0.88-2.96)	1.47 (0.80-2.71)	1.68 (0.89-3.17)	1.86 (0.99-3.50)
Facial	1	4,453	22.5	0.43 (0.06-3.16)	0.40 (0.05-2.93)	0.34 (0.04-2.79)	0.36 (0.04-2.91)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

Table 8. The cardiovascular disease (CVD) risk of internal disability compared to the matched general cohort using the stratified Cox regression analysis

Disability attributes	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	190	274,898	69.1	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Severity							
Mild	17	16,380	103.8	1.47 (0.88-2.44)	1.44 (0.86-2.40)	1.22 (0.71-2.10)	1.43 (0.82-2.48)
Severe	37	10,497	352.5	5.33 (3.57-7.98)	5.01 (3.34-7.53)	3.25 (1.98-5.32)	3.73 (2.22-6.29)
Severity, grade							
Grade 6	-	2,276	-	-	-	-	-
Grade 5	11	9,550	115.2	1.73 (0.91-3.29)	1.76 (0.92-3.35)	1.39 (0.69-2.80)	1.84 (0.90-3.77)
Grade 4	6	4,554	131.7	1.74 (0.73-4.15)	1.60 (0.67-3.83)	1.53 (0.61-3.81)	1.57 (0.62-4.00)
Grade 3	6	2,829	212.1	4.70 (1.75-12.60)	4.16 (1.55-11.20)	5.65 (2.06-15.54)	6.56 (2.33-18.45)
Grade 2	30	7,271	412.6	5.60 (3.57-8.79)	5.32 (3.38-8.39)	2.97 (1.70-5.19)	3.46 (1.93-6.21)
Grade 1	1	397	252.1	3.24 (0.34-31.21)	3.31 (0.34-32.36)	1.41 (0.12-16.49)	1.62 (0.12-21.50)
Duration							
0-5y	26	16,007	162.4	2.15 (1.40-3.28)	2.09 (1.36-3.20)	1.23 (0.75-2.03)	1.39 (0.83-2.35)
5-10y	23	9,882	232.7	3.71 (2.30-6.00)	3.55 (2.19-5.76)	3.14 (1.85-5.35)	3.47 (2.01-5.99)
10-15y	5	979	510.5	16.67 (3.98-69.74)	15.92 (3.69-68.68)	16.96 (3.54-81.32)	17.86 (3.63-87.89)
>15y	-	9	-	-	-	-	-
Subtype							
Renal	42	14,512	289.4	3.89 (2.72-5.57)	3.80 (2.65-5.45)	2.33 (1.48-3.66)	2.88 (1.78-4.66)
Respiratory	3	938	319.9	6.09 (1.33-27.81)	5.58 (1.22-25.42)	8.56 (1.78-41.11)	11.69 (2.46-55.63)
Liver ds.	-	1,307	-	-	-	-	-
Ostomy	-	3,567	-	-	-	-	-
Epilepsy	9	6,553	137.3	2.17 (1.05-4.46)	1.94 (0.94-4.02)	2.03 (0.95-4.33)	2.13 (0.98-4.61)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

Table 9. The cardiovascular disease (CVD) risk of developmental disability compared to the matched general cohort using the stratified Cox regression analysis

Disability attributes	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	839	2,111,403	39.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Severity, grade							
Grade 3	70	86,546	80.9	2.03 (1.57-2.63)	1.97 (1.50-2.59)	2.17 (1.63-2.89)	2.50 (1.85-3.36)
Grade 2	54	77,107	70.0	1.86 (1.39-2.49)	1.79 (1.31-2.45)	1.87 (1.34-2.60)	2.21 (1.57-3.11)
Grade 1	56	46,548	120.3	2.80 (2.08-3.78)	2.68 (1.94-3.70)	4.16 (2.95-5.88)	5.04 (3.50-7.26)
Duration							
0-5y	25	45,357	55.1	1.73 (1.13-2.66)	1.67 (1.08-2.57)	1.87 (1.19-2.93)	2.09 (1.32-3.31)
5-10y	70	86,807	80.6	2.21 (1.70-2.86)	2.13 (1.61-2.81)	2.46 (1.84-3.30)	2.88 (2.12-3.92)
10-15y	51	57,186	89.2	2.27 (1.67-3.08)	2.19 (1.59-3.04)	2.48 (1.76-3.51)	2.85 (1.99-4.08)
>15y	34	20,850	163.1	2.31 (1.58-3.36)	2.18 (1.47-3.24)	2.86 (1.88-4.36)	3.56 (2.31-5.50)
Subtype							
Intellectual	176	201,417	87.4	2.15 (1.83-2.54)	2.06 (1.70-2.50)	2.40 (1.96-2.95)	2.79 (2.23-3.49)
Autism	4	8,784	45.5	2.50 (0.84-7.48)	2.42 (0.81-7.27)	2.58 (0.83-8.03)	2.98 (0.95-9.36)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

Table 10. The cardiovascular disease (CVD) risk of mental disability compared to the matched general cohort using the stratified Cox regression analysis

Disability attributes	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	257	378,530	67.9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Severity, grade							
Grade 3	28	24,099	116.2	1.68 (1.12-2.51)	1.45 (0.94-2.24)	1.41 (0.89-2.22)	1.39 (0.87-2.22)
Grade 2	17	11,497	147.9	2.29 (1.35-3.88)	1.92 (1.09-3.37)	2.14 (1.18-3.87)	2.05 (1.11-3.80)
Grade 1	3	1,946	154.2	1.99 (0.58-6.87)	1.71 (0.49-5.99)	2.01 (0.54-7.51)	2.06 (0.54-7.86)
Duration							
0-5y	25	20,925	119.5	1.94 (1.26-2.98)	1.70 (1.08-2.68)	1.70 (1.05-2.75)	1.63 (0.99-2.67)
5-10y	18	14,387	125.1	1.68 (1.02-2.77)	1.40 (0.82-2.39)	1.51 (0.86-2.65)	1.49 (0.84-2.66)
10-15y	5	2,101	238	2.75 (1.02-7.41)	2.25 (0.81-6.23)	2.21 (0.76-6.43)	2.45 (0.83-7.22)
>15y	-	129	-	-	-	-	-

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

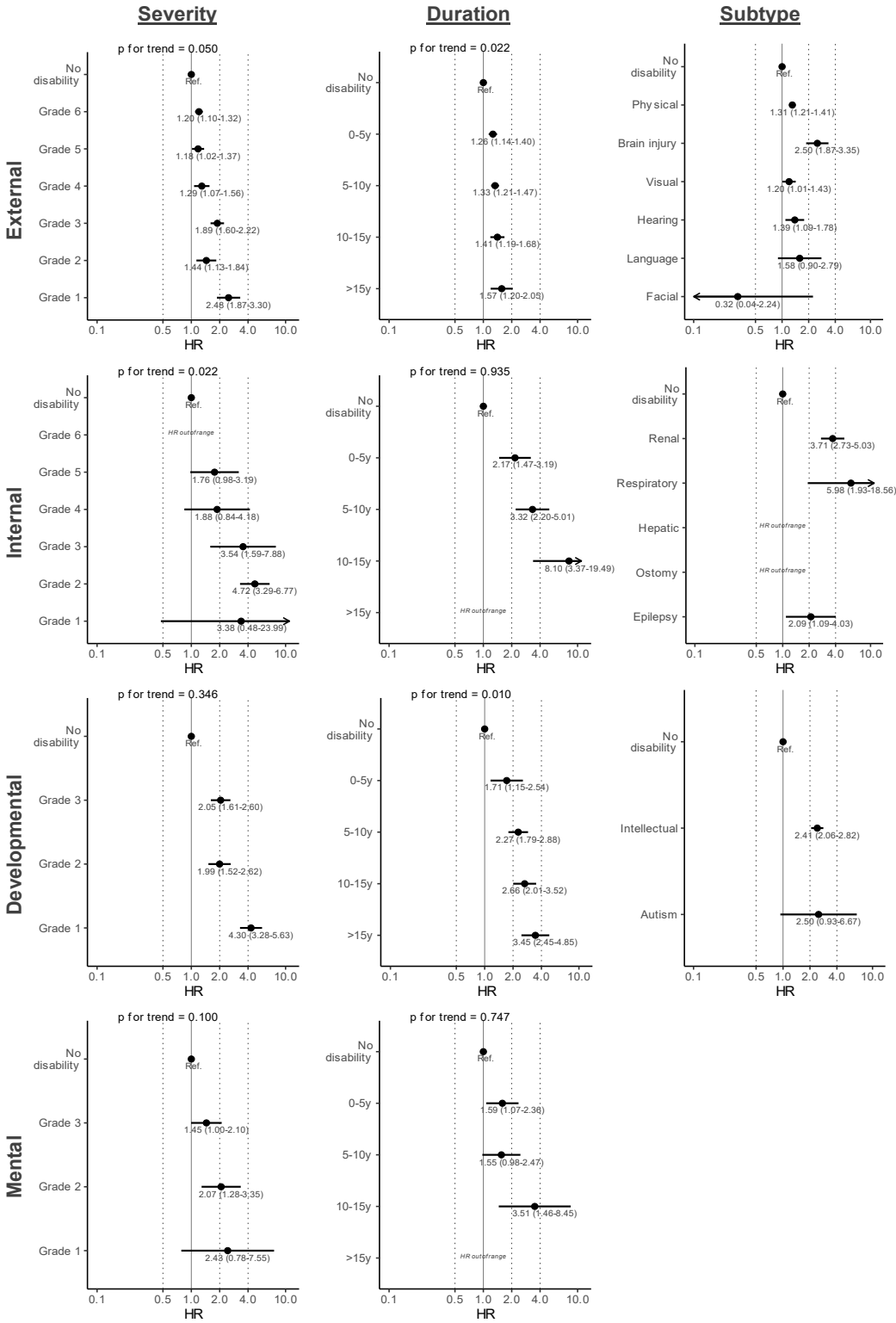

Figure 8. Forest plots computed using the fully adjusted model (Model 3)

5. End point-specific analyses for sub-outcomes

During the follow-up, 2549 MIs, 5,531 strokes, 573 HF hospitalizations, and 1,382 cardiovascular deaths occurred (Table 11). Due to the limited number of MI incidents, only external disability showed a significant association with an HR of 1.15 (95% CI, 1.01–1.31) in comparison to the general population. Developmental and mental disabilities exhibited a reduced risk but lacked statistical significance. For stroke, a fully adjusted HR was highest in internal disability followed by developmental and external disabilities. For HF, the higher risks were observed in the following order: internal, mental, developmental, and external disabilities, and the group without any disability. The risk of cardiovascular death was also higher in internal disability (HR, 6.66; 95% CI, 4.10–10.81) followed by developmental (5.39; 4.09–7.10), mental (3.91; 2.36–6.47), and external (1.60; 1.35–1.88) disabilities.

The gradual associations of the severity and duration with sub-outcomes did not show any statistical significance except for stroke and cardiovascular death in external disability and cardiovascular death in developmental disability (Figure 9, Figure 10, Figure 11, Figure 12).

Table 11. The end point-specific risk for myocardial infarction, stroke, heart failure, and cardiovascular death

Type	No. of events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for sub-outcomes			
				Unadjusted	Model 1	Model 2	Model 3
Myocardial infarction							
External disability							
No disability	1982	9874587	20.1	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	244	984566	24.8	1.18 (1.04-1.34)	1.20 (1.05-1.37)	1.20 (1.04-1.38)	1.22 (1.06-1.40)
Internal disability							
No disability	41	275424	14.9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	8	27006	29.6	3.45 (1.75-6.80)	1.80 (0.86-3.76)	1.74 (0.80-3.76)	1.69 (0.77-3.68)
Developmental disability							
No disability	188	2113629	8.9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	8	210664	3.8	0.49 (0.25-0.96)	0.40 (0.20-0.82)	0.52 (0.25-1.06)	0.64 (0.31-1.33)
Mental disability							
No disability	74	379118	19.5	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	4	37629	10.6	1.13 (0.42-3.06)	0.57 (0.21-1.56)	0.63 (0.23-1.77)	0.55 (0.19-1.53)
Stroke							
External disability							
No disability	4012	9865837	40.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	576	983081	58.6	1.39 (1.28-1.51)	1.38 (1.26-1.50)	1.30 (1.18-1.42)	1.29 (1.17-1.41)
Internal disability							
No disability	125	275058	45.4	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	31	26920	115.2	4.98 (3.50-7.09)	2.71 (1.85-3.95)	1.85 (1.25-2.75)	2.03 (1.37-3.02)
Developmental disability							
No disability	520	2112183	24.6	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	96	210316	45.6	2.02 (1.66-2.47)	1.63 (1.31-2.03)	1.68 (1.34-2.10)	1.92 (1.53-2.40)
Mental disability							
No disability	150	378806	39.6	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	21	37577	55.9	2.21 (1.45-3.37)	1.08 (0.69-1.69)	1.08 (0.69-1.71)	1.13 (0.72-1.79)
Heart failure							
External disability							

No disability	361	9881176	3.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	86	985236	8.7	2.31 (1.86-2.87)	2.20 (1.73-2.80)	2.02 (1.56-2.62)	2.05 (1.58-2.66)
Internal disability							
No disability	12	275526	4.4	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	7	26988	25.9	9.42 (4.17-21.31)	6.99 (2.97-16.46)	6.04 (2.43-15.03)	6.00 (2.38-15.13)
Developmental disability							
No disability	58	2114015	2.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	27	210602	12.8	4.87 (3.34-7.11)	4.03 (2.60-6.25)	5.44 (3.43-8.62)	5.84 (3.63-9.39)
Mental disability							
No disability	12	379362	3.2	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	10	37614	26.6	9.26 (4.85-17.68)	6.53 (3.08-13.84)	3.97 (1.77-8.92)	3.53 (1.54-8.09)
Cardiovascular death							
External disability							
No disability	945	9882428	9.6	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	166	985509	16.8	1.72 (1.47-2.01)	1.64 (1.38-1.93)	1.61 (1.35-1.91)	1.61 (1.35-1.92)
Internal disability							
No disability	26	275560	9.4	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	17	27020	62.9	9.59 (5.92-15.52)	5.50 (3.17-9.54)	4.88 (2.75-8.66)	5.07 (2.84-9.03)
Developmental disability							
No disability	110	2114221	5.2	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	64	210691	30.4	5.89 (4.60-7.54)	4.59 (3.41-6.17)	5.75 (4.23-7.80)	6.52 (4.74-8.95)
Mental disability							
No disability	38	379383	10.0	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	16	37639	42.5	8.15 (4.91-13.54)	3.94 (2.25-6.88)	4.51 (2.55-7.97)	4.53 (2.55-8.08)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

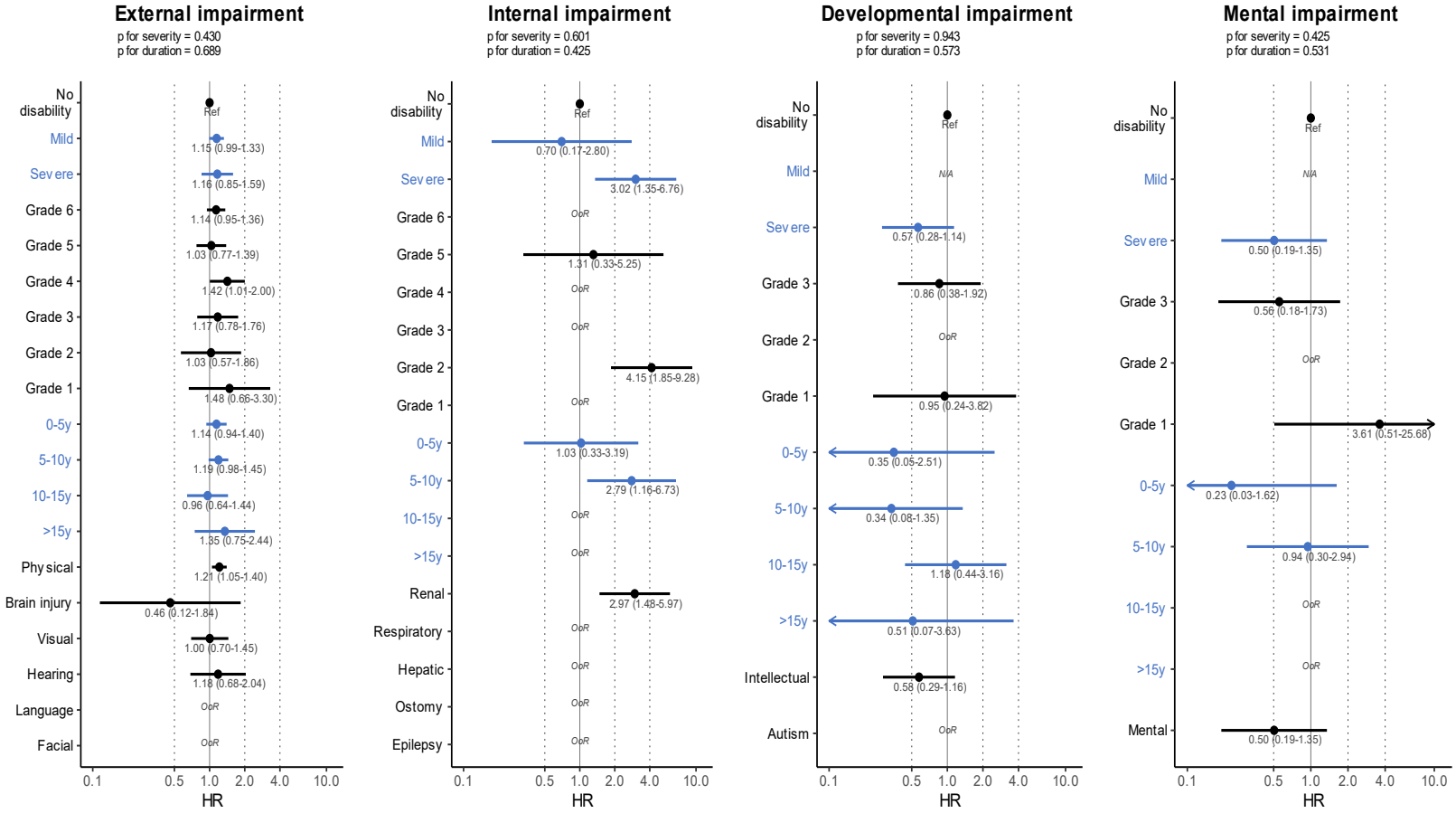

Figure 9. The risk of myocardial infarction according to disability attributes in the fully adjusted model (Model 3)
Each point represents an adjusted hazard ratio, solid lines indicate 95% confidence intervals, and arrows are plotted when the confidence intervals extend beyond the x-axis. N/A, not applicable because developmental and mental disabilities have severe grades (Grades 3, 2, and 1); OoR, hazard ratio out of axis range.

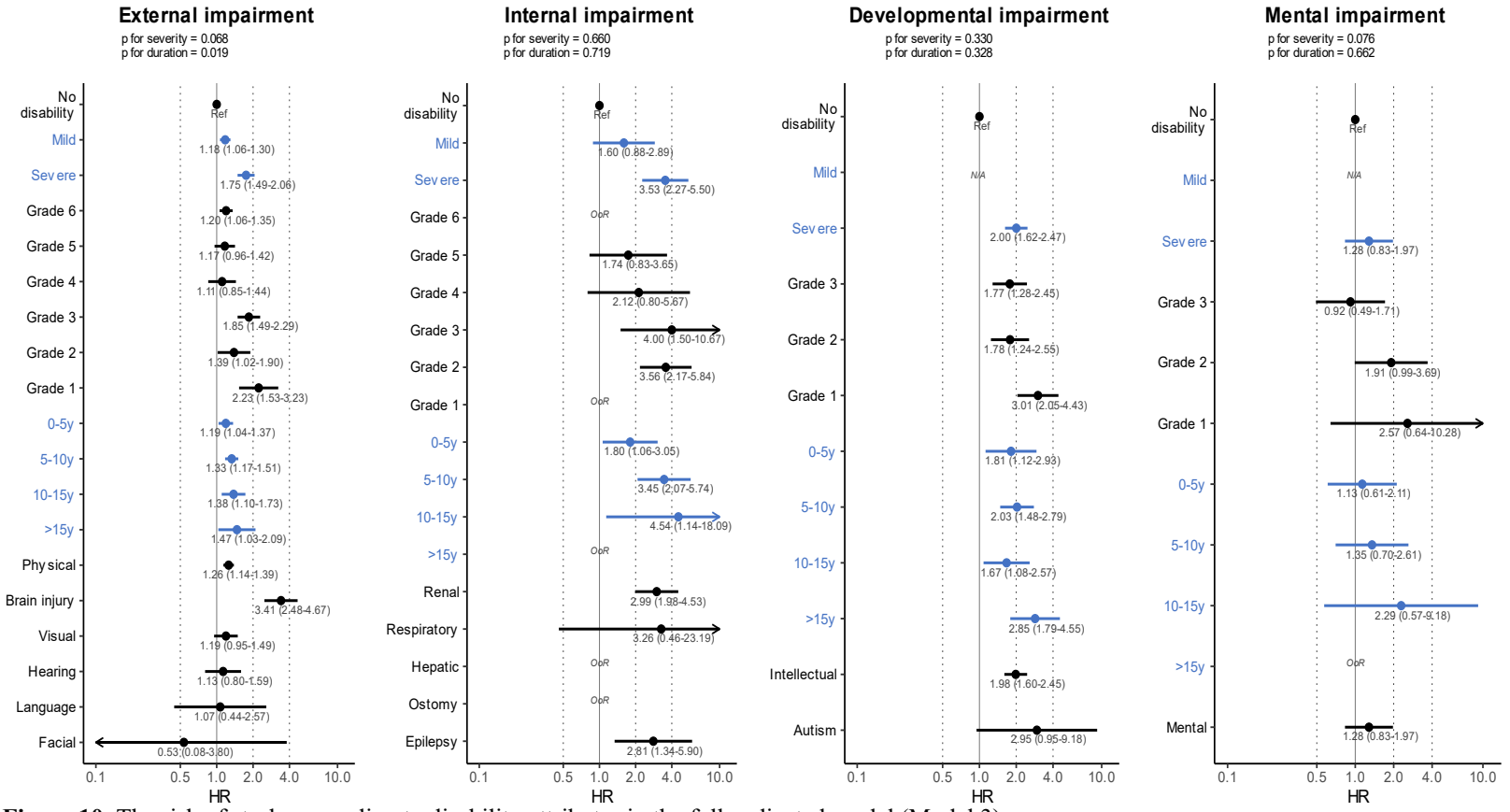

Figure 10. The risk of stroke according to disability attributes in the fully adjusted model (Model 3)
Each point represents an adjusted hazard ratio, solid lines indicate 95% confidence intervals, and arrows are plotted when the confidence intervals extend beyond the x-axis. N/A, not applicable because developmental and mental disabilities have severe grades (Grades 3, 2, and 1); OoR, hazard ratio out of axis range.

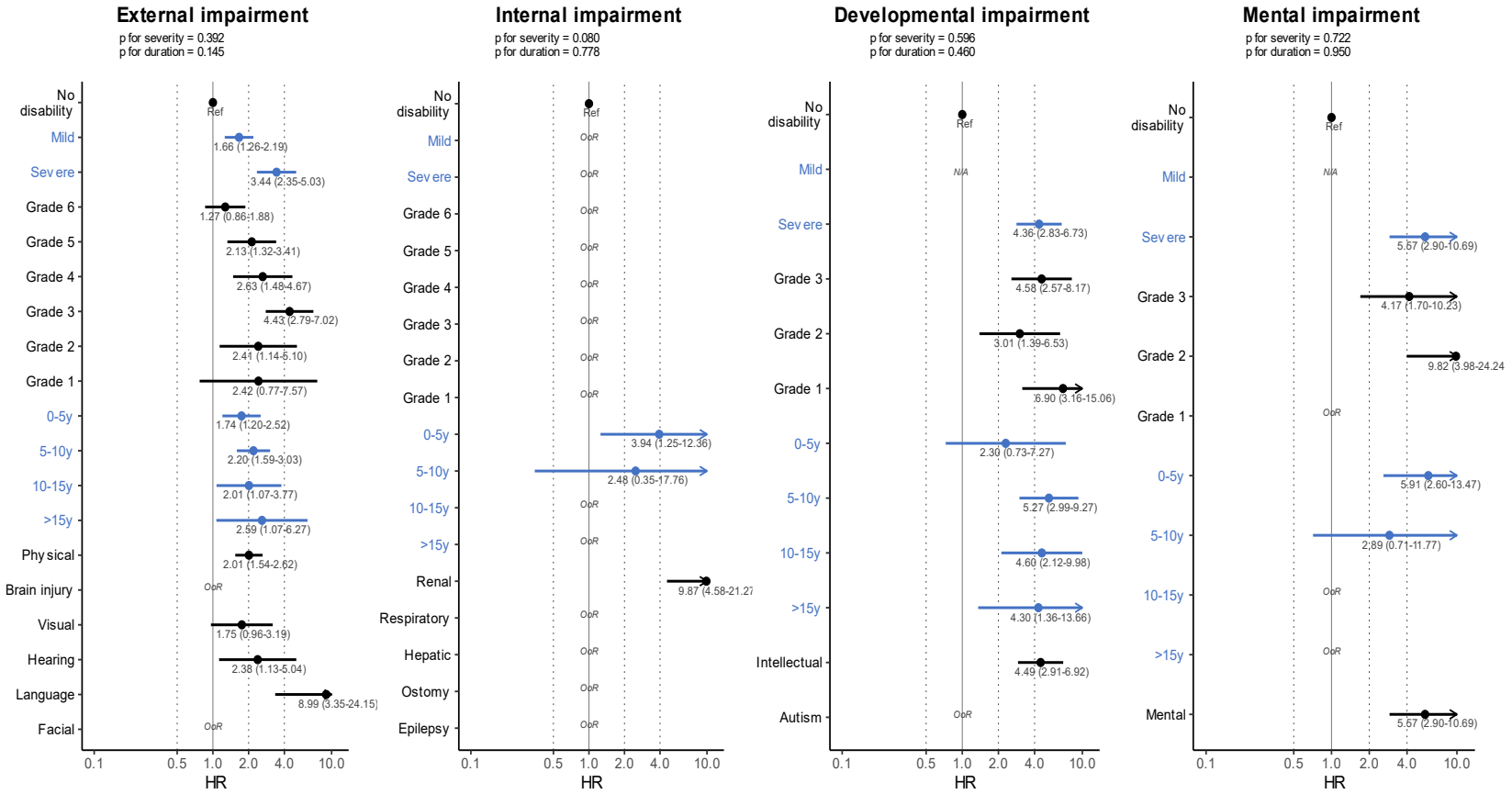

Figure 11. The risk of heart failure according to disability attributes in the fully adjusted model (Model 3)
Each point represents an adjusted hazard ratio, solid lines indicate 95% confidence intervals, and arrows are plotted when the confidence intervals extend beyond the x-axis. N/A, not applicable because developmental and mental disabilities have severe grades (Grades 3, 2, and 1); OoR, hazard ratio out of axis range.

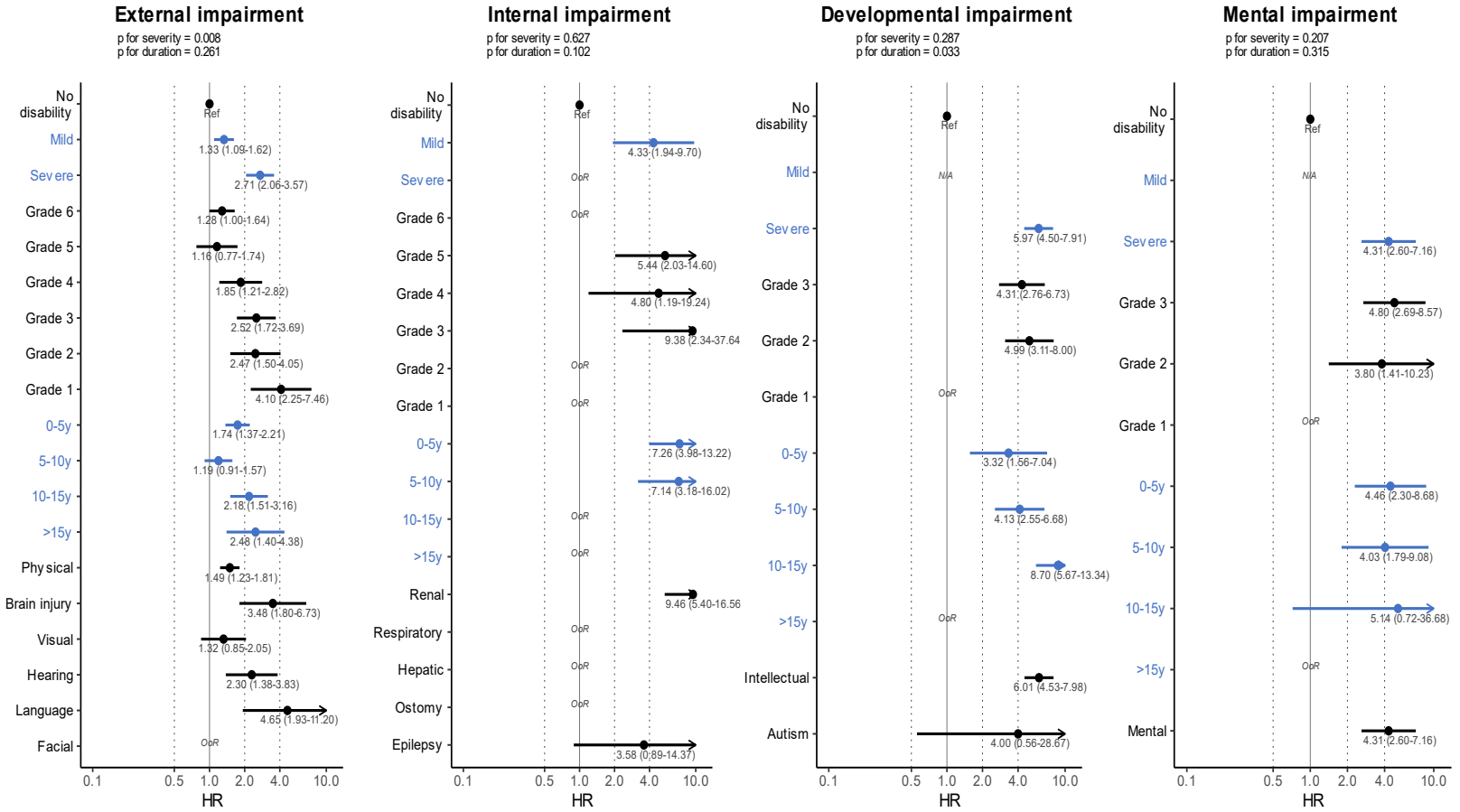

Figure 12. The risk of cardiovascular death according to disability attributes in the fully adjusted model (Model 3)
Each point represents an adjusted hazard ratio, solid lines indicate 95% confidence intervals, and arrows are plotted when the confidence intervals extend beyond the x-axis. N/A, not applicable because developmental and mental disabilities have severe grades (Grades 3, 2, and 1); OoR, hazard ratio out of axis range.

6. Sensitivity analyses

First, we conducted sensitivity analyses using the total eligible population (N =7,711,487) before the exact matching. Overall, the results represent consistent findings and slightly stronger associations; those having disabilities had a 1.50-fold HR than no disability (Table 12). In addition, gradual associations of disability severity and duration were observed more prominently than those in the main analyses (Appendix 4). For instance, the fully adjusted HRs for developmental disability were 2.09 (95% CI, 1.32–3.31) for 0–5 years, 2.88 (2.12–3.92) for 5–10 years, 2.85 (1.99–4.08) for 10–15 years, and 3.56 (2.31–5.50) for more than 15 years in the matched cohort, but 1.76 (1.19–2.60), 2.33 (1.84–2.95), 2.77 (2.10–3.65), and 3.62 (2.58–5.07) in the total eligible population, respectively.

Table 12. The overall cardiovascular disease (CVD) risk of disability in the total eligible population (N= 7,711,487)

Type of disability	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	38,497	81,304,720	47.3	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	1,292	1,256,516	102.8	2.20 (2.09-2.33)	1.55 (1.47-1.64)	1.48 (1.40-1.57)	1.50 (1.42-1.59)
External	1,010	981,896	102.9	2.17 (2.04-2.31)	1.45 (1.36-1.54)	1.37 (1.29-1.46)	1.37 (1.29-1.46)
Internal	54	26,877	200.9	4.46 (3.42-5.82)	3.05 (2.34-3.99)	2.63 (2.01-3.44)	2.86 (2.19-3.73)
Developmental	180	210,201	85.6	1.95 (1.68-2.25)	1.94 (1.67-2.25)	2.12 (1.83-2.45)	2.45 (2.12-2.84)
Mental	48	37,542	127.9	2.91 (2.19-3.86)	1.86 (1.40-2.46)	1.78 (1.34-2.36)	1.73 (1.30-2.29)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

Second, we applied overlap weighting with PS to balance the confounders between the disability and no-disability groups in each matched cohort. Balance diagnostics were performed before and after weighting by estimating the standardized difference between the disability and respective no-disability groups (Figure 13). After weighting, the standardized differences were all measured covariates balanced between the two groups. The findings in the primary analyses persisted; for instance, a gradual association of disability severity and duration with CVD (Table 13, Appendix 5).

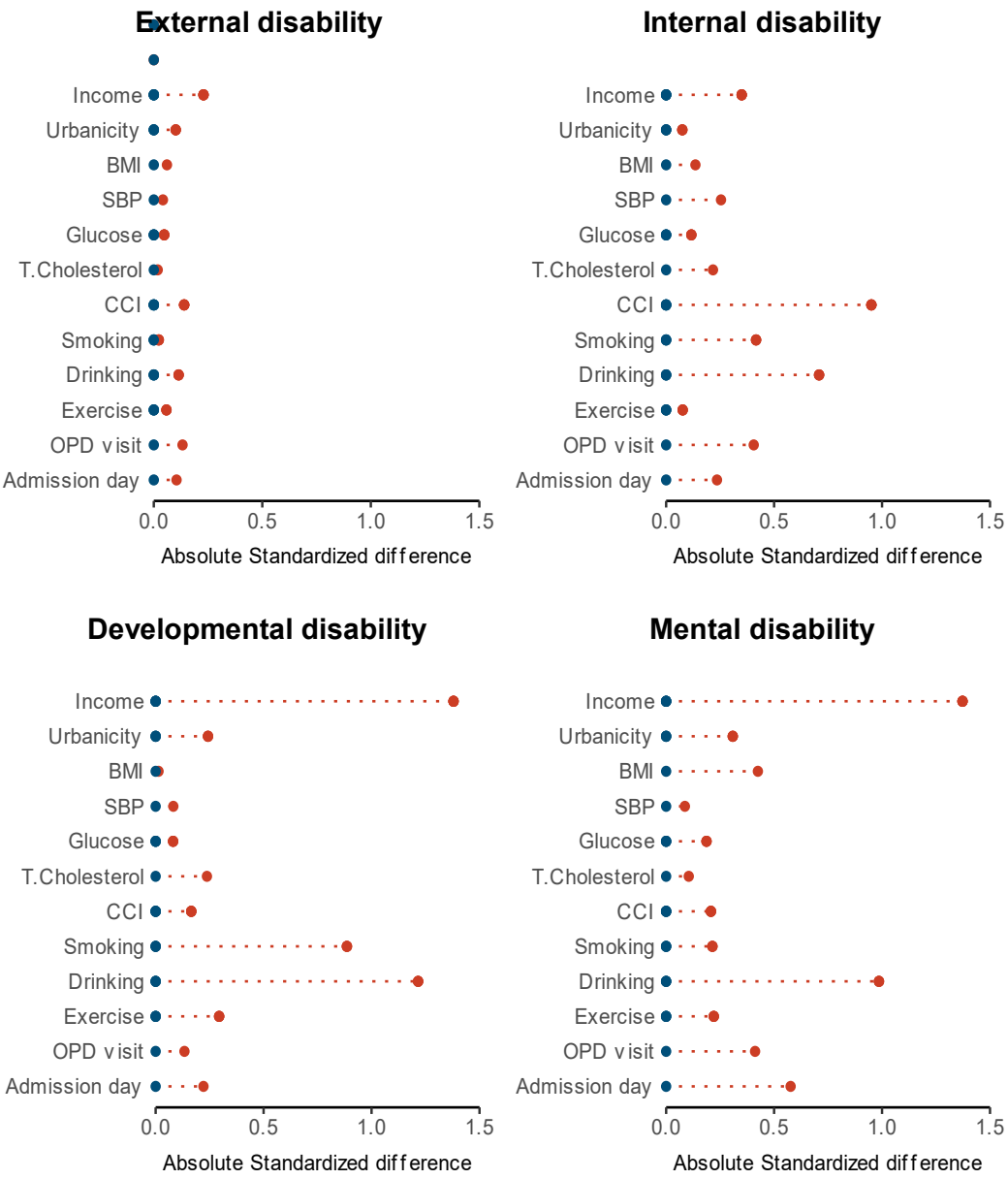

Figure 13. Balance diagnostics before (red) and after (blue) overlap weighting using propensity scores
Points refer to the standardized differences between the disability and no-disability groups. In terms of categorical variables, the highest difference was plotted.

Table 13. The adjusted cardiovascular disease (CVD) risk before and after overlap weighting using propensity score in each disability type compared to the respective matched general cohort

Disability type	Hazard ratio (95% confidence interval) for CVD	
	Before weighting*	After weighting
Total disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	1.44 (1.35-1.53)	1.37 (1.23-1.52)
External disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	1.34 (1.25-1.44)	1.29 (1.16-1.44)
Internal disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	2.45 (1.81-3.31)	2.23 (1.08-4.58)
Developmental disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	2.50 (2.12-2.96)	3.29 (1.97-5.50)
Mental disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	1.58 (1.16-2.15)	1.34 (0.61-2.94)

The model before weighting* has been matched to the fully adjusted model (Model 3), which has been adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching for age, sex, and index year.

Third, we computed the E-values to estimate the minimum strength of associations that unmeasured confounders could alter the fully adjusted hazard ratios observed in the primary analyses (Table 14, Appendix 6). For external disability, the E-value was 2.01 suggesting that the observed HR of 1.34 could be explained away by an unmeasured confounder that is associated with disability and CVD outcome by an HR of 2.01-fold each; however, a weaker confounding effect would not be sufficient to do so. Similarly, the E-value was 4.33 for internal, 4.44 for developmental and 2.54 for mental disabilities. Given that the adjusted HRs of measured risk factors were below the respective E-value for point estimate (Appendix 7), the unmeasured confounding may not significantly affect the findings in this study.

Table 14. The E-value for hazard ratios (HRs) and confidence interval (CI) limits from the fully adjusted model, Model 3

Disability type	Adjusted HR (95% CI)	E-value	
		for HR	for CI limit
Total disability	1.44 (1.35-1.53)	2.24	2.04
External disability	1.34 (1.25-1.44)	2.01	1.81
Internal disability	2.45 (1.81-3.31)	4.33	3.02
Developmental disability	2.50 (2.12-2.96)	4.44	3.66
Mental disability	1.58 (1.16-2.15)	2.54	1.59

The model used for E-value was corresponded to the fully adjusted model (Model 3), which was adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching on age, sex, and index year. The reference group was the respected matched general cohort for each type of disability.

Lastly, competing risk was treated with the sub-distribution hazard function in sensitivity analyses. The results show consistent HRs for CVD development, only with slightly changed CIs (Table 15, Appendix 8).

Table 15. The overall cardiovascular disease (CVD) risk with the Fine-Gray sub-distribution hazard model

Disability type	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
Total disability							
No disability	8,201	12,621,752	65.0	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	1292	1,256,516	102.8	1.59 (1.50-1.68)	1.49 (1.41-1.58)	1.45 (1.37-1.54)	1.47 (1.38-1.55)
External disability							
No disability	6,915	9,856,921	70.2	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	1,010	981,896	102.9	1.47 (1.38-1.56)	1.40 (1.32-1.49)	1.35 (1.27-1.44)	1.34 (1.26-1.43)
Internal disability							
No disability	190	274,898	69.1	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	54	26,877	200.9	2.90 (2.21-3.82)	2.79 (2.11-3.67)	1.98 (1.42-2.76)	2.26 (1.58-3.25)
Developmental disability							
No disability	839	2,111,403	39.7	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	180	210,201	85.6	2.16 (1.86-2.50)	2.07 (1.74-2.46)	2.41 (2.01-2.89)	2.79 (2.31-3.38)
Mental disability							
No disability	257	378,530	67.9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Disability	48	37,542	127.9	1.87 (1.41-2.49)	1.60 (1.15-2.22)	1.64 (1.15-2.33)	1.60 (1.11-2.31)

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

7. Additive considerations

A. The consideration of healthcare utilization

Healthcare utilization differed between individuals with and without disabilities (Table 16). Despite relatively high standard deviations, all disability groups utilized healthcare services more frequently than the general population. Notably, the mean number of hospitalization days was higher among those with mental disabilities, while the mean number of outpatient visits was higher among those with internal disabilities. Healthcare utilization may serve as a collider as previously described,[76,81] its adjustment was not incorporated into the main analyses but was conducted separately in an additive manner (Table 17, Appendix 9). Simple and weighted adjustments for the number of outpatient visits and hospitalization days were conducted and they weakened the associations between disability attributes and CVD in most disability, in particular, mental disability: 1.29 (1.16–1.44) for external, 2.19 (1.03–4.61) for internal, 3.37 (2.00–5.67) for developmental, and 1.24 (0.56–2.77) for mental disabilities.

Table 16. Healthcare utilization within one year from the index date

Variables		Healthcare utilizations	
		Hospitalization days	Outpatient visits
No Disability		0.6 ±4.8	1.0 ±4.7
Disability	External	1.6 ±12.1	1.8 ±7.5
	Internal	4.4 ±21.4	9.6 ±28.9
	Developmental	7.5 ±43.5	2.0 ±8.7
	Mental	42.1 ±101.1	5.6 ±13.3
p-value from the ANOVA test		< 0.001	< 0.001

Table 17. Further adjustments for healthcare utilization after overlap weighting using propensity score

Disability type	Hazard ratio (95% confidence interval) for CVD	
	Further adjustment for HC use	Further adjustment for HC use after overlap weighting
Total disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	1.41 (1.31-1.52)	1.37 (1.23-1.52)
External disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	1.31 (1.22-1.41)	1.29 (1.16-1.44)
Internal disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	2.01 (1.47-2.76)	2.19 (1.03-4.61)
Developmental disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	2.20 (1.85-2.62)	3.37 (2.00-5.67)
Mental disability		
No disability	1.00 (reference)	1.00 (reference)
Disability	0.82 (0.57-1.17)	1.24 (0.56-2.77)

The fully adjusted model (Model 3) was adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching on age, sex, and index year. In addition, the model was further adjusted for healthcare utilization (the number of outpatient visits and hospitalization days) before and after overlap weighting with propensity score. CVD, cardiovascular disease; HC, healthcare.

B. Risk factors in each type of disability: Explained relative risk

Figure 14 illustrates the relative importance of covariates in the fully adjusted model (Model 3) in each disability type using the explained relative risk (ERR). In the general population, the age variable had the highest ERR at 0.1080 for CVD incidents, followed by systolic blood pressure (0.0738), current smoking (0.0408), BMI (0.0191), total cholesterol (0.0158), and other variables.

Among those with external disability, low income prominently contributed to the explained risk of the full model with an ERR of 0.0221, while age and systolic blood pressure showed the highest ERR. The number of comorbidities was relatively more important than other variables in internal disability. For individuals with developmental disability, age played a prominent role, and physical inactivity demonstrated a higher ERR at 0.0246 compared to other disability types. In the analysis of mental disability, BMI (ERR, 0.0501) and physical inactivity (0.0498) showed greater importance.

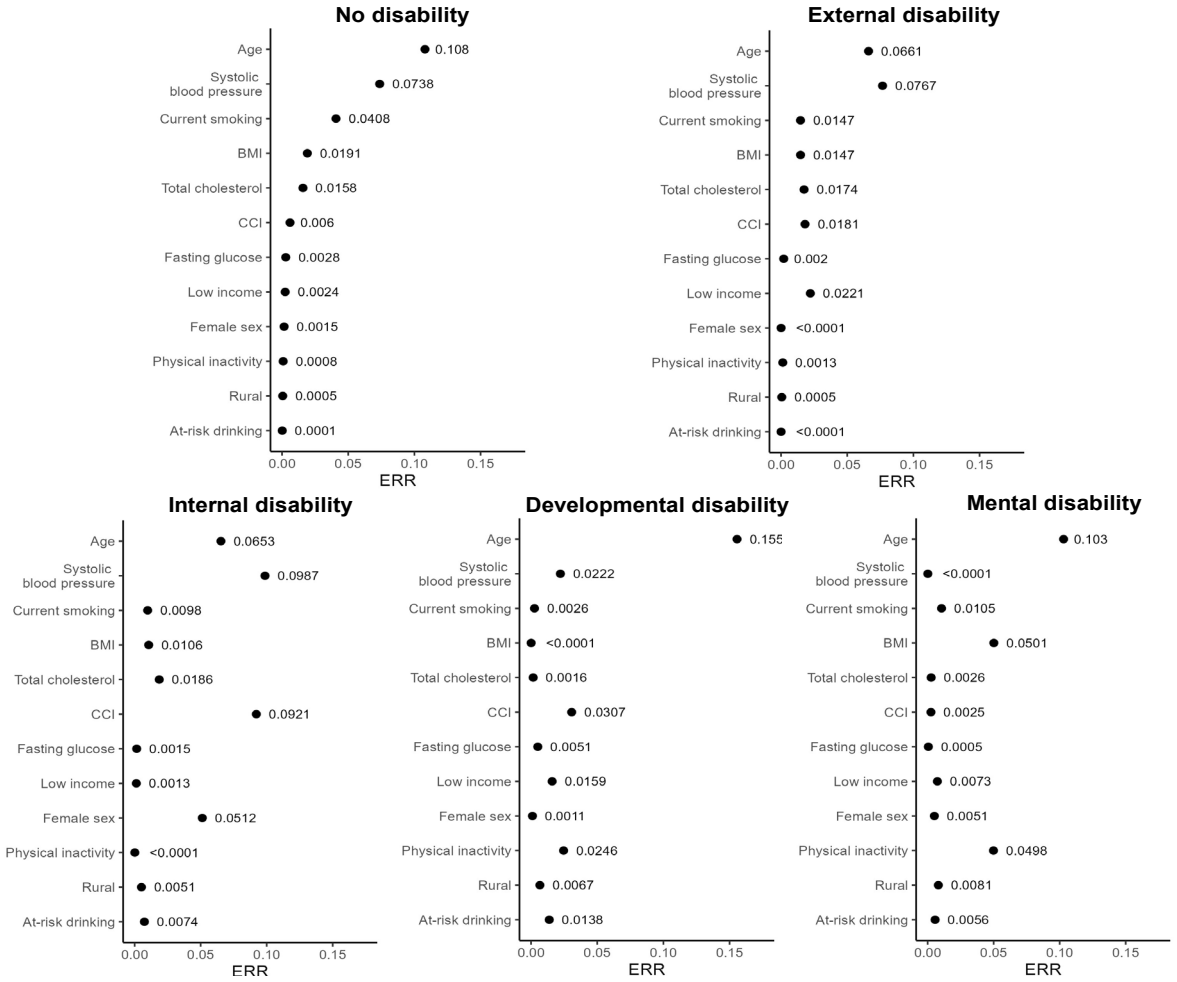

Figure 14. Explained relative risk of each covariate in the fully adjusted model

IV. DISCUSSION

1. Summary of findings

This large, population-based study of more than 8 million adults followed young individuals, aged 20–39 years, for 13 years. We obtained data corresponding to 120,287 individuals with disability among 7,711,487 eligible participants. When simply comparing the disability and general populations, the disability group exhibited a higher prevalence of male sex, lower income brackets, rural residency, higher comorbidity, poorer biomedical indicators, and unfavorable health behaviors. However, we matched on age, sex, and index year for the matched general cohorts, nullifying the high proportion of older age and male sex in the disability group. The comparison showed that those with disabilities were rather less likely to smoke or drink frequently compared to their counterparts.

During the study period, 8,201 CVD events occurred in the matched general group, and 1,292 in the disability group. It was noted that all observed CVD events occurred before the age of 55 years, which was defined as premature CVD. Overall, young adults with disabilities had a 58% increased risk of premature CVD, compared to those without disabilities. Even after controlling for age, sex, index year, sociodemographic, lifestyle-related, and biomedical variables, the CVD risk persistently increased in the disability group. Notably, distinct types of disabilities exhibited varying risks for CVD. When compared to its respective matched general cohort, a full-adjusted HR was 1.34 (95% CI, 1.25–1.44) for external, 2.45 (95% CI 1.81–3.31) for internal, 2.50 (95% CI 2.12–2.96) for developmental, and 1.58 (95% CI 1.16–2.15) for mental disabilities.

Furthermore, within each disability type group, the CVD risk differed according to the severity, duration, and subtype of disability. A gradual association between the severity and duration of disability and the risk of CVD was observed across all disabilities. However,

its statistical significance was confirmed in cases with a sufficient number of events, such as external disability.

In addition, the end point-specific analyses for sub-outcomes showed that disability was associated with a higher risk for MI (14% increased risk), stroke (48% increased risk), HF (165% increased risk), and cardiovascular death (120% increased risk) than their counterparts.

2. The association between disability and adverse health outcomes in previous studies

Previous studies have demonstrated a significant association between disability and adverse health outcomes. For instance, the disability group is at a higher risk for infectious and chronic non-communicable diseases, such as tuberculosis, Coronavirus disease 2019, obesity or underweight, hypertension, and cancer.[19,20,40,45,89-91] Moreover, individuals with disabilities face an elevated mortality risk and shorter life expectancy compared to the general population. The increased rate of mortality in the disability group is apparent even in high-income countries that are expected to provide high-quality and accessible healthcare and social services to all.[82-85] Although the exact mechanisms and interactions require further examination, the higher mortality among disabled individuals can be, at least in part, attributed to prevalent unfavorable health-related risk factors and social determinants, as well as exclusion experiences in education, occupation, social relationships, and social participation.[21,22,86-88]

Our study showed that the disability population exhibited a higher risk of premature CVD

occurrence, consistent with prior research showing a heightened risk of adverse health outcomes, including CVD. Although longitudinal studies on the relationship between disability and CVD development are scarce, one comparable study adopted an identical disability definition of our study, based on the KNDRS, which investigated the longitudinal association between disability and CVD.[57] It used the National Health Insurance Service-National Sample Cohort, which was derived from 10% (approximately 515,000) of health insurance-eligible individuals, aged 40–79 years, who underwent health examinations in 2002 and 2003.[92] In the study, individuals with disabilities had a 2.89-fold higher risk of CVD compared to those without disabilities.[57] Although the study only included participants aged 40 years and above, stratification by age revealed a more substantial increase in risk at younger ages. It suggested that the impact of disability on CVD may be attenuated in older age groups, possibly due to adjustment for conventional risk factors that were relatively prevalent in older age. In the unadjusted analysis, CVD incidence and cardiovascular death rates increased with age. However, after adjusting for sex, hypertension, diabetes, dyslipidemia, BMI, smoking, and alcohol consumption, individuals aged 40–50 years were at a greater risk than those over 50 years. The risk for other CVD incidents was five times higher in participants under 50 years, whereas it was less than four times in those over 50 years. However, the study only included participants aged 40 years and above, and possibly due to limitations in its sample size, the statistical significance disappeared after stratification by age or disability severity, while the association in the young adult population remained unclear.

Many previous disability studies have investigated disability within the scope of various causative medical conditions that result in a specific impairment. For instance, separate

studies examined the associations with CVD risk in disabled persons who had undergone lower extremity amputation; however, one was due to diabetes[93] and another due to trauma-related causes.[94] While it is crucial to assess the risks of suboptimal health outcomes associated with disability from the perspective of each underlying medical condition, it is also important to consider the comprehensive risk associated with disability, which is defined according to persistent, chronic, and stable dysfunction status after adequate treatment for the causative disease. An excessive granularity in categorizing disabilities, based on their underlying causes, may hinder individual long-term management, population-level interventions, and policy-making efforts for CVD prevention. Our study examined the risk of premature CVD development based on the current functional status rather than a diagnosis of a causative disease. Young adults with disabilities were at a greater CVD risk than their counterparts, indicating a dual burden arising from both the disability itself and the subsequent CVD risk.

3. Strengths and limitations

A. Strengths

To the best of our knowledge, this study adds novel findings by longitudinally investigating the association between disability and CVD in the young population that has been relatively understudied. All Korean adults are eligible for biennial national health check-ups, and we obtained data from eligible participants who underwent at least one examination between 2009 and 2014. In particular, disabled participants in this study represented approximately 40% of all young adults, aged 20–39 years, who were registered with disabilities in Korea.[15] Given the scarcity of extensive data on the intersection of understudied groups, young

adults, and those with disabilities, utilizing large, population-based nationwide data not only enhanced the statistical power and allowed for stratifications and subgroup analyses but also improved the representativeness of the findings.

The disability information was obtained from the national disability registry. It is nationally managed under relevant laws and predetermined medical criteria and includes information on registration date, severity, and type of disability. The findings derived from the linkage between the national registry and healthcare claims data can be valuable for conducting further epidemiological research on disability and informing relevant policies for CVD prevention.

B. Limitations

This study had several limitations. First, a general limitation in disability research may also apply to our study; the definition and operationalization of disability may vary by country or research, making the direct comparisons challenging. For instance, according to the World Health Survey, disability prevalence is estimated to be 15.6% of the global adult population, while the Global Burden of Disease reports a rate of 19.4%.[29] It also varies by country; in high-income countries, the prevalence was estimated at 22% in the United States[95] and 15% in Norway.[96] Compared to Norway and other high-income countries that have universal health coverage, Korea has a lower prevalence at 5%. This lower prevalence can be attributed to the fact that disability registration in Korea primarily relies on predetermined medical criteria. It may not fully capture the disabilities resulting from social activity and participation limitations. The evaluation for these types of disabilities could not be considered, as it may not have been registered in the disability registry. Nevertheless, this approach allows for a more objective definition and assessment of disability and offers

the advantage of utilizing medical claims data, national health examination data, and official death statistics.

Second, there was a difference in the rate of health check-up participation between people with and without disabilities. Based on the disability statistics, during the cohort enrollment period of our study, among young adults, 80% of non-disabled individuals received check-ups, while approximately 70% of individuals with disabilities did so.[91,97,98] Our selection of study participants among health check-up examinees may introduce selection bias if not accounting for those who did not undergo check-ups. Other studies using the National Sample Cohort database, which sampled data from the entire Korean population, can offer an indirect perspective on the disparities between check-up attendees and non-attendees.[99-101] Specifically, older age, rural residency, and lower income levels were associated with a higher likelihood of not undergoing check-ups. These factors were also recognized as critical social determinants of CVD.[102] Moreover, a lower check-up rate was observed among individuals with more severe disabilities and specific subtypes, such as impairments due to brain injury and mental disability, even after adjusting for socioeconomic factors.[99-101,103] Hence, when interpreting the results of this study, it is essential to consider potential differences in characteristics between participants and non-participants. Considering higher proportions of unfavorable social determinants and severe disabilities among non-participants, our estimates may underestimate the actual risk among disabled people.

Third, the participants' multiple disabilities could not be considered. We obtained the database from the NHID linked to disability information from the KNDRS. The constructed dataset contains disability information about the major type when having multiple impairments. However, information regarding the presence and type of multiple disabilities was not obtainable, and we could not consider the impact of multiple disabilities. The direct

estimation of the prevalence of multiple disabilities has not been reported before. Alternatively, we indirectly estimated the prevalence of multiple disabilities based on the 2014 National Survey on the Status of Persons with Disabilities, which surveyed 6,824 individuals with disabilities across the nation.[91] According to the survey, the number of multiple disabilities was approximated to be 238,532 accounting for 9.5% of the total disability population. Among them, the majority of multiple disabilities involve two disabilities (85.2%), while three or more overlapping disabilities account for 14.8%. Moreover, 40.6% of multiple disabilities involve the same type of disability. Therefore, the findings from the type-specific risk assessment appear to be less affected by multiple disabilities.[91]

Lastly, this study could not account for other established risk factors for CVD, such as education and dietary intake, which could have influenced the outcomes. In addition, lifestyle-related variables were collected through self-reported questionnaires, which may introduce bias or measurement error. These limitations underscore the need for caution when interpreting the study's results.

V. CONCLUSION

Various disabilities consistently elevate the risk of premature CVD, even after comprehensive adjustments for sociodemographic, biomedical, and lifestyle-related factors. Individuals with long-term disability are particularly susceptible to a heightened CVD risk compared to those with short-term disability or without any disability. Similarly, the severity of disability was observed to be gradually associated with CVD. In young adults with disabilities in addition to caring for the disability itself, the CVD burden should also be managed and reduced. Our findings emphasize the critical need for tailored CVD management and preventative measures in this vulnerable population.

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APPENDICES

Appendix 1. Baseline characteristics of the total eligible population based on disability (N =7,711,487)

Variables	Total (N = 7,711,487)	No Disability (N = 7,591,200)	Disability (N = 120,287)	p-value
Age, y	30 [26-35]	30 [26-35]	33 [28-36]	< 0.001
Sex				< 0.001
Female	3,225,515 (41.8)	3,199,076 (42.1)	26,439 (22.0)	
Male	4,485,972 (58.2)	4,392,124 (57.9)	93,848 (78.0)	
Household income quartile				< 0.001
Q4, highest	1,090,034 (14.1)	1,078,228 (14.2)	11,806 (9.8)	
Q3	2,270,098 (29.4)	2,242,287 (29.5)	27,811 (23.1)	
Q2	2,584,414 (33.5)	2,552,291 (33.6)	32,123 (26.7)	
Q1, lowest	1,766,941 (22.9)	1,718,394 (22.6)	48,547 (40.4)	
Residential area				< 0.001
Metropolitan	3,654,553 (47.4)	3,605,736 (47.5)	48,817 (40.6)	
Urban	3,548,235 (46.0)	3,488,625 (46.0)	59,610 (49.6)	
Rural	508,699 (6.6)	496,839 (6.5)	11,860 (9.9)	
Charlson comorbidity index				< 0.001
0	4,985,266 (64.7)	4,915,476 (64.8)	69,790 (58.0)	
1	1,626,222 (21.1)	1,601,091 (21.1)	25,131 (20.9)	
2	646,106 (8.4)	632,242 (8.3)	13,864 (11.5)	
≥3	453,893 (5.9)	442,391 (5.8)	11,502 (9.6)	
Systolic blood pressure, mmHg	117.5 ±13.2	117.5 ±13.2	120.2 ±13.8	< 0.001
Diastolic blood pressure, mmHg	73.6 ±9.4	73.6 ±9.4	75.5 ±9.8	< 0.001
Body mass index, kg/m^2	23.0 ±3.7	23.0 ±3.7	23.9 ±4.1	< 0.001
Fasting glucose, mg/dL	90.9 ±16.8	90.9 ±16.7	93.5 ±22.2	< 0.001
Total cholesterol, mg/dL	184.2 ±33.9	184.1 ±33.8	185.5 ±36.5	< 0.001
Tobacco smoking				< 0.001
Never	4,299,084 (55.8)	4,237,688 (55.8)	61,396 (51.0)	
Past	769,184 (10.0)	756,075 (10.0)	13,109 (10.9)	
Current	2,643,219 (34.3)	2,597,437 (34.2)	45,782 (38.1)	
Alcohol consumption				< 0.001
None	2,862,342 (37.1)	2,805,572 (37.0)	56,770 (47.2)	
1-2 times/week	3,926,288 (50.9)	3,878,700 (51.1)	47,588 (39.6)	
≥3 times/week	922,857 (12.0)	906,928 (12.0)	15,929 (13.2)	
Physical exercise				< 0.001
None	3,632,394 (47.1)	3,573,207 (47.1)	59,187 (49.2)	
1-2 times/week	2,684,453 (34.8)	2,647,507 (34.9)	36,946 (30.7)	
≥3 times/week	1,394,640 (18.1)	1,370,486 (18.1)	24,154 (20.1)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

Appendix 2. The comparison of characteristics between each disability type and the respective matched cohort: external disability and its matched general cohort

Variables	Matched general cohort (N = 915,000)	External disability (N = 91,500)	p-value
Age, y	*34 [29-37]*	*34 [29-37]*	*1.000*
Sex, Male	*744,730 (74.0)*	*74,473 (7.4)*	*1.000*
Household income quartile			< 0.001
Q4, highest	170,452 (18.6)	10,690 (11.7)	
Q3	299,278 (32.7)	26,016 (28.4)	
Q2	276,672 (30.2)	29,141 (31.9)	
Q1, lowest	168,598 (18.4)	25,653 (28.0)	
Residential area			< 0.001
Metropolitan	427,353 (46.7)	38,143 (41.7)	
Urban	427,942 (46.8)	45,570 (49.8)	
Rural	59,705 (6.5)	7,787 (8.5)	
Charlson comorbidity index			< 0.001
0	588,802 (64.4)	52,650 (57.5)	
1	182,918 (20.0)	19,546 (21.4)	
2	84,738 (9.3)	10,530 (11.5)	
≥3	58,542 (6.4)	8,774 (9.6)	
Systolic blood pressure, mmHg	120.4 ±13.2	121.0 ±13.6	< 0.001
Diastolic blood pressure, mmHg	75.5 ±9.6	76.0 ±9.8	< 0.001
Body mass index, kg/m^2	23.8 ±3.6	24.0 ±3.9	< 0.001
Fasting glucose, mg/dL	93.0 ±19.2	93.9 ±22.0	< 0.001
Total cholesterol, mg/dL	189.5 ±35.3	188.8 ±36.1	< 0.001
Tobacco smoking			< 0.001
Never	369,446 (40.4)	37,791 (41.3)	
Past	125,055 (13.7)	11,795 (12.9)	
Current	420,499 (46.0)	41,914 (45.8)	
Alcohol consumption			< 0.001
None	288,695 (31.6)	32,722 (35.8)	
1-2 times/week	489,623 (53.5)	43,735 (47.8)	
≥3 times/week	136,682 (14.9)	15,043 (16.4)	
Physical exercise			< 0.001
None	413,275 (45.2)	42,153 (46.1)	
1-2 times/week	330,096 (36.1)	30,475 (33.3)	
≥3 times/week	171,629 (18.8)	18,872 (20.6)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

Appendix 2. ***(continued)*** The comparisons of characteristics between each disability type and the respective matched cohort: internal disability and its matched general cohort

Variables	Matched general cohort (N = 27,330)	Internal disability (N = 2,733)	p-value
Age, y	*34 [30-37]*	*34 [30-37]*	*1.000*
Sex, Male	*19,280 (70.6)*	*1,928 (70.6)*	*1.000*
Household income quartile			< 0.001
Q4, highest	4,434 (16.2)	314 (11.5)	
Q3	8,458 (31.0)	681 (24.9)	
Q2	8,541 (31.3)	719 (26.3)	
Q1, lowest	5,897 (21.6)	1,019 (37.3)	
Residential area			< 0.001
Metropolitan	12,929 (47.3)	1,191 (43.6)	
Urban	12,720 (46.5)	1,331 (48.7)	
Rural	1,681 (6.2)	211 (7.7)	
Charlson comorbidity index			< 0.001
0	17,937 (65.6)	628 (23.0)	
1	5,339 (19.5)	913 (33.4)	
2	2,453 (9.0)	538 (19.7)	
≥3	1,601 (5.9)	654 (23.9)	
Systolic blood pressure, mmHg	119.3 ±13.3	123.0 ±15.9	< 0.001
Diastolic blood pressure, mmHg	74.9 ±9.7	77.4 ±11.0	< 0.001
Body mass index, kg/m^2	23.6 ±3.7	23.1 ±4.0	< 0.001
Fasting glucose, mg/dL	93.0 ±19.3	95.0 ±26.4	< 0.001
Total cholesterol, mg/dL	189.1 ±35.0	181.3 ±37.2	< 0.001
Tobacco smoking			< 0.001
Never	12,709 (46.5)	1,561 (57.1)	
Past	3,366 (12.3)	565 (20.7)	
Current	11,255 (41.2)	607 (22.2)	
Alcohol consumption			< 0.001
None	9,611 (35.2)	1,873 (68.5)	
1-2 times/week	13,788 (50.5)	722 (26.4)	
≥3 times/week	3,931 (14.4)	138 (5.1)	
Physical exercise			< 0.001
None	12,948 (47.4)	1,281 (46.9)	
1-2 times/week	9,396 (34.4)	870 (31.8)	
≥3 times/week	4,986 (18.2)	582 (21.3)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

Appendix 2. ***(continued)*** The comparisons of characteristics between each disability type and the respective matched cohort: developmental disability and its matched general cohort

Variables	Matched general cohort (N = 220,840)	Developmental disability (N = 22,084)	p-value
Age, y	*28 [23-34]*	*28 [23-34]*	*1.000*
Sex, Male	*150,240 (68.0)*	*15,024 (68.0)*	*1.000*
Household income quartile			< 0.001
Q4, highest	25,239 (11.4)	665 (3.0)	
Q3	54,776 (24.8)	891 (4.0)	
Q2	78,680 (35.6)	1,874 (8.5)	
Q1, lowest	62,145 (28.1)	18,654 (84.5)	
Residential area			< 0.001
Metropolitan	100,423 (45.5)	7,947 (36.0)	
Urban	104,589 (47.4)	10,896 (49.3)	
Rural	15,828 (7.2)	3,241 (14.7)	
Charlson comorbidity index			< 0.001
0	158,990 (72.0)	14,207 (64.3)	
1	37,673 (17.1)	4,039 (18.3)	
2	15,026 (6.8)	2,212 (10.0)	
≥3	9,151 (4.1)	1,626 (7.4)	
Systolic blood pressure, mmHg	118.0 ±12.9	116.9 ±13.8	< 0.001
Diastolic blood pressure, mmHg	73.7 ±9.2	73.5 ±9.7	< 0.001
Body mass index, kg/m^2	23.1 ±3.8	23.2 ±4.6	< 0.001
Fasting glucose, mg/dL	90.8 ±17.2	91.1 ±21.6	< 0.001
Total cholesterol, mg/dL	180.7 ±34.0	172.5 ±35.0	< 0.001
Tobacco smoking			< 0.001
Never	113,995 (51.6)	19,585 (88.7)	
Past	20,295 (9.2)	499 (2.3)	
Current	86,550 (39.2)	2,000 (9.1)	
Alcohol consumption			< 0.001
None	76,951 (34.8)	18,922 (85.7)	
1-2 times/week	114,759 (52.0)	2,555 (11.6)	
≥3 times/week	29,130 (13.2)	607 (2.8)	
Physical exercise			< 0.001
None	102,238 (46.3)	13,429 (60.8)	
1-2 times/week	74,440 (33.7)	4,685 (21.2)	
≥3 times/week	44,162 (20.0)	3,970 (18.0)	

Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

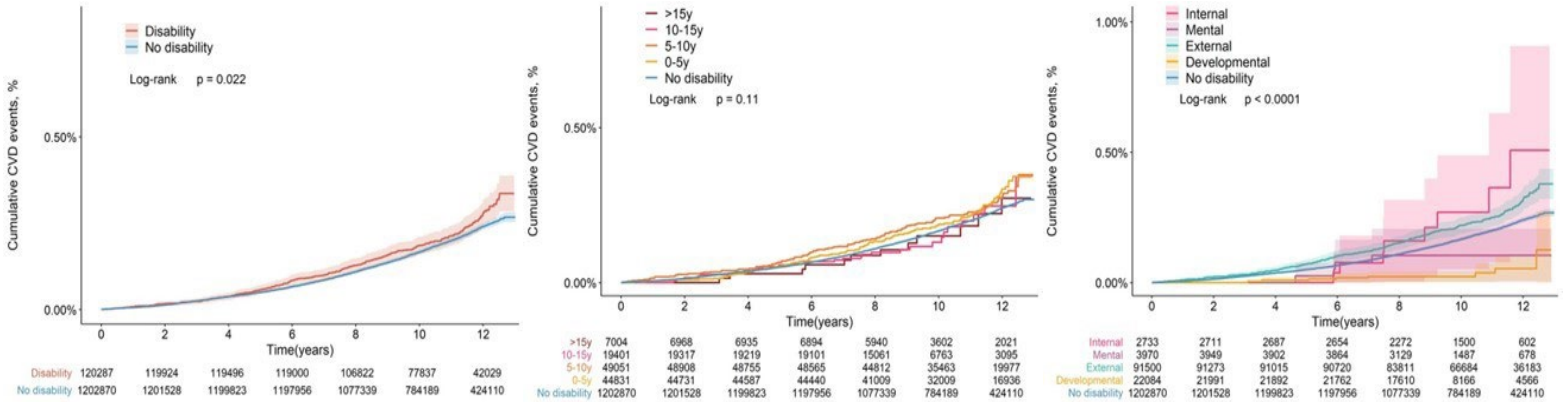
Appendix 2. ***(continued)*** The comparisons of characteristics between each disability type and the respective matched cohort: mental disability and its matched general cohort

Variables	Matched general cohort (N = 39,700)	Mental disability (N = 3,970)	p-value
Age, y	*35 [32-38]*	*35 [32-38]*	*1.000*
Sex, Male	*24,230 (61.0)*	*2,423 (61.0)*	*1.000*
Household income quartile			< 0.001
Q4, highest	6,065 (15.3)	137 (3.5)	
Q3	11,393 (28.7)	223 (5.6)	
Q2	12,461 (31.4)	389 (9.8)	
Q1, lowest	9,781 (24.6)	3,221 (81.1)	
Residential area			< 0.001
Metropolitan	18,674 (47.0)	1,536 (38.7)	
Urban	18,588 (46.8)	1,813 (45.7)	
Rural	2,438 (6.1)	621 (15.6)	
Charlson comorbidity index			< 0.001
0	26,687 (67.2)	2,305 (58.1)	
1	7,491 (18.9)	633 (15.9)	
2	3,316 (8.4)	584 (14.7)	
≥3	2,206 (5.6)	448 (11.3)	
Systolic blood pressure, mmHg	118.5 ±13.7	117.4 ±13.5	< 0.001
Diastolic blood pressure, mmHg	74.5 ±9.9	74.0 ±9.6	< 0.001
Body mass index, kg/m^2	23.5 ±3.7	25.3 ±4.6	< 0.001
Fasting glucose, mg/dL	93.0 ±18.8	96.9 ±25.0	< 0.001
Total cholesterol, mg/dL	188.8 ±34.8	184.9 ±38.5	< 0.001
Tobacco smoking			< 0.001
Never	20,399 (51.4)	2,459 (61.9)	
Past	4,484 (11.3)	250 (6.3)	
Current	14,817 (37.3)	1,261 (31.8)	
Alcohol consumption			< 0.001
None	15,357 (38.7)	3,253 (81.9)	
1-2 times/week	18,722 (47.2)	576 (14.5)	
≥3 times/week	5,621 (14.2)	141 (3.6)	
Physical exercise			< 0.001
None	19,470 (49.0)	2,324 (58.5)	
1-2 times/week	13,071 (32.9)	916 (23.1)	
≥3 times/week	7,159 (18.0)	730 (18.4)	

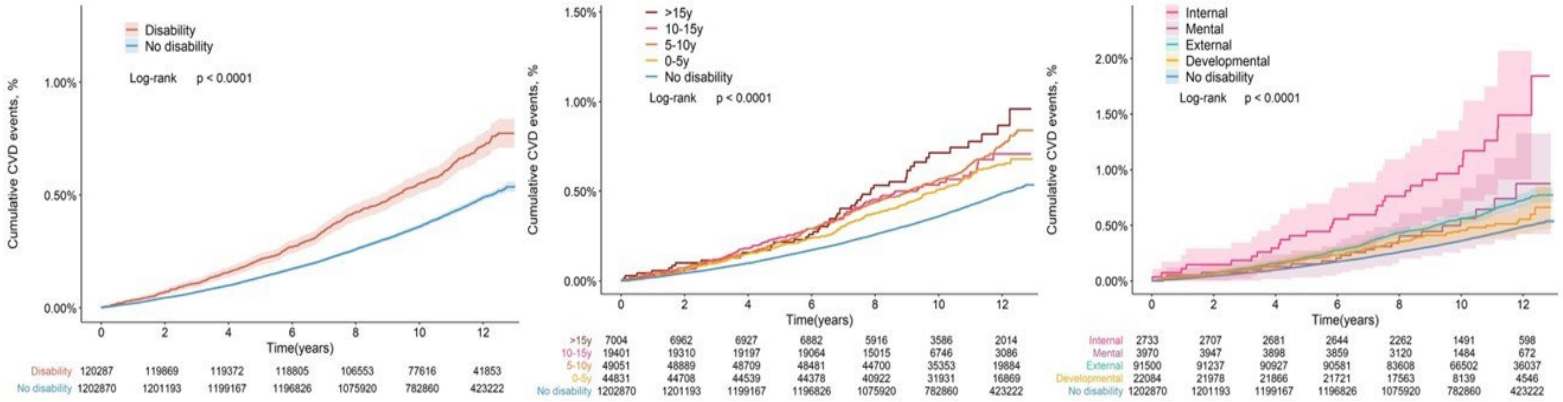
Data is presented as median [interquartile range], frequency (percent), or mean ± standard deviation.

Appendix 3. Overall cumulative incidence of sub-outcomes according to the presence, duration, and type of disability

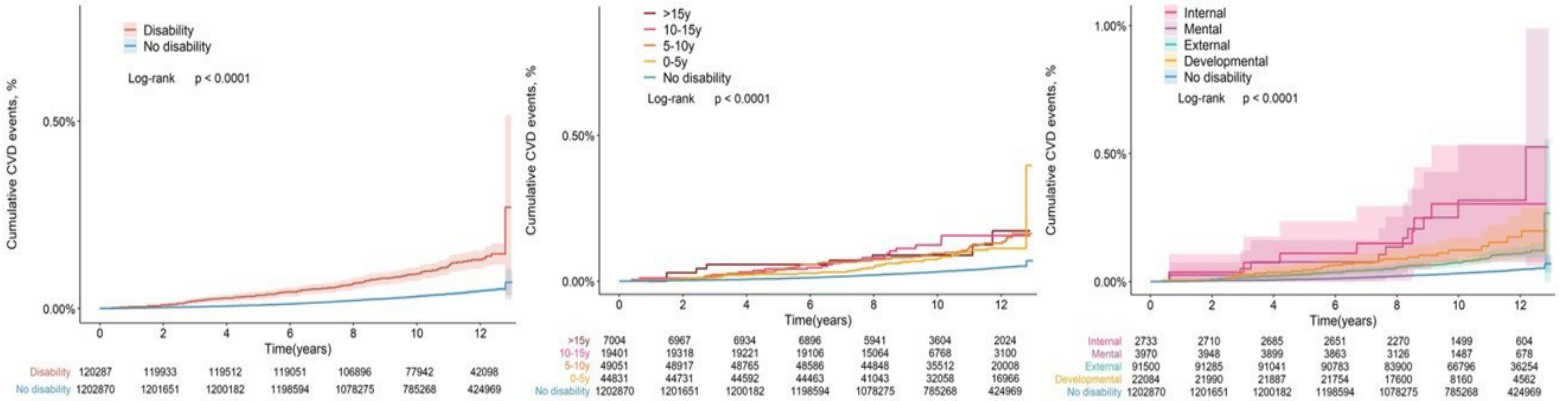
(a) Myocardial infarction



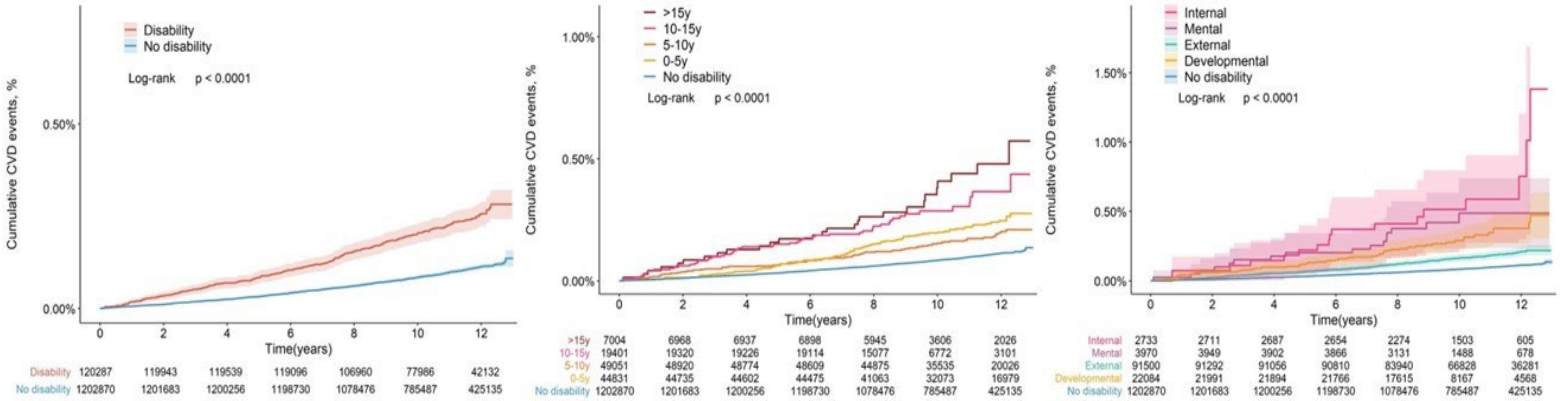
(b) Stroke



(c) Heart failure



(d) Cardiovascular death



Appendix 4. Sensitivity analyses using the total eligible population: cardiovascular disease (CVD) risk according to disability attributes

Disability attributes	No. of CVD events	Observed person-years	Rate per 100,000	Hazard ratio (95% confidence interval) for CVD			
				Unadjusted	Model 1	Model 2	Model 3
No disability	38,497	81,304,720	47.3	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
External disability							
Severity							
Mild	751	760,814	98.7	2.07 (1.93-2.23)	1.36 (1.26-1.46)	1.26 (1.17-1.35)	1.25 (1.16-1.34)
Severe	259	221,082	117.2	2.49 (2.20-2.81)	1.80 (1.60-2.04)	1.83 (1.62-2.07)	1.90 (1.68-2.15)
Duration							
0-5y	386	396,254	97.4	2.04 (1.85-2.25)	1.42 (1.28-1.57)	1.31 (1.18-1.45)	1.30 (1.17-1.43)
5-10y	439	415,131	105.7	2.20 (2.00-2.41)	1.45 (1.32-1.59)	1.38 (1.26-1.52)	1.38 (1.25-1.51)
10-15y	132	121,390	108.7	2.44 (2.05-2.89)	1.54 (1.30-1.83)	1.46 (1.23-1.73)	1.47 (1.24-1.74)
>15y	53	49,121	107.9	2.30 (1.76-3.02)	1.53 (1.17-2.01)	1.54 (1.18-2.02)	1.64 (1.25-2.15)
Subtype							
Physical	755	686,215	110	2.31 (2.15-2.48)	1.47 (1.37-1.58)	1.36 (1.27-1.46)	1.35 (1.25-1.45)
Brain injury	46	35,079	131.1	2.87 (2.15-3.83)	2.26 (1.69-3.02)	2.50 (1.87-3.34)	2.64 (1.98-3.52)
Visual	131	153,162	85.5	1.81 (1.53-2.15)	1.30 (1.10-1.55)	1.23 (1.04-1.46)	1.24 (1.04-1.47)
Hearing	65	90,012	72.2	1.52 (1.19-1.94)	1.27 (1.00-1.62)	1.36 (1.07-1.74)	1.45 (1.14-1.85)
Language	12	12,975	92.5	1.94 (1.10-3.42)	1.33 (0.76-2.34)	1.53 (0.87-2.69)	1.66 (0.94-2.93)
Facial	1	4,453	22.5	0.48 (0.07-3.43)	0.36 (0.05-2.58)	0.32 (0.05-2.30)	0.32 (0.05-2.29)
Internal disability							
Severity							
Mild	17	16,380	103.8	2.32 (1.44-3.73)	1.58 (0.98-2.54)	1.46 (0.91-2.34)	1.58 (0.98-2.54)
Severe	37	10,497	352.5	7.79 (5.65-10.74)	5.33 (3.86-7.36)	4.21 (3.05-5.81)	4.55 (3.29-6.28)
Duration							
0-5y	26	16,007	162.4	3.60 (2.45-5.29)	2.55 (1.73-3.74)	2.07 (1.41-3.04)	2.23 (1.52-3.28)
5-10y	23	9,882	232.7	5.08 (3.37-7.64)	3.34 (2.22-5.03)	3.19 (2.12-4.80)	3.46 (2.30-5.21)
10-15y	5	979	510.5	13.16 (5.49-31.57)	8.39 (3.50-20.12)	7.61 (3.21-18.03)	8.64 (3.65-20.49)
>15y	-	9	-	-	-	-	-
Subtype							
Renal	42	14,512	289.4	6.38 (4.71-8.63)	4.35 (3.22-5.89)	3.46 (2.55-4.68)	3.82 (2.82-5.18)

Respiratory	3	938	319.9	7.11 (2.29-22.04)	5.18 (1.68-16.01)	5.91 (1.91-18.32)	6.20 (2.00-19.22)
Liver ds.	-	1,307	-	-	-	-	-
Ostomy	-	3,567	-	-	-	-	-
Epilepsy	9	6,553	137.3	3.02 (1.57-5.8)	2.09 (1.09-4.01)	2.05 (1.07-3.94)	2.17 (1.13-4.16)
Developmental disability							
Duration							
0-5y	25	45,357	55.1	1.22 (0.83-1.81)	1.49 (1.01-2.21)	1.56 (1.05-2.31)	1.76 (1.19-2.60)
5-10y	70	86,807	80.6	1.77 (1.40-2.24)	1.89 (1.49-2.39)	1.99 (1.57-2.52)	2.33 (1.84-2.95)
10-15y	51	57,186	89.2	2.16 (1.64-2.85)	2.05 (1.56-2.71)	2.35 (1.79-3.10)	2.77 (2.10-3.65)
>15y	34	20,850	163.1	3.85 (2.75-5.38)	2.54 (1.82-3.56)	2.97 (2.12-4.16)	3.62 (2.58-5.07)
Subtype							
Intellectual	176	201,417	87.4	1.99 (1.71-2.30)	1.96 (1.69-2.28)	2.14 (1.84-2.48)	2.50 (2.15-2.90)
Autism	4	8,784	45.5	1.06 (0.40-2.83)	1.73 (0.65-4.61)	1.91 (0.72-5.10)	2.49 (0.94-6.65)
Mental disability							
Duration							
0-5y	25	20,925	119.5	2.66 (1.80-3.94)	1.79 (1.21-2.65)	1.73 (1.17-2.56)	1.67 (1.12-2.47)
5-10y	18	14,387	125.1	2.90 (1.83-4.60)	1.76 (1.11-2.79)	1.65 (1.04-2.62)	1.64 (1.03-2.60)
10-15y	5	2,101	238	6.15 (2.56-14.76)	3.64 (1.52-8.70)	3.80 (1.58-9.12)	3.78 (1.57-9.09)
>15y	-	129	-	-	-	-	-

Model 1, matched on age, sex, and index year, and adjusted for income and urbanicity; Model 2, extended version of Model 1 with further adjustments for body mass index, systolic blood pressure, fasting glucose, total cholesterol, and Charlson comorbidity index; Model 3, extended version of Model 2 with further adjustments for smoking, drinking, and physical activity.

Appendix 5. The adjusted cardiovascular disease (CVD) risk by disability attributes before and after overlap weighting using propensity score in each disability type compared to the respective matched general cohort

Disability attributes	Hazard ratio (95% confidence interval) for CVD	
	Before weighting*	After weighting
External disability		
Severity, category		
Mild	1.22 (1.13-1.32)	1.19 (1.05-1.35)
Severe	1.89 (1.64-2.17)	1.73 (1.37-2.19)
Severity, grade		
Grade 6 (Least severe)	1.19 (1.07-1.31)	1.18 (1.01-1.38)
Grade 5	1.22 (1.04-1.44)	1.09 (0.85-1.40)
Grade 4	1.41 (1.14-1.73)	1.42 (1.03-1.97)
Grade 3	1.96 (1.63-2.37)	1.93 (1.40-2.66)
Grade 2	1.56 (1.19-2.04)	1.34 (0.87-2.06)
Grade 1 (Most severe)	2.32 (1.66-3.24)	1.89 (1.07-3.33)
Duration		
0-5y	1.29 (1.15-1.44)	1.26 (1.06-1.50)
5-10y	1.38 (1.24-1.53)	1.31 (1.11-1.55)
10-15y	1.36 (1.13-1.65)	1.35 (1.00-1.84)
>15y	1.42 (1.05-1.93)	1.26 (0.78-2.05)
Subtype		
Physical	1.32 (1.22-1.43)	1.27 (1.12-1.44)
Brain injury	2.76 (1.98-3.86)	2.67 (1.48-4.81)
Visual	1.20 (0.99-1.45)	1.15 (0.85-1.54)
Hearing	1.44 (1.10-1.88)	1.33 (0.87-2.02)
Language	1.86 (0.99-3.50)	1.89 (0.68-5.26)
Facial	0.36 (0.04-2.91)	0.47 (0.04-5.99)
Internal disability		
Severity, category		
Mild	1.43 (0.82-2.48)	1.16 (0.44-3.06)
Severe	3.73 (2.22-6.29)	4.82 (1.53-15.19)
Severity, grade		
Grade 6 (Least severe)	-	-
Grade 5	1.84 (0.90-3.77)	1.27 (0.32-5.06)
Grade 4	1.57 (0.62-4.00)	1.24 (0.24-6.42)
Grade 3	6.56 (2.33-18.45)	5.11 (0.51-51.67)
Grade 2	3.46 (1.93-6.21)	5.87 (1.32-26.15)
Grade 1 (Most severe)	1.62 (0.12-21.50)	0.59 (0.01-46.94)
Duration		
0-5y	1.39 (0.83-2.35)	1.63 (0.61-4.38)
5-10y	3.47 (2.01-5.99)	2.80 (0.93-8.38)
10-15y	17.86 (3.63-87.89)	23.96 (0.03-17641.58)
>15y	-	-
Subtype		

Renal	2.88 (1.78-4.66)	3.75 (1.30-10.77)
Respiratory	11.69 (2.46-55.63)	6.94 (0.47-101.42)
Liver ds.	-	-
Ostomy	-	-
Epilepsy	2.13 (0.98-4.61)	1.22 (0.30-4.98)
Developmental disability		
Severity, grade		
Grade 3 (Least severe)	2.50 (1.85-3.36)	2.60 (1.26-5.40)
Grade 2	2.21 (1.57-3.11)	2.43 (1.08-5.47)
Grade 1 (Most severe)	5.04 (3.50-7.26)	7.18 (2.72-18.95)
Duration		
0-5y	2.09 (1.32-3.31)	2.49 (0.88-7.09)
5-10y	2.88 (2.12-3.92)	3.54 (1.62-7.76)
10-15y	2.85 (1.99-4.08)	3.20 (1.42-7.20)
>15y	3.56 (2.31-5.50)	3.82 (1.14-12.73)
Subtype		
Intellectual	2.79 (2.23-3.49)	3.23 (1.93-5.38)
Autism	2.98 (0.95-9.36)	4.27 (0.14-127.61)
Mental disability		
Severity, grade		
Grade 3 (Least severe)	1.39 (0.87-2.22)	1.04 (0.41-2.61)
Grade 2	2.05 (1.11-3.80)	2.62 (0.49-14.09)
Grade 1 (Most severe)	2.06 (0.54-7.86)	3.17 (0.06-158.72)
Duration		
0-5y	1.63 (0.99-2.67)	1.67 (0.61-4.61)
5-10y	1.49 (0.84-2.66)	1.01 (0.27-3.88)
10-15y	2.45 (0.83-7.22)	0.78 (0.07-8.48)
>15y	-	-

The model before weighting* has been corresponded to the fully adjusted model (Model 3), which has been adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching for age, sex, and index year.

Appendix 6. The E-value for hazard ratios (HRs) and confidence interval (CI) limits from the fully adjusted Model 3 according to disability attributes

Disability attributes	Adjusted HR (95% CI)	E-value	
		for HR	for CI limit
External disability			
Severity, category			
Mild	1.22 (1.13-1.32)	1.75	1.51
Severe	1.89 (1.64-2.17)	3.18	2.66
Severity, grade			
Grade 6 (Least severe)	1.19 (1.07-1.31)	1.66	1.35
Grade 5	1.22 (1.04-1.44)	1.75	1.25
Grade 4	1.41 (1.14-1.73)	2.17	1.55
Grade 3	1.96 (1.63-2.37)	3.34	2.63
Grade 2	1.56 (1.19-2.04)	2.49	1.66
Grade 1 (Most severe)	2.32 (1.66-3.24)	4.08	2.72
Duration			
0-5y	1.29 (1.15-1.44)	1.90	1.58
5-10y	1.38 (1.24-1.53)	2.10	1.79
10-15y	1.36 (1.13-1.65)	2.07	1.50
>15y	1.42 (1.05-1.93)	2.19	1.27
Subtype			
Physical	1.32 (1.22-1.43)	1.97	1.73
Brain injury	2.76 (1.98-3.86)	4.97	3.36
Visual	1.20 (0.99-1.45)	1.69	1.00
Hearing	1.44 (1.10-1.88)	2.23	1.42
Language	1.86 (0.99-3.50)	3.12	1.00
Facial	0.36 (0.04-2.91)	5.05	1.00
Internal disability			
Severity, category			
Mild	1.43 (0.82-2.48)	2.21	1.00
Severe	3.73 (2.22-6.29)	6.93	3.86
Severity, grade			
Grade 6 (Least severe)		-	-
Grade 5	1.84 (0.90-3.77)	3.09	1.00
Grade 4	1.57 (0.62-4.00)	2.52	1.00
Grade 3	6.56 (2.33-18.45)	12.60	4.09
Grade 2	3.46 (1.93-6.21)	6.38	3.26
Grade 1 (Most severe)	1.62 (0.12-21.50)	2.63	1.00
Duration			
0-5y	1.39 (0.83-2.35)	2.13	1.00
5-10y	3.47 (2.01-5.99)	6.41	3.44
10-15y	17.86 (3.63-87.89)	35.21	6.72
>15y	-	-	-
Subtype			
Renal	2.88 (1.78-4.66)	5.21	2.96

Respiratory	11.69 (2.46-55.63)	22.87	4.35
Liver ds.	-	-	-
Ostomy	-	-	-
Epilepsy	2.13 (0.98-4.61)	3.68	1.00
Developmental disability			
Severity, grade			
Grade 3 (Least severe)	2.50 (1.85-3.36)	4.43	3.11
Grade 2	2.21 (1.57-3.11)	3.85	2.51
Grade 1 (Most severe)	5.04 (3.50-7.26)	9.55	6.46
Duration			
0-5y	2.09 (1.32-3.31)	3.60	1.97
5-10y	2.88 (2.12-3.92)	5.21	3.65
10-15y	2.85 (1.99-4.08)	5.15	3.40
>15y	3.56 (2.31-5.5)	6.59	4.05
Subtype			
Intellectual	2.79 (2.23-3.49)	5.03	3.89
Autism	2.98 (0.95-9.36)	5.40	1.00
Mental disability			
Severity, grade			
Grade 3 (Least severe)	1.39 (0.87-2.22)	2.12	1.00
Grade 2	2.05 (1.11-3.80)	3.52	1.45
Grade 1 (Most severe)	2.06 (0.54-7.86)	3.53	1.00
Duration			
0-5y	1.63 (0.99-2.67)	2.63	1.00
5-10y	1.49 (0.84-2.66)	2.34	1.00
10-15y	2.45 (0.83-7.22)	4.34	1.00
>15y	-	-	-

The model used for E-value has been corresponded to the full adjusted model (Model 3), which has been adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching for age, sex, and index year. The reference group has been matched respectively with the general cohort for each type of disability.

Appendix 7. The fully adjusted risk of measured variables for cardiovascular disease (CVD)

Variables	Hazard ratio (95% confidence interval) for CVD			
	External	Internal	Developmental	Mental
Age, matched	-	-	-	-
Sex, matched	-	-	-	-
Household income, Q4	Ref.	Ref.	Ref.	Ref.
Q3	1.09 (1.02-1.17)	1.44 (0.93-2.22)	1.29 (1.01-1.65)	1.33 (0.89-2.00)
Q2	1.24 (1.15-1.33)	1.15 (0.73-1.83)	1.27 (1.00-1.63)	1.32 (0.87-2.01)
Q1, lowest	1.32 (1.22-1.44)	1.62 (1.00-2.62)	1.24 (0.96-1.61)	1.43 (0.92-2.21)
Residential area, Metropolitan	Ref.	Ref.	Ref.	Ref.
Urban	1.05 (1.00-1.11)	1.05 (0.78-1.41)	0.99 (0.86-1.14)	1.08 (0.84-1.40)
Rural	1.12 (1.02-1.23)	0.89 (0.49-1.64)	1.24 (0.98-1.57)	1.56 (0.99-2.45)
Body mass index, kg/m^2	1.05 (1.04-1.06)	1.02 (0.99-1.06)	1.05 (1.03-1.07)	1.06 (1.02-1.09)
Systolic blood pressure, mmHg	1.03 (1.03-1.03)	1.04 (1.02-1.05)	1.03 (1.02-1.03)	1.02 (1.01-1.03)
Fasting glucose, <100	Ref.	Ref.	Ref.	Ref.
100-125	0.95 (0.90-1.01)	0.91 (0.65-1.28)	1.06 (0.89-1.26)	0.88 (0.66-1.18)
≥126	1.52 (1.38-1.68)	1.28 (0.71-2.32)	1.56 (1.17-2.09)	1.34 (0.74-2.42)
Total cholesterol, mg/dL	1.01 (1.00-1.01)	1.01 (1.00-1.01)	1.01 (1.00-1.01)	1.01 (1.00-1.01)
Charlson comorbidity index, 0	Ref.	Ref.	Ref.	Ref.
1	1.04 (0.98-1.11)	1.00 (0.68-1.48)	1.06 (0.88-1.28)	1.35 (0.98-1.88)
2	1.23 (1.14-1.33)	1.34 (0.87-2.07)	1.47 (1.18-1.83)	1.46 (1.00-2.13)
≥3	1.60 (1.48-1.73)	1.79 (1.16-2.77)	2.29 (1.82-2.90)	1.81 (1.19-2.77)
Tobacco smoking, Never	Ref.	Ref.	Ref.	Ref.
Past	1.14 (1.04-1.24)	0.99 (0.59-1.64)	1.14 (0.88-1.49)	0.86 (0.53-1.39)
Current	1.83 (1.72-1.96)	1.97 (1.34-2.89)	1.81 (1.51-2.17)	1.91 (1.37-2.67)
Alcohol consumption, None	Ref.	Ref.	Ref.	Ref.
1-2 times/week	0.83 (0.78-0.88)	0.93 (0.65-1.32)	0.89 (0.75-1.05)	0.84 (0.62-1.13)
≥3 times/week	0.84 (0.78-0.91)	1.11 (0.71-1.74)	0.82 (0.66-1.02)	1.00 (0.68-1.46)
Physical exercise, None	Ref.	Ref.	Ref.	Ref.
1-2 times/week	0.92 (0.87-0.97)	1.10 (0.80-1.52)	0.92 (0.79-1.08)	0.91 (0.69-1.22)
≥3 times/week	0.98 (0.92-1.05)	1.26 (0.87-1.84)	0.89 (0.74-1.07)	1.11 (0.80-1.54)

Appendix 8. The cardiovascular disease (CVD) risk with the Fine-Gray sub-distribution hazard model

Disability attributes	Hazard ratio (95% confidence interval) for CVD			
	Unadjusted	Model 1	Model 2	Model 3
External disability				
Severity, category				
Mild	1.36 (1.26-1.46)	1.30 (1.21-1.40)	1.24 (1.15-1.33)	1.22 (1.14-1.32)
Severe	1.94 (1.71-2.20)	1.79 (1.58-2.03)	1.81 (1.59-2.06)	1.89 (1.66-2.15)
Severity, grade				
Grade 6 (Least severe)	1.33 (1.21-1.46)	1.29 (1.18-1.41)	1.21 (1.11-1.33)	1.19 (1.08-1.30)
Grade 5	1.36 (1.18-1.58)	1.31 (1.13-1.51)	1.23 (1.06-1.42)	1.22 (1.06-1.41)
Grade 4	1.46 (1.21-1.76)	1.36 (1.13-1.65)	1.39 (1.14-1.68)	1.41 (1.16-1.71)
Grade 3	2.17 (1.84-2.56)	2.02 (1.71-2.38)	1.97 (1.65-2.34)	1.96 (1.65-2.34)
Grade 2	1.46 (1.15-1.86)	1.35 (1.06-1.72)	1.45 (1.13-1.84)	1.56 (1.22-1.99)
Grade 1 (Most severe)	2.22 (1.66-2.97)	2.02 (1.50-2.70)	2.07 (1.53-2.81)	2.32 (1.72-3.15)
Duration				
0-5y	1.40 (1.27-1.55)	1.37 (1.24-1.51)	1.30 (1.18-1.44)	1.29 (1.17-1.43)
5-10y	1.52 (1.39-1.67)	1.44 (1.31-1.58)	1.39 (1.27-1.53)	1.38 (1.25-1.52)
10-15y	1.49 (1.25-1.77)	1.39 (1.17-1.66)	1.34 (1.12-1.61)	1.36 (1.14-1.63)
>15y	1.47 (1.11-1.93)	1.36 (1.03-1.78)	1.34 (1.02-1.76)	1.42 (1.08-1.87)
Subtype				
Physical	1.48 (1.38-1.59)	1.42 (1.32-1.52)	1.34 (1.25-1.44)	1.32 (1.23-1.42)
Brain injury	2.33 (1.73-3.12)	2.11 (1.57-2.83)	2.57 (1.90-3.48)	2.76 (2.04-3.74)
Visual	1.30 (1.09-1.55)	1.24 (1.04-1.48)	1.18 (0.99-1.39)	1.20 (1.01-1.43)
Hearing	1.37 (1.07-1.75)	1.30 (1.02-1.65)	1.35 (1.06-1.72)	1.44 (1.12-1.84)
Language	1.61 (0.91-2.85)	1.47 (0.84-2.59)	1.68 (0.91-3.10)	1.86 (1.02-3.40)
Facial	0.43 (0.06-3.05)	0.40 (0.05-2.90)	0.34 (0.03-3.47)	0.36 (0.04-3.47)
Internal disability				
Severity, category				
Mild	1.47 (0.91-2.36)	1.44 (0.89-2.32)	1.22 (0.75-2.00)	1.43 (0.86-2.38)

Severe	5.33 (3.76-7.56)	5.01 (3.50-7.17)	3.25 (2.03-5.19)	3.73 (2.25-6.19)
Severity, grade				
Grade 6 (Least severe)	-	-	-	-
Grade 5	1.73 (0.95-3.14)	1.76 (0.96-3.21)	1.39 (0.74-2.62)	1.84 (0.97-3.50)
Grade 4	1.74 (0.77-3.91)	1.60 (0.71-3.62)	1.53 (0.65-3.60)	1.57 (0.63-3.93)
Grade 3	4.70 (1.92-11.52)	4.16 (1.68-10.33)	5.65 (2.29-13.95)	6.56 (2.62-16.40)
Grade 2	5.60 (3.81-8.24)	5.32 (3.61-7.86)	2.97 (1.77-4.99)	3.46 (1.99-6.03)
Grade 1 (Most severe)	3.24 (0.42-24.85)	3.31 (0.32-34.70)	1.41 (0.08-23.78)	1.62 (0.06-47.46)
Duration				
0-5y	2.15 (1.46-3.16)	2.09 (1.43-3.06)	1.23 (0.77-1.98)	1.39 (0.84-2.31)
5-10y	3.71 (2.43-5.67)	3.55 (2.28-5.53)	3.14 (1.96-5.04)	3.47 (2.14-5.64)
10-15y	16.67 (4.86-57.20)	15.92 (4.32-58.67)	16.96 (4.87-59.03)	17.86 (4.70-67.89)
>15y	-	-	-	-
Subtype				
Renal	3.89 (2.85-5.32)	3.80 (2.76-5.23)	2.33 (1.56-3.49)	2.88 (1.85-4.48)
Respiratory	6.09 (1.45-25.56)	5.58 (1.38-22.50)	8.56 (1.64-44.70)	11.69 (2.53-53.98)
Liver ds.	-	-	-	-
Ostomy	-	-	-	-
Epilepsy	2.17 (1.11-4.22)	1.94 (0.99-3.80)	2.03 (1.02-4.06)	2.13 (1.04-4.35)
Developmental disability				
Severity, grade				
Grade 3 (Least severe)	2.03 (1.61-2.57)	1.97 (1.54-2.52)	2.17 (1.67-2.81)	2.50 (1.91-3.26)
Grade 2	1.86 (1.42-2.43)	1.79 (1.34-2.38)	1.87 (1.38-2.53)	2.21 (1.62-3.01)
Grade 1 (Most severe)	2.80 (2.14-3.67)	2.68 (2.00-3.58)	4.16 (2.99-5.80)	5.04 (3.58-7.10)
Duration				
0-5y	1.73 (1.17-2.57)	1.67 (1.12-2.48)	1.87 (1.23-2.84)	2.09 (1.38-3.17)
5-10y	2.21 (1.74-2.79)	2.13 (1.65-2.73)	2.46 (1.88-3.22)	2.88 (2.18-3.80)
10-15y	2.27 (1.72-3.00)	2.19 (1.63-2.96)	2.48 (1.79-3.45)	2.85 (2.03-4.00)
>15y	2.31 (1.65-3.23)	2.18 (1.54-3.11)	2.86 (1.93-4.25)	3.56 (2.40-5.30)
Subtype				

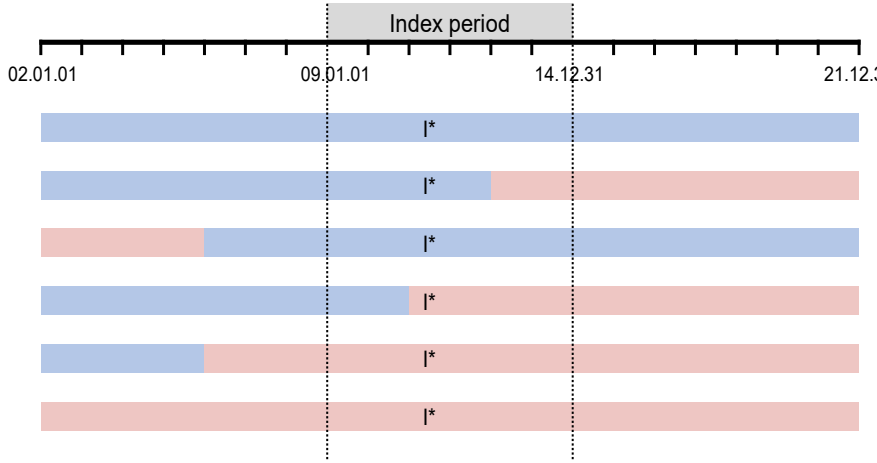
Intellectual	2.15 (1.86-2.50)	2.06 (1.73-2.45)	2.40 (2.00-2.89)	2.79 (2.30-3.39)
Autism	2.50 (0.93-6.76)	2.42 (0.91-6.41)	2.58 (1.03-6.48)	2.98 (1.23-7.18)
Mental disability				
Severity, grade				
Grade 3 (Least severe)	1.68 (1.16-2.44)	1.45 (0.96-2.18)	1.41 (0.90-2.20)	1.39 (0.88-2.20)
Grade 2	2.29 (1.42-3.68)	1.92 (1.16-3.17)	2.14 (1.24-3.69)	2.05 (1.17-3.59)
Grade 1 (Most severe)	1.99 (0.63-6.30)	1.71 (0.55-5.32)	2.01 (0.71-5.70)	2.06 (0.66-6.41)
Duration				
0-5y	1.94 (1.31-2.88)	1.70 (1.11-2.60)	1.70 (1.07-2.72)	1.63 (1.00-2.64)
5-10y	1.68 (1.06-2.66)	1.40 (0.86-2.28)	1.51 (0.91-2.49)	1.49 (0.89-2.48)
10-15y	2.75 (1.11-6.80)	2.25 (0.91-5.53)	2.21 (0.77-6.40)	2.45 (0.81-7.43)
>15y	-	-	-	-

Appendix 9. Further adjustments for healthcare utilization after overlap weighting using propensity score

Disability attributes	Hazard ratio (95% confidence interval) for CVD	
	Further adjustment for HC use	Further adjustment for HC use after overlap weighting
External disability		
Severity		
Mild	1.19 (1.10-1.29)	1.19 (1.05-1.36)
Severe	1.79 (1.55-2.06)	1.70 (1.34-2.16)
Duration		
0-5y	1.24 (1.11-1.39)	1.25 (1.05-1.49)
5-10y	1.36 (1.22-1.51)	1.32 (1.12-1.57)
10-15y	1.29 (1.06-1.57)	1.34 (0.99-1.83)
>15y	1.37 (1.01-1.86)	1.26 (0.77-2.04)
Subtype		
Physical	1.27 (1.17-1.38)	1.27 (1.12-1.44)
Brain injury	2.64 (1.88-3.70)	2.53 (1.40-4.56)
Visual	1.17 (0.97-1.42)	1.15 (0.86-1.55)
Hearing	1.44 (1.10-1.89)	1.36 (0.89-2.08)
Language	1.84 (0.98-3.46)	1.88 (0.68-5.21)
Facial	0.36 (0.04-2.92)	0.47 (0.04-6.02)
Internal disability		
Severity		
Mild	1.42 (0.82-2.47)	1.10 (0.40-3.03)
Severe	3.46 (2.00-5.96)	4.64 (1.47-14.61)
Duration		
0-5y	1.27 (0.74-2.19)	1.51 (0.54-4.20)
5-10y	3.41 (1.97-5.92)	2.92 (0.95-8.98)
10-15y	15.96 (3.07-82.90)	24.79 (0.03-19142.32)
>15y	-	-
Subtype		
Renal	2.86 (1.74-4.70)	3.86 (1.32-11.25)
Respiratory	10.29 (2.02-52.43)	5.48 (0.36-83.75)
Liver ds.	-	-
Ostomy	-	-
Epilepsy	1.75 (0.78-3.94)	0.97 (0.22-4.24)
Developmental disability		
Duration		
0-5y	1.97 (1.24-3.14)	2.60 (0.91-7.42)
5-10y	2.70 (1.97-3.68)	3.54 (1.61-7.79)
10-15y	2.68 (1.86-3.86)	3.43 (1.49-7.87)
>15y	3.06 (1.95-4.80)	3.63 (1.08-12.15)
Subtype		
Intellectual	2.58 (2.06-3.24)	3.30 (1.97-5.55)

Autism	2.68 (0.81-8.86)	4.19 (0.14-127.17)
Mental disability		
Duration		
0-5y	1.33 (0.79-2.23)	1.50 (0.53-4.28)
5-10y	0.93 (0.48-1.81)	0.89 (0.23-3.41)
10-15y	1.64 (0.53-5.10)	1.08 (0.10-12.02)
>15y	-	-

The fully adjusted model (Model 3) has been adjusted for income, urbanicity, body mass index, systolic blood pressure, fasting glucose, total cholesterol, Charlson comorbidity index, smoking, drinking, and physical activity, in addition to matching on age, sex, and index year. In addition, the model has been further adjusted for healthcare utilization (the number of outpatient visits and hospitalization days) before and after overlap weighting with propensity score. CVD, cardiovascular disease; HC, healthcare.



Baseline	Change	Total	External	Internal	Developmental	Mental
No disability	N					
No disability	Y	3,499 (0.3%)	2763	87	514	135
No disability	Y	151 (0.01%)	115	2	29	5
Disability	Y	15,703 (13%)	11664	922	2050	1067
Disability	Y	2,886 (2%)	2249	241	167	229
Disability	N					

Appendix 10. Changes of disability status
I* indicates the index date.

ABSTRACT (IN KOREAN)

젊은 성인에서의 장애와 심뇌혈관 질환의 관련성 분석

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신체활동 부족과 비만과 같은 위험 요인들의 증가로, 전세계적으로 젊은 성인들의 심혈관 질환 발생이 증가하는 추세이다. 특히, 전체 장애인에서의 높은 만성질환 유병률과 CVD 발생 위험으로 미루어 볼 때, 젊은 장애인에서의 CVD 발생 위험은 규명되어야 할 것이다. 하지만, 젊은 연령층의 낮은 CVD 및 장애 유병률, 참가자 모집의 어려움 등으로, CVD 관련 연구는 제한적이었다. 본 연구는 젊은 장애인에서 동 연령대의 비장애인보다 더 높은 CVD 위험을 가질 것이라는 가설을 토대로, 대한민국 젊은 성인에서의 장애와 CVD 발생 위험 간의 관련성을 조사하는 것을 목표로 한다.

국민건강보험공단 맞춤형 DB를 통해, 2009년부터 2014년까지 건강 검진을 받은 20세부터 39세까지의 대상자 전수를 확보하였으며, 그 중 선별기준에 맞는 7,711,487명의 참가자를 선별하였다. 이들 중 장애가 있는 자는 120,287명이었다. 장애는 장애등록정보에 근거하여, 외적 장애, 내적 장애, 발달 장애 및 정신적 장애 네 가지 유형으로 분류되었다. 각 장애유형에 따라, 이들의 성별과 나이, 기준연도에 대해 1:10으로 중복없는 exact matching을 수행하여, 총 1,202,870명의 matched general cohort를 추출, 1,323,157 명의 최종 샘플을 얻었다. 해당 일반 대조군에 비교하여, 전반적 및 장애유형별 CVD의 조기 발생 위험을 평가하기 위해 계층화된 Cox 비례위험 회귀분석을 시행하였다. 조기발생 CVD는 심근경색, 뇌졸중, 심부전 및 심혈관 사망이

포함되었다. 기준 날짜는 연구 코호트 등록기간 (2009.01.01-2014.12.31) 동안 수검한 건강검진 중 가장 빠른 검사 날짜로 정의되었으며, 추적은 CVD 발생, 사망, 혹은 관찰 종료 (2020.12.31) 중 먼저 일어난 사건일까지 이루어졌다. 추가로 다음과 같은 감수성 분석이 수행되었다: (1) 분석 표본을 총 자격 대상 인구로 확장 (N= 7,711,487); (2) 장애 및 비장애 그룹에 경향점수를 사용하여 가중치 부여; (3) 결과의 견고성을 평가하기 위해 E-값을 계산하고 검토; (4) 경쟁위험을 sub-distribution hazard function 로 처리. 더불어, 의료 이용에 대한 고려 및 각 장애유형의 위험 요인의 상대적 중요성을 추가로 고려하였다.

결과적으로, 장애가 있는 그룹은 전반적으로 사회 경제적 지위가 낮고 동반 질환율이 높으며 고혈압, 고혈당, 고콜레스테롤의 비율이 높으며, 신체 활동 부족 비율이 높은 것으로 나타났다. 흡연 및 빈번한 음주 비율은 장애 인구에서 낮게 나타났다. 사회경제적요인, 생체지표적요인, 생활습관적 요인 등을 보정 후, 외적 장애는 Hazard ratio가 1.34 (95% 신뢰 구간 1.25-1.44)이었고, 내적 장애는 2.45 (1.81-3.31)였으며, 발달 장애는 2.50 (2.12-2.96)이었으며, 정신적 장애는 1.58 (1.16-2.15)이었다. 또한, 장애의 심각도 및 장애 기간은 모든 유형의 장애에서 조기 CVD 사건의 위험과 점진적으로 관련되었다. Sub-outcome 분석에서는 일부 관련성이 통계적으로 유의하지, 전반적으로 뇌졸중, 심부전 및 심혈관 사망의 위험 또한 장애 그룹에서 더 큰 것으로 나타났다. 다양한 감수성 분석을 실시하여 일관된 결과를 확인하였으며, Explained relative risk를 사용한 부가 분석은 일반 인구에서 확인된 CVD 위험 요인이 장애 인구에서도 적용될 수 있으나, 각 장애 유형마다 이질적인 패턴이 있음을 보여주었다.

젊은 성인 인구에서 장애는 모든 유형의 장애에서 CVD 위험을 증가시켰으며, 장애의 심각도와 기간은 점진적 관련성을 보였다. 하지만, 관련성의 강도 및 기저 위험 요인은 장애 유형에 따라 다르므로, 젊은 장애인의 CVD 예방 및 관리 전략에 있어서 고려되어야 한다.

핵심되는 말: 장애; 심뇌혈관질환; 젊은 성인; 위험요인