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Research Paper

The multidimensional vulnerability of people with disability to HIV infection: Results from the handiSSR study in Bujumbura, Burundi

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ABSTRACT

Background: In resource-limited contexts, available data indicate that people with disability are disproportionally affected by the HIV epidemic. While disability resulting from chronic HIV infection has received some attention, few epidemiologic studies have examined the vulnerability of people with disability to HIV acquisition. The aims of the study were as follows: to estimate and compare HIV prevalence among people with and without disability living in Bujumbura, Burundi; to examine how the interaction among disability, gender and socioeconomic environment shapes vulnerability to HIV; and to identify potential pathways to higher HIV risk.

Methods: In this cross-sectional population-based study, 623 persons with disability (302 with disability onset ≤10 years ["early disability"]) and 609 persons without disability matched for age, sex and location were randomly selected to be tested for HIV and to participate in an interview about their life history, their social environment and their knowledge of sexual health.

Findings: A total of 68% of men and 75% of women with disability were affected by multidimensional poverty compared to 54% and 46% of their peers without disability ($p<0.0001$). Higher HIV prevalence was observed among women with disability (12.1% [8.2−16]) than among those without (3.8% [1.7−6], OR_a 3.8, $p<0.0001$), while it was similar among men with disability and those without ($p = 0{\cdot}8$). Women with disability were also at higher risk of sexual violence than were those without (OR_a 2.7, $p<0.0001$). The vulnerability of women with early disability to HIV was higher among those who were socially isolated (HIV prevalence in this group: 19% [12−27]). In addition, education level and sexual violence mediated 53% of the association between early disability and HIV ($p = 0.001$).

Interpretation: This study highlights how the intersection of disability, gender and social environment shapes vulnerability to HIV. It also shows that the vulnerability to HIV of women who grew up with a disability is mediated by sexual violence.

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1. Introduction

In resource-limited contexts, people with disability are disproportionally affected by the HIV epidemic [1−5]. Available studies have found that HIV prevalence is at least twice as high among people with disability compared to the general population [3,4]. There are various pathways that could result in this high burden of HIV among people with disability, and a better understanding of the HIV-disability relation is necessary to develop relevant interventions. First, disability can be a consequence of HIV infection. There is an increasing body of literature showing that chronic HIV infection remains associated with various impairments and functional limitations despite the tremendous progress made in the treatment of HIV/AIDS over the last several decades [6−8]. According to

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Research in context

Evidence before this study

A recent population-based study conducted in Cameroon in 2015, which used a probability-based sampling design and included a control group, showed higher prevalence of HIV among men and women with disability compared to controls matched for sex and age. Most of the other published studies that have examined the prevalence of HIV infection among people with disability living in African contexts have methodological limitations and showed heterogenous results. Therefore, additional evidence is needed with data collected in other settings. In addition, the understanding of the factors influencing the association between HIV and disability remains poorly understood and more research is important to better identify the factors shaping the HIV and disability intersection.

Added value of this study

This study was designed to provide quality evidence on the intersection between HIV and disability. First of all, it confirms the higher prevalence of HIV infection among women with disability compared to those without and shows how the intersection of disability, gender and social environment shapes the vulnerability to HIV. In addition, this study highlights the important role of sexual violence in women with disability's vulnerability to HIV.

Implications of all the available evidence

This research adds strength to the growing evidence showing the vulnerability of women with disability to HIV infection and indicates areas for future interventions. It also show the complexity of the intersection between HIV and disability and the need for more specific studies.

available studies, between one-quarter and one-half of the people living with HIV and treated with antiretroviral therapy (ART) experience some form of activity limitation [6,9–14]. On the other hand, people with disability can be at increased risk of acquiring HIV infection. In contrast to the former direction, this direction of the relationship between HIV and disability has been less examined. Most of the data available come from qualitative research [2], which offers important insight into the contextual factors associated with vulnerability to HIV among people with disabilities but has more limited empirical generalizability. Epidemiological evidence on the vulnerability to HIV infection among people who grow up with disability (early disability) is therefore needed to help decision-makers prioritize interventions towards this group.

Although biological and behavioral risk factors have been the main focus of epidemiologic research until recently, there is increasing awareness that HIV infection results more from the social and economic constraints surrounding people than from their individual choices [15,16]. Economic deprivation, social isolation and power inequality shape individual HIV-related behaviors, thereby creating risk environments [17–19]. In the case of people with disability, the social vulnerability resulting from disability is likely to play an important role in HIV risk. There is consistent evidence showing that people with disability are at higher risk of multidimensional poverty, which includes a lack of education, a lack of access to health services and employment and other forms of social exclusion [11,20]. All of these conditions are well-established determinants of negative health outcomes [12–14]. However, the relation between poverty and HIV infection is more complex, and discordant findings have been reported, suggesting that contextual factors may modify the direction of this relation; therefore, these factors need to be examined [21,22]. Interpersonal factors related to partnerships and to social networks also influence the risk of HIV acquisition [23–25] and possibly intersect with poverty. For instance, economic constraints can push people to engage into risky sexual activities such as sex work [26]. At the intersection between the structural and interpersonal levels, sexual violence merits special attention, as it is associated with HIV infection, poverty and disability [27,28]. However, little is known about the intersection between HIV risk and sexual violence among men and women with disability.

Building on previous research conducted in Cameroon [3], we conducted a population-based survey in Bujumbura, Burundi, to estimate and compare the prevalence of HIV infection among people with and without disability. In this analysis, in addition to reporting on HIV prevalence, we examined how it varies across the intersection of gender, disability and categories related to the social and economic environment and whether it was associated with other adverse sexual events like sexual violence and risky sexual activities. More specifically, we aim to provide answers to the following questions: 1) among people with disability, how can the most vulnerable persons to HIV infection be identified so that they can be prioritized, and 2) what are the potential pathways to higher HIV risk that could be targeted by intervention?

2. Methods

2.1. Study design and sampling strategy

This cross-sectional study took place in Bujumbura between 20 December 2017, and 20 December 2018. A two-stage sampling strategy was used to randomly select people with and without disability from the general population. In the first stage, enumeration areas that have been defined for the 2016 DHS were sampled with probability proportional to the number of households. The total number of enumeration areas was 16,244. Each sampled enumeration area was enumerated again in an exhaustive way to update the data. Then, 100 households were randomly sampled in each sampled enumeration area from the updated list of households and contacted for the second stage. During this stage, study interviewers collected general information on the households and used the Washington Group disability questionnaire with each households' member to ascertain the presence of activity limitation and, thereby, identify people with disabilities eligible for the study. People without disabilities of similar age, sex and residential area were randomly sampled from the list of eligible household members without functional limitation. A sample size of 600 participants with disability was targeted to detect with a power $\geq$80% and an alpha risk set at 5% a prevalence ratio of HIV infection or of sexual violence $\geq$1·5 among participants with disability compared to controls under the assumptions that these prevalence range from 10 to 50% and that 10% of the subjects may refuse the HIV test.

2.2. Study population

All people aged 15 to 49 years with severe difficulties performing basic activities in at least one domain of the Washington Group Short Set (WGSS) or with moderate difficulties in at least two domains for $\geq$12 months were considered to have a disability and eligible for the study [20]. The WGSS covers six functional domains: seeing, hearing, walking, cognition, self-care, and communication (see details in Appendix A). For each person with disability included in the study, a person of similar age and sex who was living in the same enumeration area but in a different household and who did not meet the functional limitation criteria was recruited.

2.3. Procedures

Face-to-face structured interviews were conducted with eligible subjects identified from the screening stage after informed consent is granted. During the informed consent process, special attention was

given to provide adapted information to people with intellectual and/or hearing disabilities, for instance using pictogram. For people with intellectual disabilities and minors, informed consent was sought from both participants and from their representatives. These interviews were conducted in the subjects' homes or in another place when asked. Eligibility of the participant was first confirmed with the Washington Group questions.

Then, the following data were collected during the interview: activity limitations; economic characteristics; social participation and social environment; knowledge, attitudes and behaviors regarding HIV and sexual and reproductive health; experience of physical and sexual violence; and life-course history of employment, resources, sexual partnership and fertility.

2.4. Research tools

The life-grid method was used to retrospectively collect the life-course data [29,30] (Appendix A). Knowledge of HIV transmission and prevention was assessed through open questions. Social participation was assessed with the participation scale [31]. This scales includes 18 questions and provides a global score ranging from to 0 to 90. Social participation restriction was defined as a participation score >12. Different components of the social environment were explored. First, difficulties in accessing health care and difficulties in daily life resulting from the attitudes of other people were assessed on a four-point scale. Second, social capital was another aspect of the social environment used in the analysis. It is a multifaceted concept that can be loosely defined as the resources available from the community [32]. Two dimensions of social capital were distinguished: structural social capital, which refers to the presence of community linkage, and cognitive social capital, which refers to the appreciation of this linkage in terms of trust, mutual help and reciprocity [33,34]. Structural social capital was measured by the reported number of persons (friends or family) who could provide help to the participant if needed. Cognitive social capital was measured with the sub-scale of the Short Social Capital Assessment Tool (SASCAT) [35]. It provides a score ranging from 0 to 4 that was further dichotomized into low cognitive social capital (1−2) and high cognitive social capital (3−4), as suggested by De Silva et al. [35]. The list of the scales used in this study is provided in Table 1.

In addition to the interview, participants were offered voluntary HIV counselling and testing. HIV infection was initially screened using the sensitive rapid blood test Parallel Determine® (Abbott, Japan) and confirmed using the HIV 1/2 Stat-pak® (Chembio Diagnostic Systems) assay. Test results were communicated after the interview to people who desired them. The proportion of participants who refused the test was 3.2%.

2.5. Statistical analysis

The primary outcome was the prevalence of HIV infection among participants with and without disability. It was estimated accounting for the sampling design for the following groups: men and women with disability, men and women without disability, men and women with disability onset before 10 years as a proxy of people who grew up with disability ("early disability"), and men and women with disability onset after 10 years ("late disability"). The Mantel-Haenzel method and logistic regression adjusted for age (<30, [30−40), ≥40) were used to compare binary outcomes between the different groups. As a sensitivity analysis, the E-value approach was used to assess the potential effect of unmeasured confounding on the estimated associations [36]. In short, the E-value represents the minimum strength of association that an unmeasured confounder would need to have with both disability and HIV-infection to fully explain away the disability - HIV association.

We adopted a socio-ecological framework to describe the multiple levels of influence (e.g., individual, social environment) on HIV risk. More specifically, we assessed if the association between disability and HIV varied across economic and social environmental categories or in the presence of violence or risky sexual activity. This analysis was restricted to women because of the excessively small number of such events among men. Different economic and social indicators were considered to define the economic and social categories, as no single indicator can capture the multiple aspects of poverty or of the social environment [37]. Economic indicators for poverty included low household wealth index, low education level, important difficulties in accessing health care and reduced lifetime participation in education or work (see Table 2 for detailed definitions of the indicators). For the social environment, the social support network size, the cognitive social capital score and the presence of important difficulties related to the attitude of other people were used in the analysis. Economic and social indicators were considered separately and were combined into a multidimensional index (MPI) by summing them up in a second step [37]. Two distinct variables were used for risky sexual activity: reported multiple and/or casual relationships and reported sexual activity in exchange for money. Modification of the association between disability and HIV infection by factors related to economic or social categories, violence and risky sexual activity was assessed using the relative excess risk due to interaction (RERI), the synergy index (SI) and the attributable proportion (AP) after estimating the odds ratio (OR) of HIV infection for each stratum defined by disability and factor levels, with participants without disability and from the better-off category as the reference groups [38] (Appendix B). This analysis was conducted for the entire sample and by disability subgroup (early versus late disability). In addition, in the subset of participants with early disability onset, further analysis was performed to identify whether education, social capital, violence and risky sexual activity mediate the HIV disparities associated with disability [39]. The potential outcome approach was used to conduct this mediation analysis, as detailed in the appendix [40] (Appendix B). The mediation analysis was adjusted for childhood poverty, measured by the education level of each parent, the characteristics of paternal work (paid versus not paid), and the occurrence of food insecurity at age 10, which is a potential confounding factor of the associations between disability and HIV and the mediating factors. Missing values were not imputed. All analyses were performed using R [41].

The final protocol was approved by the "Comité National d'Ethique pour la Protection des Etres Humains participants à la Recherche Biomédicale et Comportementale" in Burundi (No. 214/CAB/SN/243/2017) and "Comité Consultatif de Déontologie et d'Ethique" from the Institut de Recherche pour le Développement.

The STROBE guidelines were used to ensure the reporting of this study (Appendix C) [42]. The dataset used for this analysis is available at Zenodo (http://doi.org/10.5281/zenodo.3885141)

2.6. Funding

Netherlands Organization for Scientific Research (Grant W08.560.005) and the Initiative HIV-TB-Malaria (new name of the organisation). The funding sources was not involved in the writing of the manuscript nor in the decision to submit it for publication.

3. Results

3.1. Study participants characteristics

Of the 43,339 persons initially screened for disabilities, 623 persons with disability (302 with disability onset before 10 years) and 609 persons without disability were eventually included in the study (Fig. 1). The demographic and socioeconomic characteristics of the participants are displayed in Table 3. In analyses adjusted for age and sex, people with disability achieved lower education levels

Table 1
Overview of questionnaires and scales used in the HandiSSR.

Scale name	Measurement	Type of scale	No of items	Reliability (alpha)	Dimensionality [56]
Washington Group questionnaire on disability (short and extended sets) [51]	Activity limitations for basic activities (mobility, seeing, hearing, taking care of oneself, remembering or concentrating, communicating)	Ordinal scale (4 points Likert scale)	6 in the short set + 2 in the extended set added	NA	NA
Participation scale [31]	Social participation	Ordinal scale. Provides a score ranging from 0 to 90	18	0.98	EFA: single factor explains 72% CFA (one factor): chi2 634.1, $p<0.0001$
Short Social Capital Assessment Tool (ASCAT) [35]	Structural and cognitive social capital (SC). Only cognitive social capital subscale was used in this study.	Ordinal scale Structural SC: score from 0 to 20 Cognitive SC: score from 1 to 4	9 Structural SC: 5 Cognitive SC: 4	Structural SC: 0.68 Cognitive SC: 0.85	Structural SC - EFA: single factor explains 44% of variance - CFA (one factor): chi2 4.8, $p = 0.091$ Cognitive SC: - EFA: single factor explains 62% of variance - CFA (one factor): chi2 14.7, $p = 0.001$
Craig Hospital Inventory of Environmental Factors (CHIEF) Short-Form [57,58]	Effect of environmental factors on functioning and social participation	Ordinal scale (4 points Likert scale)	12 in the original version but only 5 in the survey	0.91	- EFA: single factor EFA explains 66% of variance - CFA (one factor): chi2 19.4, $p = 0.002$
Knowledge and attitude on HIV, sexuality and reproductive health	Questions derived from the "Illustrative questionnaire for interview-survey with young people" designed by Cleland et al. [59].	Open and closed questions	34 items	NA	NA
Access to sexual and reproductive health services	Inspired from a questionnaire developed by the NGO Humanity & Inclusion	Mixed (open and closed questions, visual rating scale)	7 items	NA	NA
Abuse assessment screeen - disability (AAS-D) [60]	Explore abuse, physical and sexual violence. Derived from AAS-D (item 3 removed)	Mixed (nominal and ordinal)	8 items	NA	NA
Transactional sex and sex in exchange for money	Questions included in the DHS surveys (optional) [61]	Ordinal	2 items	NA	NA
Social network index [62]	Questions adapted from the social network index exploring availability of social support.	Ordinal	6 items	NA	NA

EFA: exploratory factorial analysis; CFA: confirmatory factorial analysis; TLI: Tucker-Lewis index; CFI: Comparative Fit Index; RMSEA: root mean square error of approximation.

Table 2
Definitions of categories and factors.

Label	Definition	Categories
Education and living conditions		
Household wealth	Index computed from household assets using principal component analysis [63]	First quartile versus quartiles 3 to 4
Educational achievement	Highest completed level of education	Primary level not completed versus higher level
Lifetime participation in education or work	Proportion of one's lifetime since age 10 year during which the participant was studying or working *Time spent working or studying (years) since age 10/(age at survey − 10)*	Reduced lifetime participation: <75% in women and <90% in men (versus ≥75% in women and ≥90% in men)
Access to health care	Over the last 12 months, was access to health care an important/moderate/small/no problem?	Important problem versus moderate or less
Social resources and environment		
Social support network	Number of friends or family members who could provide help to the participant if needed	Low social support: ≤1 versus >1
Cognitive social capital score	ASCAT subscale (score ranging from 0 to 4)	Low score: 1 − 2 versus high score: 3 - 4
Other people's negative attitudes	Over the last 12 months, was the attitude of other people an important/moderate/small/no problem?	Important problem versus moderate or less
Multidimensional poverty index	Index combining low education level, low household wealth, reduced lifetime participation in work/education, low social network and low cognitive social capital	Coded 1 if at least two indicators indicate poverty (i.e., if the sum of the indicators >1)
Violence		
Physical violence	Frequent physical violence reported by participant	Yes versus no
Sexual violence	Any unwanted sex reported by participant on one of the questions	Yes versus no
Sexual activities		
Multiple / casual partners	Other sexual partner(s) while already engaged in a long term relationships (>12 months) and/or any short term relationship (<12 months) This information was collected with the life-course grid	Yes or no
Sex in exchange for money	Any sexual intercourse in exchange for money	Yes or no

($p<0.0001$), lived in more deprived households ($p = 0.03$), were more likely to report food insecurity during childhood ($p = 0.0005$), and had reduced lifetime participation in education or work ($p<0.0001$). Participants with early disability had the lowest education levels ($p = 0.0003$) and the shortest lifetime participation in education or work ($p = 0.07$), while those with later disability onset were more likely to live in poorer households ($p = 0.07$).

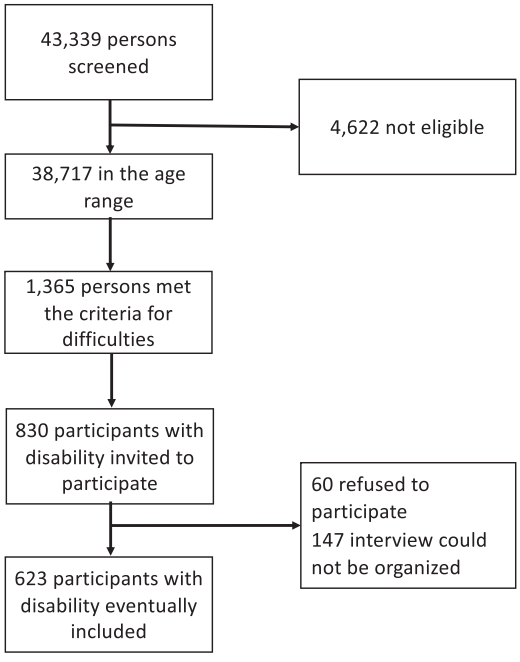

Fig. 1. Study flowchart.

Regarding the social environment, people with disability reported a smaller social support network ($p<0.0001$) as well as lower scores for social participation ($p<0.0001$) and for cognitive social capital ($p<0.0001$). The prevalence of multidimensional poverty was significantly higher among participants with disability than among those without ($p < 0.0001$), without a difference between those with early versus late disability onset ($p = 0.8$).

3.2. HIV prevalence and other outcomes

Higher HIV prevalence was observed among women with disability than among women without disability (age-adjusted OR [OR_a]: 3.8, 95%CI: 1.9 - 7.6, $p<0{\cdot}0001$), while the prevalence of HIV infection was similar among men with disability and men without disability ($p = 0.8$, Table 4). This translated into a significant additive interaction with a synergy index of 4.3, 95%CI 1.2−16 (RERI: 7, 95%CI 0−14 and AP: 69%, 95%CI 44−94). In other words, the intersection of sex and disability was responsible for a 4-fold increase in the OR of HIV infection compared to the effects of sex or disability alone. Because of the low prevalence of HIV infection observed among men (1.6%, 95%CI 0·8−2.5, $n = 10$), the remaining results on HIV are restricted to women. In the age-adjusted analysis, the ORs of HIV infection were 4.6 (95%CI 2.2−9.7) in women with late disability and 3.0 (95%CI 1.2−7.4) in those with early disability compared to participants without disability. The E-values for these ORs were 8.7 and 5.4, respectively, meaning that the OR between HIV and an unmeasured confounder should be greater than 8.7 and 5.4, respectively, to explain the observed OR between disability and HIV.

Women with disability were also at increased risk of sexual violence (Table 4): the age-adjusted OR for sexual violence was 2.7 (95%CI 1.6−4.4) in women with late disability onset and 1.8 (95%CI 1−3.1) in those with early disability onset compared to participants without disability. The prevalence of sexual violence was similar among men with disability and those without ($p = 1$).

Risky sexual activities were reported with a similar frequency by women without and with late disability (49% and 50%, respectively,

Table 3
Study participant characteristics.

	Participants with disability			Participants without disability
	All participants with disability	Disability onset before age 10 years	Disability onset >10 years	
Men	*N* = 319	*N* = 155	*N* = 164	*N* = 312
Age, median (IQR)	28 (21 – 38)	24 (19 – 31)	34·5 (26 – 41)	28 (21 – 37)
Education level, n (%)				
Never been to school	54 (17)	33 (21)	21 (13)	12 (4)
< Primary level	51 (16)	34 (22)	17 (10)	15 (5)
Primary	73 (23)	20 (13)	53 (32)	64 (20)
Secondary	65 (20)	25 (16)	40 (24)	84 (27)
Higher education level	11 (3)	5 (3)	6 (4)	37 (12)
Still a student	65 (20)	38 (25)	27 (17)	100 (3)
Food insecurity				
N (%) reporting	225 (70·5)	100 (64·5)	125 (76·2)	240 (77)
Household wealth index				
Median score (IQR)	−0·32 (−0·56 to 0·33)	−0·32 (−0·56 to 0·57)	−0·54 (−0·56 to −0·15)	−0·32 (−0·56 to 0·41)
Lifetime participation in work and education				
% of lifetime working or studying, median (IQR)	62 (23 – 95)	57 (12 – 100)	67 (31 – 91)	92 (70 - 100)
Social participation scale				
Median score (IQR)	23 (10 - 42)	31 (12 – 47)	19 (6 – 37)	0 (0 – 1)
N (%) with score >12	202 (70)	105 (77)	97 (63)	1 (0·5)
Missing	30	11	19	6
Social capital				
No of people close to the respondent[c] who could bring support, median (IQR)	2 (1 – 4)	2 (1 – 4)	2 (1 – 4)	3 (2 – 5)
N (%) with low cognitive social capital score	108 (34)	59 (38)	49 (30)	45 (14)
Environmental barriers: *n* (%) reporting important difficulties in				
Transportation	102 (32)	51 (33)	51 (31)	5 (2)
Missing	2	0	2	0
Access to information	108 (35)	71 (47)	37 (23)	5(2)
Missing	6	2	4	0
Access to health services	139 (44)	72 (47)	67 (41)	11 (4)
Missing	2	1	1	0
Related to the attitude of other people	62 (20)	35 (23)	27 (17)	4 (1)
Missing	5	2	3	0
Aid for daily tasks	127 (40)	65 (43)	62 (38)	29 (9)
Missing	4	1	3	0
Participation in organizations for disabled persons	23 (8)	15 (10)	8 (5)	–
Multidimensional poverty, n (%)	51 (68)	23 (64)	28 (72)	108 (54)
Activity limitation, n (%)[a]				
Mobility	113 (35)	48 (31)	65 (40)	–
Visual	36 (11)	15 (10)	21 (13)	–
Hearing	48 (15)	31 (20)	17 (10)	–
Intellectual or mental[b]	105 (33)	65 (42)	40 (24)	–
Women	*N* = 304	*N* = 147	*N* = 157	*N* = 297
Age, median (IQR)	32 (23 – 41)	25 (19 – 35)	37 (30 – 44)	30 (23 – 39)
Education level				
Never been to school	61 (20)	32 (22)	29 (19)	26 (9)
< Primary level	52 (17)	21 (14)	31 (20)	19 (6)
Primary	76 (25)	37 (25)	39 (25)	58 (20)
Secondary	68 (22)	23 (16)	45 (29)	108 (36)
Higher education level	11 (4)	4 (3)	7 (4·5)	23 (8)
Still student	36 (12)	30 (20)	6 (4)	63 (21)
Food insecurity				
N (%) reporting	213 (70)	95 (65)	118 (75)	216 (73)
Household wealth index				
Median score (IQR)	−0.32 (−0.56 to 0.39)	−0.2 (−0.56 to 0.09)	−0.52 (−0.56 to 0.29)	−0.32 (−0.56 to 0.33)
Time spent in activity				
Time spent in activity (work/study)	38 (11–81)	47 (8–100)	32 (12–67)	79 (35–100)
Social participation scale				
Median score (IQR)	26 (13–44)	29 (15–50)	25 (12–37)	0 (0–2)
N (%) with score >20	214 (78)	107 (81)	107 (75)	5 (2)
Missing	29	15	14	14
Social capital				
No of people close to the respondent[c] who could bring support, median (IQR)	2 (1–4)	2 (1–4)	2 (1–4)	3 (2–5)
N (%) with low cognitive social capital score	127 (42)	72 (49)	55 (35)	46 (16)
Environmental barriers: *n* (%) reporting Important difficulties in		17 (11)	9 (5.5)	
Transportation	109 (36)	58 (40)	51 (33)	15 (5)
Missing	2	1	1	1
Access to information	94 (32)	55 (39)	39 (25)	7 (2)
Missing	6	1	5	1

(*continued*)

Table 3 (*Continued*)

	Participants with disability			Participants without disability
	All participants with disability	Disability onset before age 10 years	Disability onset >10 years	
Access to health services	150 (49)	70 (48)	80 (51)	24 (8)
Missing	0	0	0	1
Related to the attitude of other people	81 (27)	43 (30)	38 (25)	5 (2)
Missing	5	2	3	0
Aid for daily tasks	136 (45)	71 (49)	65 (42)	36 (12)
Missing	4	1	3	0
Participation in organizations for disabled persons	26 (8.2)	17(11)	9 (5.5)	–
Multidimensional poverty, n (%)	46 (75)	22 (82)	24 (71)	76 (46)
Activity limitation, *n* (%)[a]				
Mobility	97 (32)	52 (35)	45 (29)	–
Visual	54 (18)	20 (14)	34 (22)	–
Hearing	49 (16)	33 (22)	16 (10)	–
Intellectual or mental[b]	82 (27)	49 (33)	33 (21)	–

p = 0·8) but less often by those with early disability (32%, p = 0.0007). In contrast, risky sexual activities were more often reported by men without disability (64%) than by those with late (53%, p = 0.001) or early (34%, p<0.0001) disability. Sexual activities in exchange for money were more frequent among women with late disability onset (15%) than among those without or with early disability (3.4% and 4%, respectively; p = 0.0002). Few men reported having had sex in exchange for money (without disability: 3%, with late disability onset: 2%, with early disability onset: 1·3%; p = 0.6).

3.3. Risk factors and interactions

When the entire population of female participants was considered, the different risk factors assessed (economic, social environment, sexual activity at risk and violence) were all significantly associated with HIV infection (Fig. 2). Overall, ORs were similar among women without disability, those with early disability onset or those with late disability onset. There was a significant interaction on the additive scale between early disability and the social support network size regarding the risk of HIV infection (p = 0.05, Table 5), indicating that the vulnerability of women with early disability to HIV infection was higher among those who were socially isolated (HIV prevalence in this group: 19%, 95%CI 12–27%). In fact, the prevalence of multidimensional poverty and of sexual activities in exchange for money was high in this group (64%, 95%CI 55–73% and 13%, 95%CI 6–20%, respectively). There was no evidence of interaction for the other socioeconomic variables on the additive scale (Table 5), although interactions on the multiplicative scale were found for sexual violence (p = 0.04).

3.4. Mediation analysis

Mediation analysis was performed for the subset of women with disability onset before 10 years compared to those without disability and showed evidence that the association between early disability and HIV infection could be mediated by low education level (proportion mediated: 28%, p = 0.05) and sexual violence (proportion mediated: 28%, p = 0.07). Taken together, low education and sexual violence mediated approximately half of the association between disability and HIV (OR of the natural indirect effect: 1.7, 95%CI 1·3–2.4; OR of the natural direct effect: 1.7, 95%CI 0.6–4.4). There was no evidence of a mediated effect for the other variables (Table 6).

4. Discussion

This study adds to previous work showing a strong association between disability and HIV [3] and provides some insight into the complex relation between disability and HIV, which is crucial for planning future interventions. Using a large and representative sample of people with disability from Bujumbura and a control group of similar age, sex and residential location, we found a three-fold higher prevalence of HIV infection among women with disability than among women without, which translates into a ten-fold increase compared to men. These results are in line with those of a previous survey conducted in Cameroon, in which women with disability had nearly twice the risk of HIV infection compared to those without (OR 1.7) [3], and with those of a meta-analysis indicating a 1.25 relative risk of HIV infection among women with disability compared to those without [4]. By contrast, we found a non-significant slight increase in

Table 4
Prevalence of HIV infection and sexual violence among men and women with and without disability, overall and by subgroups (disability onset before and after 10 years, overall and with restricted social participation [participation score≥12]).

	Men				Women			
	HIV infection		Sexual violence		HIV infection		Sexual violence	
	N	% (95%CI)	*N*	% (95%CI)	*N*	% (95%CI)	*N*	% (95%CI)
Participants without disability	301	1.3 (0.1–2.6)	303	2.9 (1.2–4.6)	286	3.8 (1.7–6)	297	12.1 (8.2–16.0)
Participants with disability								
Overall	309	1.9 (0.5–3.4)	309	2.8 (1.2–4.5)	296	13.5 (9.5–17·5)	303	23.8 (18.9–28.6)
Onset before age 10 years								
All subjects in this subset	152	0.7 (0.1–3.6)	155	0.6 (0.1–3.6)	144	7.6 (4.3–13.2)	146	18.5 (13–25.6)
Restricted social participation	103	1 (0–2.9)	107	1 (0–2.8)	104	7.7 (2·2–13.1)	106	17.9 (10.5–25.4)
Onset after age 10 years								
All subjects in this subset	157	1.9 (0.8–4.4)	271	2.6 (1.3–5.2)	242	14 (10.2–18.9)	248	21.4 (16.7–26.9)
Restricted social participation	92	4.3 (0.5–8.2)	96	4.2 (0.1–8.2)	104	24.0 (15.5–32.5)	105	32.7 (23.3–42.1)

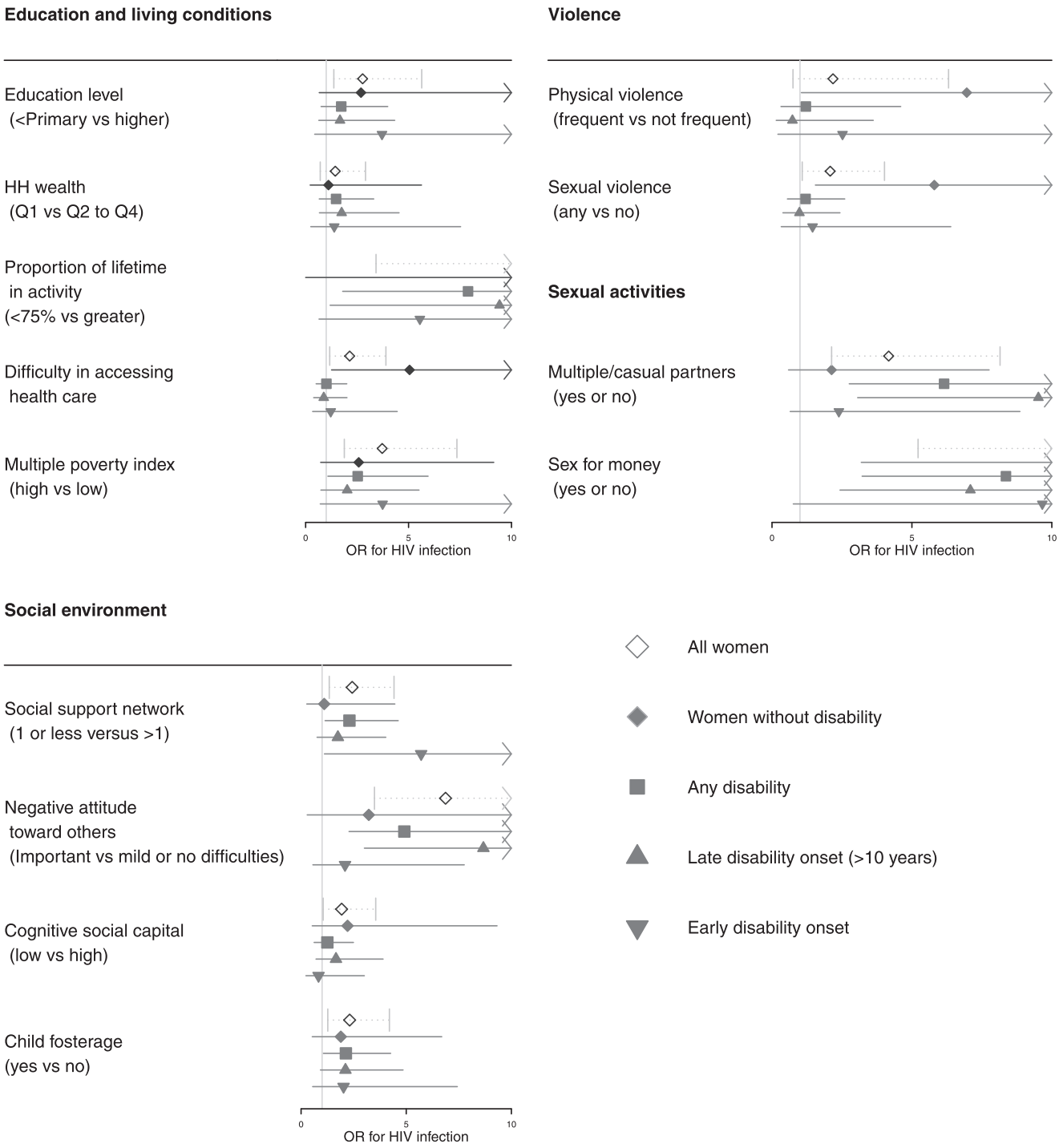

Fig. 2. Age-adjusted association (OR) between HIV risk and (a) economic factors (upper left), (b) social environment characteristics (bottom left), (c) experience of violence and (d) risky sexual activity (upper right) overall and by subgroups (women without disability, women with disability, women with disability since age 10 years, women with disability onset after age 10 years, women with disability and restricted social participation). *Note at the bottom of the figure* : symbols and horizontal lines represent ORs and their confidence intervals of HIV infection for each variable (indicated on the left) and for each sub-group (as indicated by the legend).

HIV prevalence among men with disability. This highlights the intersectionality of gender and disability regarding vulnerability to HIV infection in the urban context of Burundi. Although intersectional studies on disability have developed over the last decade, few have examined vulnerability to HIV [43,44]. Most often, intersectional studies adopt a qualitative approach, which seems to be more suitable to report on the multidimensionality of individual experiences. However, epidemiologic studies such as this one could provide some insight into the multiple levels of disadvantage and oppression that shape women with disability's vulnerability [45]. As it has been done with gender over the last decades, disability should be included as a category of analysis in epidemiologic work to better understand the diversity of human experience [46].

An important aspect of the association between HIV and disability is the bidirectional relationship that needs to be accounted for when interpreting the results. In this study, we differentiated between people who grew up with a disability and were therefore exposed to HIV infection after becoming disabled and those who acquired a disability later in their lives. Although HIV could be acquired at birth or during childhood, no participant reported such a situation. In contrast to

Table 5
Factors associated with HIV infection among women with and without disability.

	Women without disability	Women with disability		OR_a (95%CI) within factors strata	
		Onset ≤age 10 years	Onset >age 10 years		
	OR_a (95%CI)	OR_a (95%CI)	OR_a (95%CI)	≤age 10 years	>age 10 years
Education and living conditions					
Household wealth					
Quartile Q2–Q4	Ref	2.9 (1–7.8)	4.2 (1.8–9.5)	1.7[#] (0.1–25.1)	
Lower quartile Q1	1.0 (0.2–5.2)	3.8 (0.7–20.6)	7 (2.3 – 20.6)	2.8 (1.0–7.6)	
RERI (95%CI)		*0.9 (−5.4 to 7.2)*	*2.7 (−3.8 to 9.3)*		
Educational achievement					
Primary or greater	Ref	1.9 (0.2–18.9)	7.6 (1.9–30.8)	3.3 (0.2–49.1)	3.2 (1.3–7.7)
<Primary level	3 (0.8–12)	6.9 (1.8–26.6)	10.9 (3.1–38.4)	1.9 (0.7–5.5)	7.7 (1.9–32.1)
RERI (95%CI)		*3.1 (−3•8 to 10•0)*	*0.7 (−7.8 to 9.3)*		
% of lifetime working/studying					
>75%	Ref	3.52 (0.84–14.80)	4.71 (1.26–17.55)		
≤75%	3.18 (0.88–11.54)	5.03 (1.41–17.96)	10.64 (3.42–33.12)		
RERI (95%CI)		*−0.7 (−6.8 to 5.4)*	*3.8 (−4 to 11.5)*		
Access to health care					
Important difficulties	Ref	3.7 (0.97– 10.65)	7.01 (2.69–18.32)		
No or mild difficulty	5.82 (1.52–22.33)	4.09 (1.30–12.87)	6.20 (2.36–16.30)		
RERI (95%CI)		*−3.9 (−12.7 to 4.8)*	*−5.6 (−15.5 to 4.2)*		
Multidimensional poverty index					
Above threshold	Ref	1.65 (0.31–8.89)	5.09 (1.47–17.65)		
Below threshold	3.58 (1.03–12.47)	6.02 (1.93–18.81)	9.12 (3.26–25.49)		
RERI (95%CI)		*1.8 (−4 to 7.6)*	*1.5 (−5.5 to 8.4)*		
Social resources and environment					
Social support network					
>1 persons	Ref	0.91 (0.19–4.49)	3.63 (1.43–.22)		
≤1 person	1.19 (0.30–4.69)	4.81 (1.73–13.34)	6.92 (2.73–17.57)		
RERI (95%CI)		*3.7 (−0.7 to 8.1)*	*3.1 (−2 to 8.2)*		
Cognitive social capital					
Low score	1 (ref)	1.26 (0.28–5.76)	3.28 (0.84–12.76)		
High score	0.45 (0.11–1.79)	1.45 (0.33–6.29)	1.99 (0.53–7.46)		
RERI (95%CI)		*0.7 (−1 to 2.5)*	*−0.7 (−3.9 to 2.5)*		
Attitude of other people					
Important difficulties	Ref	2.22 (0.76–6.46)	2.42 (1.01–5.82)		
Mild or no difficulty	3.58 (0.34–38.29)	4.91 (1.50–16.10)	23.03 (8.54–62.15)		
RERI (95%CI)		*0.1 (−9.6 to 9.9)*	*18 (−4.4 to 40.5)*		

OR_a: odds ratio adjusted for age; 95%CI: 95% confidence interval; RERI: relative excess risk due to interaction.

Table 6
Mediation analysis between early disability (onset ≤age 10 years) and HIV infection.

	% mediated (*p*-value)	Natural indirect effect (95%CI)	Natural direct effect (95%)
Education			
<Primary level vs greater	30% ($p = 0.05$)	1.4 (1–1.9)	2. (0.8–5.5)
Social resources			
Social support network <1 person vs ≥1	22% ($p = 0.1$)	1.3 (1–1.7)	2.4 (1.0–5.3)
Any sexual violence	32% ($p = 0.03$)	1.4 (1–2.1)	2.1 (0.8 - 5.5)
Any multiple/casual partners	2% ($p = 0.8$)	1 (0.8–1.3)	2.7 (1.2–6.2)
Sex in exchange for money	0% ($p = 0.3$)	0.9 (0.7–1.1)	2.9 (1.3–6.8)

Analyses were adjusted for a nonlinear effect of age and for childhood poverty using the following variables: father's and mother's education level, father's work and experience of food insecurity ≤10 years.

participants with early disability, those with late disability constitute a more heterogeneous group, with some persons having functional limitations resulting from HIV infection. Therefore, the time ordering between disability and HIV infection may not be respected in the latter group, which was not included in the mediation analysis.

Differences and commonalities between these two groups need to be highlighted. Both groups were affected by a higher prevalence of multidimensional poverty, sexual violence and HIV infection. However, participants with late disability were older than those with early disability. In addition, negative sexual health outcomes and deprivation were more frequent among participants with late disability, while those with early disability were more likely to have lower education levels, spend less time working and report more difficulties in social participation. The relatively better standard of living of the participants with early disability compared to participants with late disability may have resulted from a selection of the population whereby children from better-off families were more likely to survive [47].

Our results show that among women with early disability, those with restricted support networks were highly vulnerable to HIV infection. Although we cannot rule out the possibility that part of this interaction could result from the negative impact of HIV on people's lives (so-called inverse causality), we believe that this result warrants attention, as it highlights possible methods of intervention. A first approach could focus on interventions that would develop support networks through disabled person organizations (DPOs). However, in this study, as in the study conducted in Cameroon, it was found that only a small proportion of the participants with disability were involved in such organizations. Intervening through DPOs will therefore require increasing the identification of people with disabilities and their participation in DPOs. An alternative (or complementary) approach would be to work with the whole community to increase its social capital, i.e., its social cohesion and the resources that could be available to its more vulnerable members. It has been shown that social capital has a protective influence against HIV infection [48]. In this study, we found an association between disability, HIV and structural

social capital measured by the support network size but not by cognitive social capital. However, there were limitations in our evaluation of social capital: first, the questions used only partially covered the different components of social capital, and second, the assessment was made at the individual level and not at the community level. Therefore, more research in this area with the perspective of identifying interventions to decrease the vulnerability of people with disability to HIV is needed.

It is important to point out that disability is not directly modifiable. However, it is possible to intervene in its social and economic impacts, and our results show that at least one-third of the disparity in HIV infection associated with disability would be removed if we were able to improve education and reduce poverty from the levels observed among women with disability to the levels observed among those without. Another third of the disparity may also be removed if we were able to reduce the rate of sexual violence among women with disability. These results also help to identify interventions that could reduce vulnerability to HIV infection among women with disability. They show that a broad approach addressing structural factors is needed for this population rather than only interventions focusing on behavioral factors, as is common in many programmes [49].

A number of limitations of this study should be noted. First, the main limitation concerns our ability to draw strong conclusions regarding causality because of the study design. Retrospective longitudinal data were collected to overcome the limitations of the cross-sectional design, but these data may be prone to recall bias. Although attention was given in the analysis on potential confounding factors, there may be residual unmeasured confounding factors responsible for bias. For instance, childhood living conditions was imperfectly captured through parents education and work and through the reporting of food insecurity at age 10. However, the high E-values found in the analysis indicate that the effect of confounding need to be very strong to explain the observed OR, which does not seem likely. Another challenge encountered in this study was the evaluation of disability [50]. The pragmatic approach adopted in this study was to first focus on functional limitations using the WGSS questionnaire, which has been extensively evaluated and used [51]. However, it should be noted that this instrument does not measure cognitive and mental disability well, which prompted us to add questions to better capture this dimension. It is also important to remember that, given the specific urban coverage of this study, these results cannot be extrapolated to other settings such as rural areas. Including disability indicators such as the WGSS questions in national HIV surveys would be an efficient way to collect additional data from different contexts.

In summary, in Bujumbura, the HIV prevalence was higher among women with disability than among women without, higher in women than in men and similar between men with and without disability. Among women who grew up with disability, those with limited social networks were highly vulnerable to HIV infection. Future interventions to reduce HIV acquisition among women with disability may target education and sexual violence, as these two risk factors mediate a large part of the association between disability and HIV.

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Data sharing

The dataset used for this analysis is available at Zenodo (http://doi.org/10.5281/zenodo.3885141).

Declaration of Competing Interest

The authors declare they have no conflicts of interest.

Acknowledgments

The corresponding author has full access to all the study data and had final responsibility for the decision to submit for publication.

Appendix A. Study tools

Washington Group questionnaire

To overcome the practical and conceptual difficulties in measuring disability, a group of experts set up by the UN Statistical Commission has proposed an operational tool for the identification of people with disabilities in surveys with good accuracy and reproducibility from one setting to another. This tool includes a small number of questions covering six functional domains or basic actions: seeing, hearing, walking, cognition, self-care, and communication. Each question asks the respondent to rate how much difficulty he/she has experienced in the domain on a four-point scale (see below). The Washington Group questionnaire is available in various forms; a short set questionnaire includes six questions and is recommended for use in national surveys because of its simplicity. Additional questions are available from the extended set to supplement those from the short set and provide more detail on functional limitations.

Short set of the Washington Group questionnaire:
Because of a physical, mental, or emotional health condition. . .

1 Do you have difficulty seeing even if wearing glasses?
2 Do you have difficulty hearing even if using hearing aid/s, or are you deaf?
3 Do you have difficulty walking or climbing stairs?
4 Do you have difficulty remembering or concentrating?
5 Do you have difficulty (with self-care such as) washing all over or dressing?
6 Do you have difficulty communicating (for example, understanding or being understood by others)? Two additional questions from the extended set of the Washington Group questionnaire were added to better capture individuals with intellectual disabilities:
7 Do you have difficulty learning a new task, for example, learning how to get to a new place?
8 Do you have difficulty analysing and finding solutions to problems in day-to-day life?

Question response categories: No, Some, A lot, and Unable.

Life-grid method

The life grid comprised two A3 sheets divided into several columns. The vertical axis is divided into the time units for which the events are to be recorded; the first column shows the time (in years) from birth to the current year, the second column shows the age from 0 to the current age, and the third column shows the time elapsed. The other columns related to the different areas explored during the life-history interview are as follows: family environment, main occupations/activities, resources, quality of life, sexual relationships, periods of transactional sex or sexual violence, pregnancies, children and disability onset.

Appendix B. Statistical analysis

Additive interaction

Three measures of additive interaction between two risk factors can be derived from the results of logistic regression [52]. Let OR_{11} denotes the odds ratio of exposure to both factors compared to none and OR_{01} or OR_{10} the odds ratio of exposure to only one factor compared to none. The relative excess risk due to interaction (RERI) is defined as

$$RERI = OR_{11} - OR_{01} - OR_{10} + 1$$

It measures the extent to which the OR under joint exposure exceeds the risk that is expected on the basis of the addition of the ORs under each exposure.

The attributable proportion due to interaction (AP) is defined as AP = RERI/OR_{11} and is interpreted as the proportion of risk in the group with joint exposure that is due to interaction.

The synergy index (S) is defined as $S = [OR_{11}-1]/[(OR_{10}-1)+(OR_{01}-1)]$ and can be interpreted as the excess risk from exposure to both exposures when there is interaction relative to the risk from exposure without interaction.

Mediation analysis

The potential outcome approach is based on the counterfactual framework. Let D denotes the exposure of interest (disability), Y the outcome, and M a potential mediator (e.g., education level). In addition, C denotes the baseline covariates (e.g. age or sex).

The counterfactual outcome Y_d (counterfactual mediator M_d) is defined as the value of the outcome (mediator) that would have been observed had exposure D been set to level d. The total (counterfactual) effect (TE) of D on outcome Y is defined as $Y_1 - Y_0$, and the total effect of D on mediator M is defined as $M_1 - M_0$. As one of the counterfactual outcomes is unobservable ("counter to the fact"), the counterfactual effect cannot be measured at the individual level. However, it can be estimated at the population level.

In addition, the natural direct effect of D on Y is defined as $Y_{1M0} - Y_{0M0}$ and compares the counterfactual outcome under $D = 1$ with $D = 0$ assuming M is set to what it would have been if exposure had been $D = 0$. The natural indirect effect, defined as $Y_{1M1} - Y_{1M0}$, assumes that D is set to the level $D = 1$ and compares the outcome for the mediator M set to what it would have been with $D = 1$ with the outcome for M set to what it would have been with $D = 0$.

The primary analysis was conducted using the Medflex package for R [53]. An alternative approach to mediation based on weighted regression was also used to assess the robustness of our results [54]. The later approach consists first in modeling the relation between mediator(s) and exposure (disability) then computing weights from the odds ratios estimated during the first step that will be used to assess the marginal association between the exposure and the outcome. A detailed description of the procedure is given in Nguyen et al. 2015 [55].

Appendix C. STROBE checklist

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8 - 9 Table 2
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7 Table 1
Bias	9	Describe any efforts to address potential sources of bias	8–9
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8–9
		(*b*) Describe any methods used to examine subgroups and interactions	8–9
		(*c*) Explain how missing data were addressed	10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10 Fig. 1
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig. 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 3
		(b) Indicate number of participants with missing data for each variable of interest	Table 3
Outcome data	15*	Report numbers of outcome events or summary measures	Table 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 4 p11
		(*b*) Report category boundaries when continuous variables were categorized	-
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12 Table 4
Discussion			
Key results	18	Summarize key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15–16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14–17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10 and 17

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