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Gaps in Accessibility and Affordability to Achieve Health Equity for Cancer Patients with Disability

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Biomedical and Translational Science

by

Jiali Cai

Thesis Committee:
Assistant Professor Thuy B. Tran, Chair
Assistant Professor Jeremy P. Harris
Professor Sherrie H. Kaplan

2024

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LIST OF ABBREVIATIONS

ADL	Activity of daily living
AI/AN	American Indian/Alaska Native
API	Asian & Pacific Islander
CDC	Centres for Disease Control and Prevention
COVID-19	Coronavirus 2019
CRC	Colorectal cancer
ICD-10	The 10th version of the international classification of disease diagnosis
IQR	Interquartile range
IRB	Institutional Review Board
SDOH	Social determinants of health
SEER	Surveillance, Epidemiology, and End Results
SMD	Standardised mean difference
NIH	National Cancer Institute
NH	Non-Hispanic
NHPI	Native Hawaiian and Pacific Islander

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Special thanks also go to my parents and grandparents, for motivating me throughout all stages of the research work. And to my friends who in one way or another motivate and support me, I would like to say a big thank you to you all from the bottom of my heart.

ABSTRACT OF THE THESIS

Gaps in Accessibility and Affordability to Achieve Health Equity for Cancer Patients with

Disability

by

Jiali Cai

Master of Science in Biomedical and Translational Science

University of California, Irvine, 2024

Assistant Professor Thuy B. Tran, Chair

Cancer health disparities in people with disability have received limited attention. This study aimed to investigate the barriers to accessing timely healthcare and health-related outcomes in cancer patients with disability. Cancer patients with a diagnosis of breast cancer, lung cancer, colorectal cancer, skin cancer, pancreatic cancer, gastric cancer and oesophageal cancer were extracted from the NIH All of Us Research Program. Participants were stratified by disability status and then matched by propensity scores. Survey responses were compared using Pearson's chi-squared tests for categorical variables and t-tests for continuous variables. Patients with disability (N=4,546) were more likely to be non-White, unemployed for wages, uninsured, had less annual household income and less advanced education. Propensity score matching resulted in 4,437 participants in each cohort. The disability cohort was more likely to report delayed medical care due to high out-of-pocket (15%), feeling nervous about seeing a provider (12.2%), lacking transportation (10.8%), co-pay (7.1%) and distance (4.2%). In addition, the financial burden of accessing healthcare was more profound in patients with disability. Dental care (20.5%) was the most common unaffordable service, followed by eyeglasses (15.5%), prescription medicines (14.5%), specialty care (10.6%), follow-up care (8.1%), mental health care or counselling (7.1%) and emergency care (4.5%). Also, cost-related

medical non-adherence was more frequent in the disability cohort, including delaying filling prescriptions (11.1%) and skipping doses (6.5%). Further, the disability cohort reported worse physical health, mental health and quality of life. In conclusion, this study demonstrated that cancer patients with disability face significant disadvantages and encounter significant barriers in accessing and affording healthcare, resulting in poorer overall health and quality of life.

CHAPTER 1: INTRODUCTION

Cancer is a disease that severely impacts on the quality of life of people around the world. Globally, it causes nearly 10 million deaths each year and is estimated to be the second leading cause of death in the US in 2024 according to the American Cancer Society, with breast cancer, lung cancer, colorectal cancer and skin cancer accounting for almost half of the total cases (1, 2).

According to the Centres for Disease Control and Prevention (CDC), health equity in cancer is when every patient has an equal opportunity to receive screening, treatment and follow-up care. Cancer health disparities arise when health measures differ in people of varied age, sex, race or ethnicity, education and employment (3-5). Cancer can affect anyone, however, accumulating evidence suggests that cancer may not affect everyone equally.

Social determinants of health (SDOH) are highly associated with cancer prevention, incidence and survivorship (6-8). It has been pointed out that SDOH are responsible for 75% of the cancer burden, intertwining with biological traits and clinical factors to lead to higher risk (9). For example, the incidence of cancer is higher among less educated people (10). The extent to which patients adhere to healthier lifestyles is likely to increase as they receive more education. Also, healthcare access can be affected by housing status, such that unstable housing including renting or not owning a home could result in a lower cancer screening rate (11). Additionally, poverty and low income drive the low cancer screening uptake, particularly due to the perception of potentially high future costs (12, 13). Furthermore, people lacking social connections are at significantly higher risk of tumour recurrence, lower quality of life and lower survival (14). If men with prostate cancer do not receive encouragement from their support networks, the emotional burden is more commonly reported throughout the diagnosis and treatment by dealing with anxiety, stigma, awkwardness and unwanted sympathy (15). The

importance of active support in facilitating treatment adherence and post-treatment recovery has

also been demonstrated in breast cancer and head and neck cancer (16, 17). Thus, SDOH are

persistent barriers that can hinder one's access to timely care, contributing to a profound

negative impact on health-related outcomes in the long run.

CHAPTER 2: BACKGROUND

2.1 Cancer health disparities in subpopulations

Age disparities in cancer incidence and mortality rates have been well documented. The receipt of palliative radiation therapy was found to be lower in the elderly with metastatic cancer, implying that older adults were less likely to be offered this potentially quality of life–enhancing treatment (18). Although confounding covariates such as primary tumour site, geography, patient demographics and comorbidity accounted for a portion of age-related discrepancy, age was still a leading factor of attenuated care.

The well-documented racial inequalities in cancer have revealed the differences in cancer susceptibility and survival. The 5-year survival rate was 33% lower in non-Hispanic Blacks and 51% lower in non-Hispanic American Indians/Alaska Natives as compared to the non-Hispanic whites in patients diagnosed during 2006-2012 (19). The Surveillance, Epidemiology, and End Results (SEER) program from the National Cancer Institute (NIH) highlighted that they also led the incidence and mortality rate during 2016-2020 in breast cancer, prostate cancer and colorectal cancer (CRC) (Figure 1). Notably, the NH Black females had a substantially higher death rate than the NH White, despite the lower incidence. This year, the American Cancer Society projected that the trend was very likely to continue, with the Black remain to have poor survival in most cancer types (1).

Geography is another socioeconomic factor that is heavily involved in disadvantaging people and placing them at higher risk of cancer. It has been established that living in a rural area hinders access to health care due to transportation and limited resources, which lowers the adherence to health care relative to urban areas. The death rate of preventable cancers such as lung cancer, colorectal cancer and cervical cancer were all found higher in people residing in rural areas, indicating the negative potential of rural dwelling on early detection (20).

Cancer health disparities may also be driven by pandemics (21). The challenging part of such special considerations is that they not only add complexity to the weakened immune system but also prioritise and allocate medical resources to urgent scenarios where cancer patients who are supposed to get routine diagnoses or treatment are obliged to postpone their appointments (22). For example, according to the National Cancer Institute, the diagnosis of new cancer reduced by 50% during the early coronavirus 2019 (COVID-19) pandemic. Between March 2020 and March 2021, 19.8% of cancer patients reported cancellation or rescheduling of medical care, including routine check-ups, blood tests, screening tests and treatments (surgery, chemotherapy, radiation therapy) (23). Although the cancer diagnosis rate revealed a recovery for most common sites during the latter waves of COVID-19, the health implications could be long-lasting and the damage to one's health is sometimes irreversible after missing the best treatment time window (24).

Taken together, certain population groups are significantly disadvantaged in healthcare and bear a disproportionate burden of cancer with limited access to cancer diagnosis, treatment and follow-up. However, research is highly needed to investigate other rapidly growing segments of the US population to further our understanding of cancer health disparities and eliminate the gap in health inequity.

2.2 Cancer health disparities in people with disability

The International Classification of Functioning, Disability and Health defines disability as the loss of body structure or body function either hereditarily, congenitally or acquisitively (25). Individuals living with disability are deemed one of the key minority groups in the US. The CDC estimated that approximately 27% of adults live with at least one type of disability.

Incidence   **Mortality**

Female Breast

	Incidence		Mortality
All races	126.9		19.6
NH White	136.3		19.7
NH Black	128.3		27.6
NH API	106.4		11.7
NH AI/AN	107.4		17.6
Hispanic	98.5		13.7

Prostate

	Incidence		Mortality
All races	113.4		18.8
NH White	111.5		17.8
NH Black	184.2		37.5
NH API	59.3		8.6
NH AI/AN	73.2		19.5
Hispanic	86.9		15.3

Lung and Bronchus

	Incidence		Mortality
All races	50		35
NH White	56.4		38
NH Black	53.8		37.2
NH API	34		19.8
NH AI/AN	47.3		34.2
Hispanic	26.2		15.4

Colon and Rectum

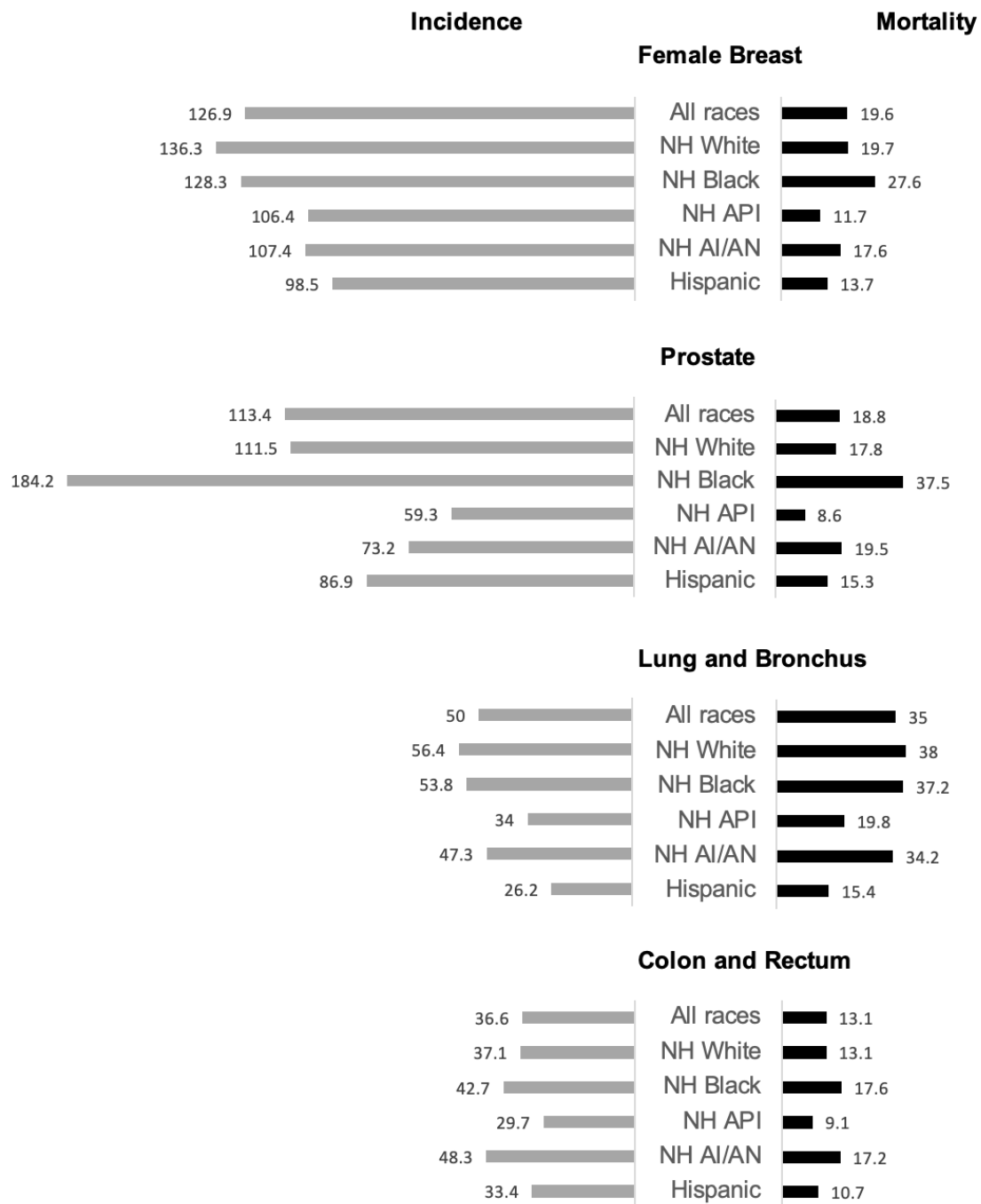|	Incidence		Mortality
All races	36.6		13.1
NH White	37.1		13.1
NH Black	42.7		17.6
NH API	29.7		9.1
NH AI/AN	48.3		17.2
Hispanic	33.4		10.7

Figure 1. Age-adjusted incidence and mortality rate by cancer site and race/ethnicity in the US, 2016-2020.
Data source: The Surveillance, Epidemiology, and End Results (SEER) 22, 2016-2020. Incidence=rate of new cases per 100,000, mortality=death rate per 100,000. NH=Non-Hispanic, API=Asian & Pacific Islander, AI/AN=American Indian/Alaska Native.

Specifically, physical disability makes up 12.1% of the total population (26). The leading cause is often the impairment due to musculoskeletal disorders, which disrupts the integrity of the body system (27). The individuals usually experience active pathology such as back pain, sprains, strains and tears. Another cause inducing mobility limitation is arthritis which happens when the cartilage lying in between the bones starts to deteriorate and causes joint instability (28). Cognitive disability is highly heterogeneous and is estimated in 12.8% of US adults, encompassing a range of intellectual impairments that affect memory, communication and behaviour. It is typically found in the elderly and is considered an acquired impairment associated with aging (29). In addition, the prevalence of dementia is moderately high among people living with cognitive deficits, with Alzheimer's disease accounting for the majority of the cases (30, 31). The CDC also revealed that around 10% of adults in the population have a sensory problem, including people who are deaf or live with hearing difficulties, and those who are blind or have a serious vision issue.

There is a growing emphasis on the wellness of people living with disability. The government and communities have put a huge effort to prioritise their needs highlighted by the ever-increasing medical expenditure. As one study pointed out, disability-associated healthcare expenditures composed half to two-thirds of all Medicare and Medicaid expenditures, and the spending on people with disability rose by around $4,000 from 2003 to 2015, while that for people without disability remained fairly constant (32). Of note, in September 2023, the NIH designated people with disability as a population with health disparities, further highlighting the need for research to address the complexities people face in healthcare.

People with disability are often more demanding in health needs compared to the general population (33). They had a higher rate of emergency care and hospitalisation as demonstrated by Freire et al. that Brazilian people living with hearing impairment were 2.1-fold more likely to

have been hospitalised (34). Similar findings were established by Gulley et al. that compared to people without a disability, the rate of outpatient care due to acute conditions was higher among individuals with limitations affecting their activity of daily living (ADL) (35). Also, they are more susceptible to chronic conditions such as diabetes and hypertension, posing a threat to their mental health as well (35, 36). Thus, life-long management with timely access to quality care is therefore essential in maintaining the health of people with disability.

2.3 Overview of challenges to equitable care in people with disability

However, people with disability face greater barriers to engaging the healthcare services than the general public. Firstly, the challenges brought by functional limitations are embodied in the loss of self-care that worsens over time. As the pathology progresses, people are commonly characterised by limited communication such as having difficulty understanding the terms during a consultation; or a need for support in everyday life such as walking, climbing stairs, bathing, dressing; or entering a health care establishment through the steps and curbs. It has been shown that functional limitations give rise to a low cancer screening rate. Women with mobility and cognitive disabilities were less likely to have the Pap test for cervical cancer screening, even after receiving the guidelines from the health care providers (37-40). Breast cancer exhibited a similar trend and specifically, visual impairments would lower the likelihood of regular screening by 36% (41). The probability of CRC screening differed by disability type, screening tests and age. In men aged 40-64, the CRC screening rate by sigmoidoscopy or colonoscopy was higher in people with complex disabilities, in comparison to people without disability and people with mild limitations (42). Yet in men aged 65 and above with complex disabilities, the CRC screening rate dropped dramatically. A more recent study showed that faecal immunochemical testing was more commonly used for CRC screening in people without disability (27.8% vs. 22.47%); notably, rates varied by types of disability, such that people with

dementia (12.24%), intellectual and developmental disability (15.09%), and multiple disabilities

(15.13%) showed the lowest participation rate (43).

Secondly, the marginalisation of people with disability still exists persistently in society,

regardless of the ongoing optimisation of healthcare policies. To improve health outcomes in the

minority population, it is imperative to minimise the delays in the initiation and continuation of

cancer screenings and treatments. However, a large proportion of the physicians in the US were

found to either have negative perceptions of people with disability or lack confidence in treating

them equally (44). It was found that physicians were less likely to schedule mammography for

women with disabilities, especially in the case of older women and those with multiple

disabilities (44-46). The lack of physician recommendations was probably because they did not

get sufficient training to understand and accommodate people's needs. However, since effective

cancer care is closely associated with timely diagnosis and treatment, delays in healthcare can

lead to a multitude of negative outcomes. Studies have shown that it can increase the risk for

treatment with the mortality rate rising by approximately 6-13% for surgery, radiotherapy and

systemic therapy for each four-week delay for any reason (47, 48). Moreover, according to the

CDC, cancers often have a better chance of being cured if detected at an early stage and

treated effectively, thus prolonging the time-to-treatment or non-adherence to subsequent

medical care may result in worse outcomes and survival (49, 50). Taken together, the

physicians' beliefs may promote the discrimination of people with disability in many forms,

leading to serious consequences for being excluded from healthcare.

Thirdly, it is worth noting that the necessity of accessible equipment is although often addressed

not always enforced. This may be attributed to the fact that when the responsibility is passed

down from the federal to the state, and then to the healthcare entities, there is a failure of

coordination and implementation due to the separation of each organisation (51). Consequently,

the healthcare system is incapable of delivering services to the disability cohort since the policies are not being put into effect in practice. Overlooking the obstacles that disability brings with it could result in delayed medical care and a lower chance of long-term survival. Fourthly, it has been implicated that the technology adoption rate in people with disability is low. According to Pew Research Centre, Americans with a disability were less likely to own a computer or smartphone (62%, 72%), compared to those without a disability (81%, 88%). What's more, technophobia is often observed in people with disability. The technology-based assistive devices have been around in the marketplace for decades, which act to reduce a person's effort to perform ADL by enhancing their functional capabilities, e.g., wheelchairs, listening devices, and screen readers (52). However, the feeling of fair, overwhelm and resistance to new technology, impedes the rate of device adoption (53, 54). As such, the generic health services are difficult to be engaged by people with disability given that they are less likely to be exposed to the available resources, thus a lesser access to healthcare.

Taken together, health inequities in people with disability manifesting through functional deficits, stigma, pervasive resource inadequacy and unremitting facility inaccessibility may only reflect a small fraction of the challenges they face. There remains great motivation to gain a better understanding of the factors contributing to disparate health outcomes in patients with disability.

2.4 Study aim and hypothesis

Therefore, this study aimed to demonstrate the current gaps in healthcare for people with disability to receive equitable care. By exploring the reasons for delayed medical care, the study characterised the multifaceted barriers to accessing healthcare and the impact of disparities may have on overall health in the physical and mental domain. The purpose of this study was to provide insights into the components that can be addressed in future research to mitigate the gap in accessibility and affordability to promote the national health. The hypothesis of this study

is that cancer patients living with disability would have limited utilisation of healthcare and worse

overall health outcomes than those without disability.

CHAPTER 3: METHODS

3.1 Data collection

Data was obtained from the NIH All of Us, a national database with more than 1 million people (55). The database comprising electronic health records (conditions, drug exposure, procedures, lab measurements), physical measurements, genomics and surveys, is in an effort to support medical research and improve health outcomes. The All of Us institutional review board (IRB) is responsible for reviewing the informed consent signed by the participants, after which the approved data is de-identified and made available for researchers. This study utilised the All of Us controlled tier dataset v7 which was released in April 2023 with a total of 413,457 participants.

3.2 Study population

The population of interest was patients who reported a history of cancer. A collection of 7 cancer types were selected based on the 10th revision of the International Classification of Disease diagnosis (ICD-10) codes, namely, breast cancer, lung cancer, colorectal cancer, skin cancer, pancreatic cancer, gastric cancer and oesophageal cancer. The patients were then divided into 2 groups, i.e., patients with disability and patients without disability (Figure 2).

The categorisation of disability was based on the response to the "The Basics" survey (sourced from American Community Survey). 6 questions were studied: whether the participants are deaf or have serious difficulty hearing; whether they are blind or have serious difficulty seeing, even when wearing glasses; whether they have serious difficulty walking or climbing stairs; whether they have difficulty dressing or bathing; whether they have difficulty doing errands alone such as visiting doctor's office or shopping; whether they have serious difficulty concentrating, remembering or making decisions. The responses were "yes", "no" or "prefer not to answer".

Those who answered "prefer not to answer" or skipped the questions were not counted.

Participants were defined as having disability if they responded "yes" to any of the 6 questions.
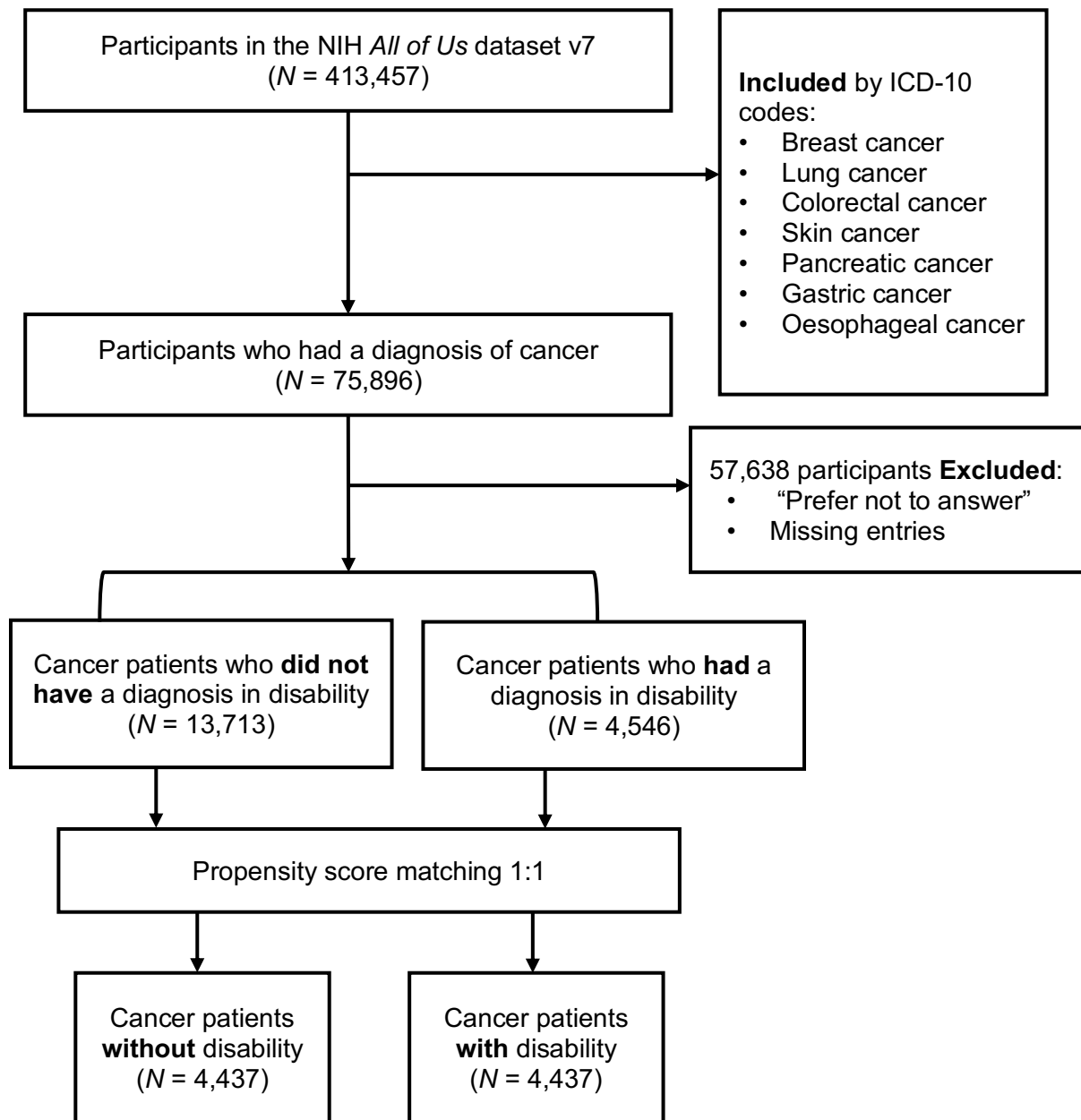
Figure 2. Flowchart of patient selection and propensity score matching.

3.3 Analyses of surveys

3.3.1 Baseline demographics

The demographic and socioeconomic data were extracted from the "The Basics" survey. Age was calculated from the date of birth. Race was grouped as White, Black, Asian, Hispanic and Native Hawaiian and Pacific Islander (NHPI). The marital status was grouped as divorced/separated/widowed, married/living with a partner and never married. The education level was grouped as advanced degree, college graduate, some college and high school or less. The employment status was grouped as employed for wages and not employed for wages. The annual household income was grouped as < 50k, 50k-100k and >100k. The housing status was categorized as own, rent, or other arrangements. The baseline patient characteristics before being matched by propensity score are shown in Table 1.

3.3.2 The accessibility and affordability in healthcare

From the "Health Care Access and Utilization" survey, a total of 24 questions were analysed. The first 9 questions investigated the acceptance of insurance and the reasons for patients getting delayed medical care, which included a lack of transportation, living in a rural area where the distance to the health care provider is too far, too nervous to see a healthcare provider, couldn't get time off work, couldn't get child care, provided care another adult and cannot leave him/her, couldn't afford the co-pay, couldn't afford the deductible and couldn't afford the out of pocket for some/all of the procedure. The next 8 questions assessed the affordability of the healthcare system by finding out the time when the participants needed care but did not get it because they could not afford it, including prescription medicine, mental health care or counselling, emergency care, dental care (including check-ups), eyeglasses, to see a regular doctor or general health provider (in primary care, general practice, internal medicine, family medicine), to see a specialist, follow-up care. The last 6 questions explored the behaviours

contributing to medical non-adherence. These included skipping medication doses, taking less medicine, delaying filling a prescription, asking for a lower-cost medication, buying prescription drugs from another country and using alternative therapies. For all questions, participants could choose from "yes", "no" or "don't know". Those who ticked "don't know" or with missing entries were excluded from this study.

3.3.3 The evaluation of overall health

The "Overall Health" survey is made up of 19 questions, of which this study selected 10 questions that focused on patient's feelings about health and social activities. The data source of these 10 questions was the patient-reported outcomes measurement information system (PROMIS), a heath scale that was developed by NIH for use in evaluating physical and mental health in the clinical setting. The survey asked the participants to self-report their health ("In general, would you say your health is"), their quality of life ("In general, how would you say your quality of life is"), their physical health ("In general, how would you rate your physical health?"), their mental health ("In general, how would you rate your mental health, including your mood and your ability to think?"), their ability to carry out physical activities ("To what extent are you able to carry out your everyday physical activities such as walking, climbing stairs, carrying groceries, or moving a chair?"), their fatigue level ("In the past 7 days, how would you rate your fatigue?"), if they had experienced emotional problems ("In the past 7 days, how often have you been bothered by emotional problems such as feeling anxious, depressed or irritable?"), their pain on average from 0-10, with 0 meaning no pain and 10 meaning the worst pain imaginable ("In the past 7 days, how would you rate your pain on average?"), whether they were satisfied with social relationships ("In general, how would you rate your satisfaction with your social activities and relationships?") and the social roles ("In general, please rate how well you carry out your usual social roles. This includes activities at home, at work and in your community, and

responsibilities as a parent, child, spouse, employee, friend, etc."). The survey was a 5-point

Likert scale questionnaire as shown in Appendix 1.

3.4 Propensity score matching (PSM)

To account for the covariates between patients who had and did not have a disability,

participants were matched by propensity scores estimated by logistic regression (Figure 2). The

variables of interest in the model were age, sex, race, annual household income, education,

marital status, insurance, homeowner and employment. The patients were matched to the

nearest neighbour without replacement using the "MatchIt" package in R, with a caliper width of

0.2. The seed was set at 100 for replication purposes.

The quality of balancing was assessed in two ways; one by comparing the standardised mean

differences (SMDs) before and after matching (SMD<0.1 suggested good balancing, Table 2),

and two by visualising the size of the overlapping area under the propensity score matching

curve, with a greater overlapping area indicating higher similarity of the covariate distributions

between patients by disability status (Figure 4).

3.5 Missing data imputation with regression

Due to a substantial amount of missing data in the survey, logistic regression was employed to

impute the values for maximising the possible available data. The covariates of the model were

sex, age, race, home status, insurance, annual household income, education, marital status and

employment. The area under the ROC curve for disability status prediction was 0.755,

suggesting that the model has a moderate ability to discriminate between patients with and

without disability (Figure 3). The imputed data was analysed separately from the original dataset

and was reported in Appendix 5-9.
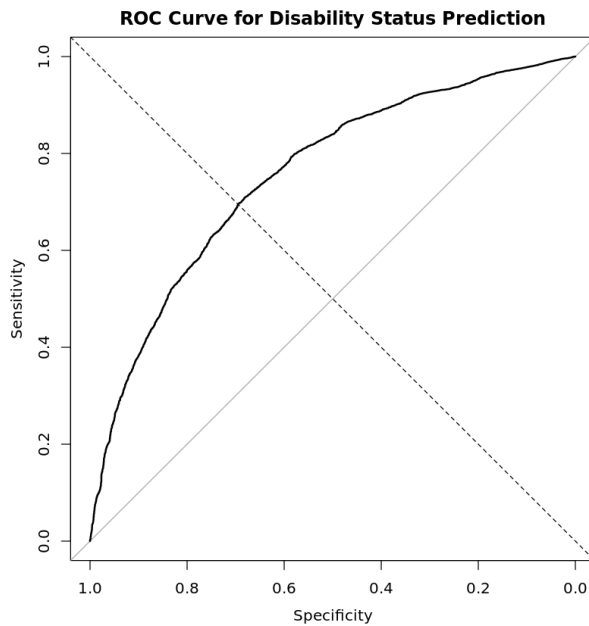
Figure 3. ROC curve for disability status prediction by RStudio.

3.6 Statistical analysis

Categorical variables were depicted as frequency and percentage by Pearson's chi-squared test. Continuous variables (age, pain) were measured as the median and interquartile range (IQR) by the independent samples t-test for comparisons between the 2 groups. The statistical analyses were performed within the NIH All of Us cloud-based Jupyter Notebook environment using the RStudio. The following packages were used: ggplot2, tibble, tidyr, readr, purrr, dplyr, stringr, forcats, matching, tableone, MatchIt, pROC. Figures were generated by GraphPad Prism 10 unless otherwise noted. Bonferroni correction was applied to account for the large number of simultaneous comparisons in the study. Analyses were 2-sided and the significance level threshold was set at 0.05/number of comparisons.

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CHAPTER 4: RESULTS

The baseline patient characteristics are shown in Table 1. Of the 18,259 cancer patients who met the inclusion criteria, 4,546 (24.9%) reported a disability. Before being matched by the propensity score, the majority of the study population was female and white. Patients with disability had a significantly higher median age of 67 (IQR: 58-75) while that for patients without disability was 64 (IQR: 54-72). Chi-squared tests showed that patients with disability had a higher Black population and a lower White population (p<0.001). They also had lower annual household income (p<0.001), and were less likely to attend college (p<0.001), be covered by health insurance (p<0.001) and owned a home (p<0.001). However, the disability cohort was more likely to be divorced or separated or widowed (p<0.001) and not employed for wages (p<0.001).

After 1:1 PSM without replacement, the matching curves with a larger overlapping area indicated a greater balance in the covariates such that more participants with similar scores were present in both study groups (Figure 4). In addition, all SMDs were below 0.1, suggesting an overall balance between the 2 study groups (Table 2). After PSM, 4,437 participants from each group were enrolled in the study. There were no significant differences between 2 groups in age, sex, annual household income, insurance, house arrangement and employment. As compared to patients without disability, patients with disability were less likely to be White (p<0.001) and receive advanced degrees (p<0.001) but more likely to be divorced/separated/widowed (p=0.0013).
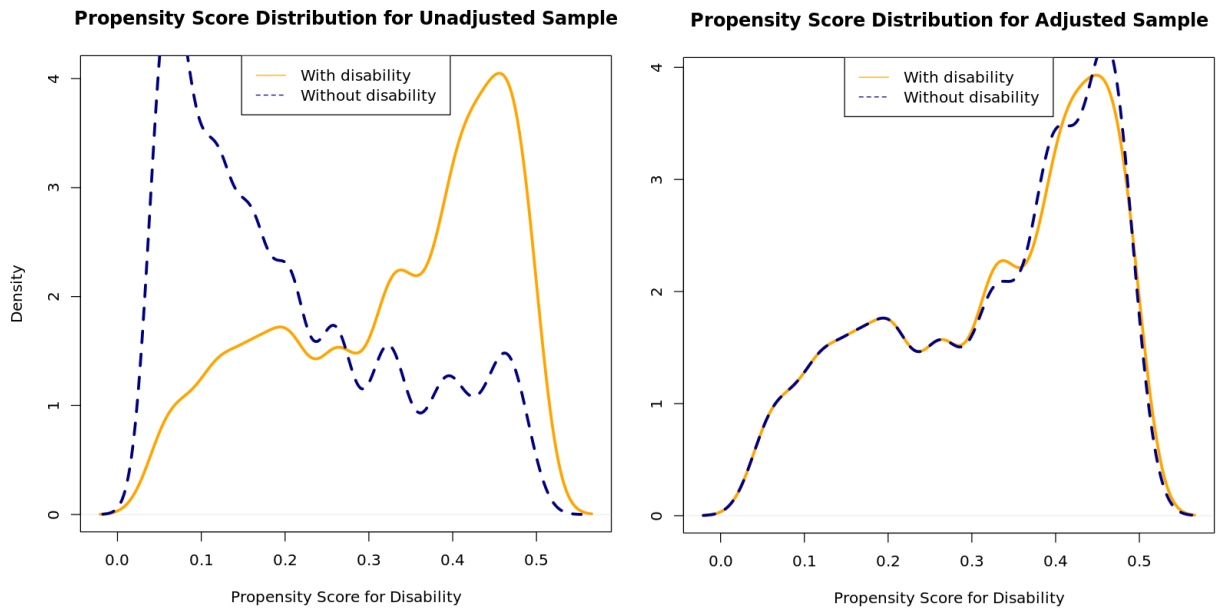
Figure 4. Propensity score distribution before and after matching by RStudio.

Table 1. Patient characteristics at baseline before PSM.

	Without disability (N=13,713)	With disability (N=4,546)	P	SMD
Age, median (IQR)	64 (54, 72)	67 (58, 75)	<0.001	0.259
Sex				
Male	3980 (29.0)	1629 (35.8)	<0.001	0.146
Female	9733 (71.0)	2917 (64.2)		
Race				
White	11162 (81.4)	3267 (71.9)	<0.001	0.172
Black	1354 (9.9)	1785 (17.3)		
Asian	272 (2.0)	29 (0.6)		
Hispanic	919 (6.7)	462 (10.2)		
NHPI	6 (0.04)	3 (0.07)		
Annual household income				
<50k	3533 (25.8)	2683 (59.0)	<0.001	0.772
50k-100k	4158 (30.3)	1115 (24.5)		
>100k	6022 (43.9)	748 (16.5)		
Education				
Advanced degree	5069 (37.0)	842 (18.5)	<0.001	0.615
College graduate	4177 (30.5)	929 (20.4)		
Some college	3033 (22.1)	1551 (34.1)		
High school or less	1434 (10.5)	1224 (26.9)		
Marital status				
Divorced/separated/widowed	3269 (23.8)	1664 (36.6)	<0.001	0.133
Married/living with partner	8867 (64.7)	2167 (47.7)		
Never married	1577 (11.5)	715 (15.7)		
Insurance				
Uninsured	156 (1.1)	93 (2.0)	<0.001	0.073
Insured	13556 (98.9)	4453 (98.0)		
Homeowner				
Rent	2603 (19.0)	1668 (36.7)	<0.001	0.252
Own	10586 (77.2)	2511 (55.2)		
Other arrangement	524 (3.8)	367 (8.1)		
Employment				
Not employed for wages	6387 (46.6)	3479 (76.5)	<0.001	0.647
Employed for wages	7326 (53.4)	1067 (23.5)		

* Significance was set at P < 0.0056 due to Bonferroni correction

Table 2. Patient characteristics at baseline after PSM.

	Without disability (N=4,437)		With disability (N=4,437)		P	SMD
Age, median (IQR)	69 (59, 75)		67 (58, 75)		0.0608	0.040
Sex						
Male	1601	(36.1)	1589	(35.8)	0.8077	0.006
Female	2836	(63.9)	2848	(64.2)		
Race						
White	3312	(74.6)	3201	(72.1)	<0.001	0.026
Black	635	(14.3)	763	(17.2)		
Asian	56	(1.3)	29	(0.7)		
Hispanic	433	(9.8)	441	(9.9)		
NHPI	1	(0)	3	(0.1)		
Annual household income						
<50k	2507	(56.5)	2578	(58.1)	0.056	0.013
50k-100k	1210	(27.3)	1111	(25)		
>100k	720	(16.2)	748	(16.9)		
Education						
Advanced degree	865	(19.5)	842	(19)	<0.001	0.070
College graduate	1047	(23.6)	909	(20.5)		
Some college	1475	(33.2)	1493	(33.6)		
High school or less	1050	(23.7)	1193	(26.9)		
Marital status						
Divorced/separated/widowed	1596	(36)	1614	(36.4)	0.0013	0.031
Married/living with partner	2253	(50.8)	2125	(47.9)		
Never married	588	(13.3)	698	(15.7)		
Insurance						
Uninsured	99	(2.2)	91	(2.1)	0.6077	0.012
Insured	4338	(97.8)	4346	(97.9)		
Homeowner						
Rent	1335	(30.1)	1603	(36.1)	<0.001	0.047
Own	2884	(65)	2467	(55.6)		
Other arrangement	218	(4.9)	367	(8.3)		
Employment						
Not employed for wages	3309	(74.6)	3370	(76)	0.1399	0.032
Employed for wages	1128	(25.4)	1067	(24)		

* Significance was set at P < 0.0056 due to Bonferroni correction

4.1 Cancer patients with disability experienced greater barriers to timely medical care

The results were fairly consistent before and after the matching, such that patients with disability reported consistently higher frequency of getting delayed medical care (Table 3).

After matching (Figure 5), chi-squared tests showed that the rate at which the coverage was not accepted by their healthcare provider or doctor's office was 11.8% in patients with disability, in contrast to 6.4% of patients without disability (p<0.001). A substantial proportion of the disability cohort had delayed healthcare due to high out-of-pocket (15% vs. 11.3%, p<0.001), including high co-payment (7.1% vs. 4.5%, p<0.001). They also showed a higher frequency of feeling too nervous to see a healthcare provider (p<0.001). Additionally, the biggest difference between the 2 cohorts was observed in arranging transportation, 193 of patients with disability lack transportation for receiving medical care promptly, compared to a significantly lower number of patients without disability (10.8% vs. 3.8%, p<0.001). A similar trend was found in travel distance that patients with disability were approximately 3 times more likely to defer an appointment by living in a rural area where the distance to the health care provider was too far (p<0.001). The deductible was noted as non-significant between the groups. The chance of receiving timely medical care was also not influenced by having to take care of another adult or child.

Table 3. Reasons for delayed medical care by disability status.

	Unmatched			Matched		
	Without disability (N=9,573)	With disability (N=2,754)	P	Without disability (N=2,035)	With disability (N=1,780)	P
Insurance Not accepted (during the past 12 months)	679 (7.1)	322 (11.7)	<0.001	130 (6.4)	210 (11.8)	<0.001
No transportation	264 (2.8)	349 (12.7)	<0.001	80 (3.9)	193 (10.8)	<0.001
Lived in a rural area where distance to the health care provider is too far	113 (1.2)	133 (4.8)	<0.001	32 (1.6)	74 (4.2)	<0.001
Nervous about seeing a healthcare provider	755 (7.9)	355 (12.9)	<0.001	148 (7.3)	217 (12.2)	<0.001
Couldn't get time off work	611 (6.4)	126 (4.6)	<0.001	86 (4.2)	92 (5.2)	0.1936
Couldn't get child care	167 (1.7)	46 (1.7)	0.857	24 (1.2)	31 (1.7)	0.1878
Take care of an adult and cannot leave him/her	118(1.2)	82 (3)	<0.001	30 (1.5)	51 (2.9)	0.0042
Unaffordable co-pay	327 (3.4)	208 (7.6)	<0.001	91 (4.5)	126 (7.1)	<0.001
High/unaffordable deductible	511 (5.3)	208 (7.6)	<0.001	113 (5.6)	131 (7.4)	0.0272
Had to pay out of pocket for some/all of the procedure	1074 (11.2)	411 (14.9)	<0.001	229 (11.3)	267 (15)	<0.001

* Significance was set at P < 0.00313 due to Bonferroni correction

Figure 5. Reasons for delayed medical care by disability status (the matched cohort). Without disability N=2,035; With disability N=1,780. Between-group comparisons were done by Pearson's chi-squared tests with Bonferroni correction in the Jupyter Notebook using RStudio. Figure was generated by GraphPad Prism 10. Analyses were 2-sided and p < 0.00313 was considered statistically significant. Significance is indicated in asterisk.

4.2 Healthcare was less affordable for patients with disability

To better examine the financial burden of healthcare on cancer patients, this study evaluated the services that were unaffordable for patients with and without disability. It was found that in both the matched and unmatched cohort, patients with disability were less likely to be able to pay for the medical costs (Table 4). The only exception was that the rate of missing primary care including seeing a regular doctor or general health provider was found similar regardless of the disability status after matching.

Figure 6 shows the bar graph comparing the affordability of healthcare services by disability status in the matched cohort. 20.5% of patients with disability could not get dental care (including check-ups) when they needed it, compared to 13.1% of patients without disability (p<0.001). Striking differences between the 2 groups were also exhibited in eyeglasses (15.5% vs. 9%, p<0.001), prescription medicines (14.5% vs. 7.7, p<0.001) and specialty care (10.6% vs. 6.2%, p<0.001). A total of 161 patients with disability reported that they could not afford follow-up care (8.1%, p<0.001) and 140 could not afford mental health care or counselling (7.1%, p<0.001). Despite less than 5% of patients from both groups reported not being able to afford emergency care, the difference still differed by disability status substantially (p<0.001).

Table 4. Unaffordable services by disability status.

	Unmatched			Matched		
	Without disability (N=10,516)	With disability (N=3,074)	P	Without disability (N=2,275)	With disability (N=1,985)	P
Prescription medicine	651 (6.2)	458 (14.9)	<0.001	175 (7.7)	288 (14.5)	<0.001
Mental health care or counselling	388 (3.7)	230 (7.5)	<0.001	89 (3.9)	140 (7.1)	<0.001
Emergency care	190 (1.8)	140 (4.6)	<0.001	42 (1.8)	90 (4.5)	<0.001
Dental care (including check-ups)	1033 (9.8)	665 (21.6)	<0.001	297 (13.1)	407 (20.5)	<0.001
Eyeglasses	666 (6.3)	495 (16.1)	<0.001	204 (9)	307 (15.5)	<0.001
To see a regular doctor or general health provider (in primary care, general practice, internal medicine, family medicine)	329 (3.1)	180 (5.9)	<0.001	98 (4.3)	109 (5.5)	0.0853
To see a specialist	538 (5.1)	330 (10.7)	<0.001	140 (6.2)	211 (10.6)	<0.001
Follow-up care	414 (3.9)	261 (8.5)	<0.001	110 (4.8)	161 (8.1)	<0.001

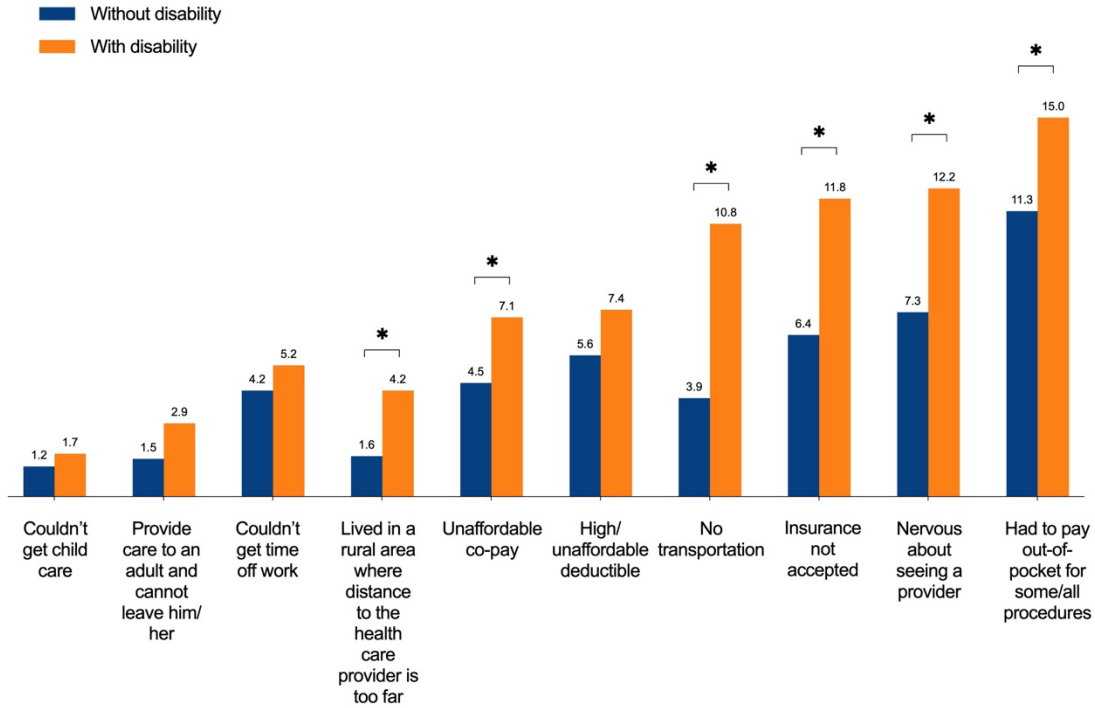* Significance was set at P < 0.00625 due to Bonferroni correction
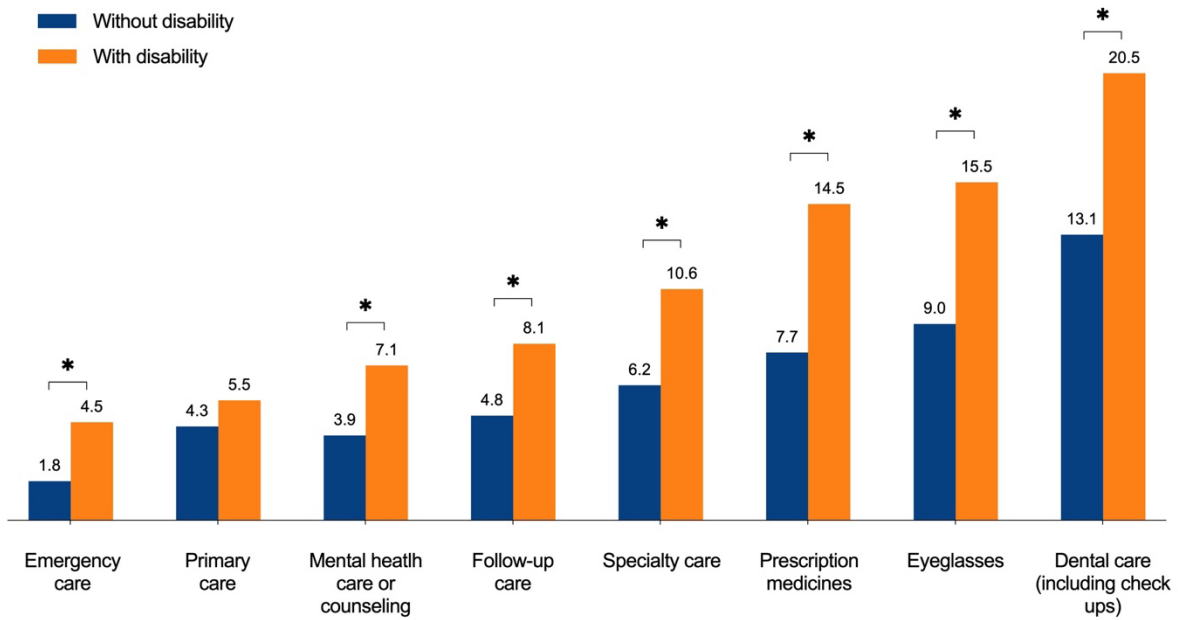
Figure 6. Unaffordable healthcare services by disability status (the matched cohort). Without disability N=2,275; With disability N=1,985. Between-group comparisons were done by Pearson's chi-squared tests with Bonferroni correction in the Jupyter Notebook using RStudio. Figures were generated by GraphPad Prism 10. Analyses were 2-sided and p < 0.00625 was considered statistically significant. Significance is indicated in asterisk.

4.3 Cost-related medical non-adherence was more often observed in patients with disability

Patients with disability reported a higher frequency of cost-related medical non-adherence than patients without disability (Table 5). In the matched cohort, figure 7 showed that both groups claimed a fairly high rate of having asked for a lower-cost medication in the past, although it happened more frequently among patients with disability (20.2% vs. 16%, p<0.001). They also reflected a profound rate of delaying filling a prescription (11.1% vs. 6.8%, p<0.001), taking less medicine (7.5% vs. 4.9%, p=0.0013) and skipping medication doses (6.5% vs. 4%, p<0.001). Using alternative therapies and buying prescription drugs from another country did not differ by disability status.

Table 5. Cost-related medical non-adherence by disability status.

	Unmatched			Matched		
	Without disability (N=9,573)	With disability (N=2,754)	P	Without disability (N=2,035)	With disability (N=1,780)	P
Skipped medication doses	285 (3)	198 (7.2)	<0.001	81 (4)	116 (6.5)	<0.001
Took less medicine	356 (3.7)	228 (8.3)	<0.001	100 (4.9)	133 (7.5)	0.00123
Delayed filling a prescription	545 (5.7)	318 (11.5)	<0.001	139 (6.8)	197 (11.1)	<0.001
Asked for a lower cost medication	1375 (14.4)	549 (19.9)	<0.001	326 (16)	359 (20.2)	0.00101
Bought prescription drugs from another country	214 (2.2)	72 (2.6)	0.2747	40 (2)	42 (2.4)	0.4684
Used alternative therapies	377 (3.9)	183 (6.6)	<0.001	87 (4.3)	109 (6.1)	0.0122

* Significance was set at P < 0.00313 due to Bonferroni correction
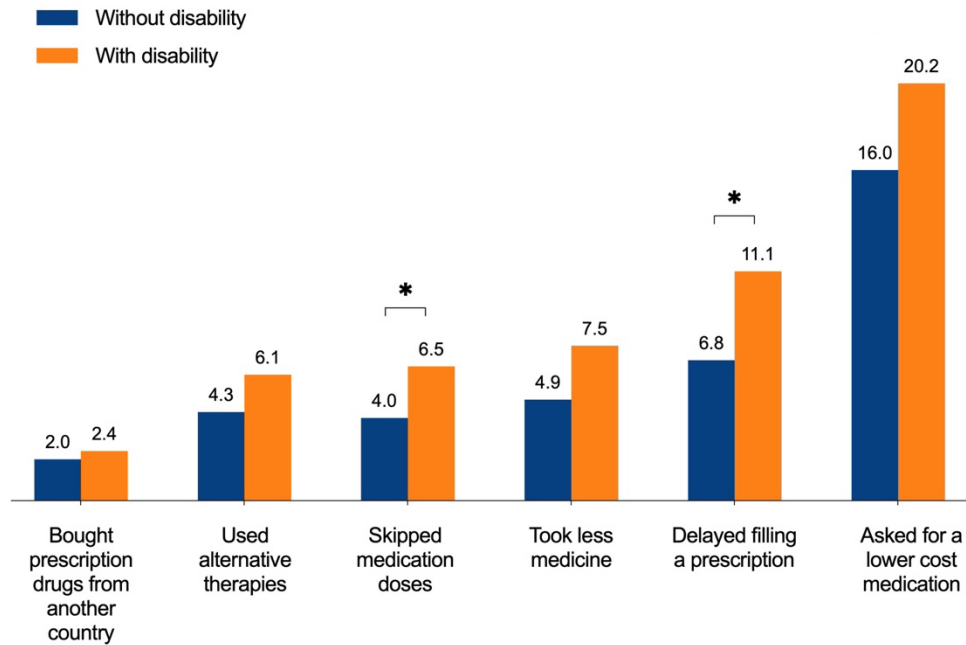
Figure 7. Cost-related medical non-adherence by disability status (the matched cohort). Without disability N=2,035; With disability N=1,780. Between-group comparisons were done by Pearson's chi-squared tests with Bonferroni correction in the Jupyter Notebook using RStudio. Figures were generated by GraphPad Prism 10. Analyses were 2-sided and p < 0.00313 was considered statistically significant. Significance is indicated in asterisk.

4.4 Cancer patients living with disability showed worse overall health

The study further looked into the mediating effect of healthcare accessibility and affordability on patients' health. It was determined that the disability cohort had consistently poorer physical health and mental health, although the absolute difference between the two groups was slightly reduced after matching (Table 6).

In the matched cohort, figure 8A showed that cancer patients with disability were 6 times more likely to self-report poor physical health (12.4% vs. 2%, p<0.001). The extent to which they could perform physical activities such as walking, climbing stairs, carrying groceries or moving a chair was also heavily impacted, with 3.1% indicating a complete loss of capability (p<0.001). Under mental health, 6.3 % of patients with disability reported negative emotions, such that they always felt anxious, depressed or irritated, as compared to only 1.1% of patients without disability. Further, patients with disability did worse in activities and responsibilities as a parent, child, spouse, employee or friend (5.5% vs. 0.6%, p<0.001). They were also more likely to have poor satisfaction in social activities and relationships (8.9% vs. 2%, p<0.001). Strikingly, the disability cohort had worse general health (10.6% vs. 2%), worse quality of life (4.8% vs. 0.8%) and higher frequency of very severe fatigue (3.5% vs. 0.7%) than patients without disability. In addition, patients with disability reported higher pain intensity (Figure 8B). The median score was 5 with an IQR of 2 to 7 whilst that for patients without disability was 2 with an IQR of 1 to 4 (p<0.001). The full response to the overall health survey is listed in the appendix 3 and 4.

Table 6. Self-reported health by disability status.

	Unmatched			Matched		
	Without disability (N=16,936)	With disability (N=6,892)	P	Without disability (N=3,975)	With disability (N=4,021)	P
Poor physical health	235 (1.4)	895 (13)	<0.001	76 (2)	471 (12.4)	<0.001
Could not carry out physical activities at all	25 (0.1)	295 (4.3)	<0.001	10 (0.3)	118 (3.1)	<0.001
Poor mental health	87 (0.5)	395 (5.7)	<0.001	28 (0.8)	210 (5.4)	<0.001
Always be bothered by emotional problems	164 (1)	460 (6.7)	<0.001	43 (1.1)	233 (6.3)	<0.001
Poorly carried out social roles	55 (0.3)	377 (5.5)	<0.001	18 (0.6)	211 (5.5)	<0.001
Poor social satisfaction	236 (1.4)	601 (8.7)	<0.001	76 (2)	348 (8.9)	<0.001
Poor general health	229 (1.4)	797 (11.6)	<0.001	78 (2)	403 (10.6)	<0.001
Poor quality of life (QoL)	74 (0.4)	333 (4.8)	<0.001	33 (0.8)	177 (4.8)	<0.001
Very severe fatigue	98 (0.6)	289 (4.2)	<0.001	26 (0.7)	131 (3.5)	<0.001
Pain, median (IQR)	2 (0,4)	5 (2,7)	<0.001	2 (1,4)	5 (2,7)	<0.001

* Significance was set at P < 0.005 due to Bonferroni correction
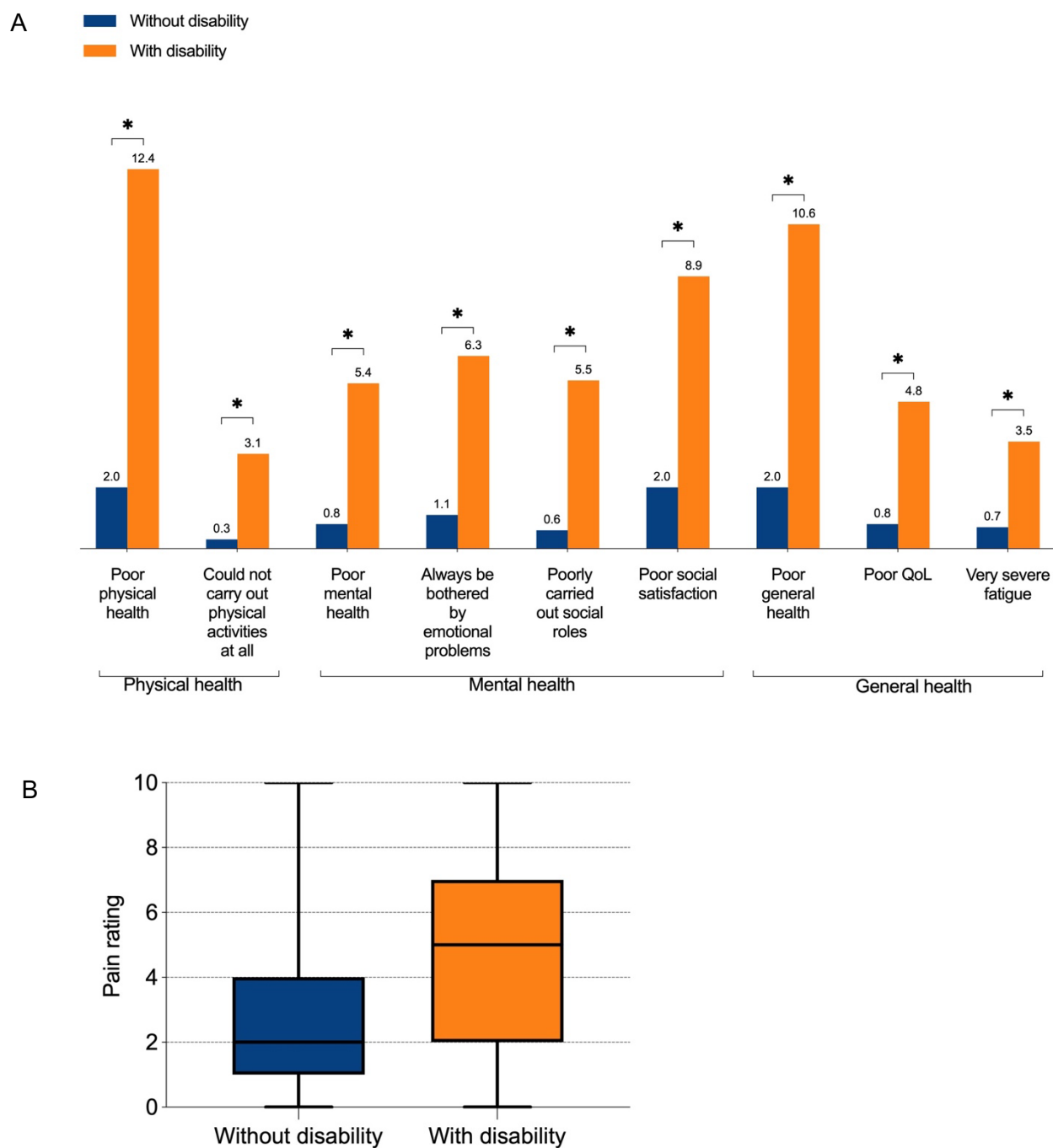
Figure 8. Self-reported health by disability status (the matched cohort).
A) Physical, mental and general health.
B) Pain intensity (Without disability: N=3,975; With disability: N = 4,021).
Between-group comparisons for categorical variables were done by Pearson chi-squared tests in the Jupyter Notebook using Rstudio. Pain depicting as median with IQR was compared by independent t-test between 2 groups. Figures were generated by GraphPad Prism 10. Analyses were 2-sided and $p<0.005$ was considered statistically significant. Significance is indicated in asterisk.

CHAPTER 5: DISCUSSION

Cancer health disparities in the subpopulation of people with disability have received limited

attention in the current literature. There is a lack of comprehensive understanding of the

challenges in accessing timely quality healthcare. As such, this study explored the factors

contributing to the inaccessibility and unaffordability of healthcare in cancer patients with

disability in the US using data obtained from the NIH All of Us database.

We showed that as compared to cancer patients living without disability, individuals with

disability exhibited poorer healthcare access overall. Specifically, they were unable to seek

timely services primarily due to the high out-of-pocket costs, high co-payments, feeling nervous

about seeing a provider, lacking appropriate transportation and residing in a rural area where

the distance to healthcare providers was too far. Further, people with disability were more likely

to experience financial hardship and have difficulty getting a range of necessary care. They then

delayed filling prescriptions and skipping doses to counteract the high cost of healthcare. Also,

the health-related outcomes were compromised in patients living with disability. They self-

reported worse general health, quality of life, physical health and mental health.

Healthcare accessibility

Transportation has been well implicated in the literature for its counterproductive role in

reaching cancer health equities (56, 57). Having difficulty arranging transportation can lead to

the termination of treatments such as radiotherapy and chemotherapy (58). Living in an area

where the healthcare facility is at a distance or inconvenient location may incur extra costs and

wait times, affecting patients' decision-making on medical adherence. Travel distance puts a

huge burden on patients, especially among those living with cancer whose treatments often

come with repeated cycles. Consistent with these findings, this study also revealed a

transportation gap among cancer patients with disability. Many of these individuals who relied

heavily on caregivers for ADLs, faced significant challenges due to either lacking transportation

or residing too far from healthcare providers. Consequently, they often miss timely care,

exacerbating existing health disparities.

Notably, this study showed that the rate of insurance acceptance was significantly lower in the

disability cohort. The reason for non-acceptance was unknown, possibly stemming from a

failure of negotiation between insurers and physicians, or from physicians being overwhelmed

with their workload, thus hindering the delivery of quality care. Either way, patients left without

insurance coverage would have to explore alternative in-network providers, which often caused

troubles and delays in receiving medical care. Some might also consider discontinuing their

cancer treatments, posing serious threats to their health and survival. Alternatively, they would

face a financial burden by paying the full out-of-pocket cost. As such, the availability of

healthcare including new drugs and treatments was not always equally utilised by every patient.

The disability cohort faced more difficulties covering their medical expenses which might in part,

be attributed to the low insurance acceptance rate.

Healthcare affordability

The medical expenses associated with cancer treatment are often unmanageable. 1 in 3

patients incurred debt due to cancer and younger patients were more likely to suffer from debts

given fewer deposits compared to the older patients (59). Yet living with disability often incur

extra costs to accommodate their life, including buying wheelchairs, purchasing a house with an

accessible facility, and ordering things from a convenient location (60). Therefore, higher

incomes are necessary for patients with disability to maintain the same living standard as the

general population. However, this study showed that the annual household income distribution

for them was right-skewed, with the majority earning under $50,000, contrasting with the

national cohort's median income of $74,580 in 2022 (U.S. Census Bureau data). It is worth

noting that despite their more disadvantaged socioeconomic status than their counterparts, cancer patients with disability were confronted with higher medical expenses. As a result, they were found less compliant with the health guidance for prescription drug use, either skipping the doses or delaying the fillings in order to make the prescription last longer so that they could save money and manage the financial burden along the treatment. This is in line with the report by the World Health Organisation Europe which pointed out in early 2024 that healthcare was affordable among only half of the people with disabilities, and the rate of cost-related medical nonadherence was substantially higher in adults with disability (61). The consequence of non-adherence to healthcare due to financial toxicity could potentially lead to disease progression, higher cancer mortality and poorer health (62).

Health outcomes

Physical health is a key indicator of general well-being encompassing bodily function and performance. In cancer, an active lifestyle could reduce the risk of recurrence but it becomes challenging for patients with disability who reported struggles with physical activities, high levels of pain and fatigue to adhere to this adjunct therapy for cancer, thus losing the potential benefits in QoL and mortality (63, 64).

Mental health as defined by the CDC encompasses the emotional, psychological and social well-being that shapes people's daily thoughts, feelings and actions. Cancer is associated with a broad range of emotional distress, with feelings of anxiety and depression develop along with the treatment and can persist long into the future (65-67). In addition to the previous findings, this study demonstrated that cancer patients with disability were 7 times more likely to have poor mental health than those without disability, indicating that the disability status could exacerbate the emotional disturbance stemming from the fear of disease progression or recurrence. The low employment rate among the disability cohort could be another mechanism

explaining the mental distress. Employment income serves as a buffer for them to adapt to the new changes in life, thus losing control of the labour market may trigger fear, insecurity and disappointment, which may significantly disrupt their daily activities and overall quality of life (68-70). Moreover, individuals with cognitive impairments were less likely to be capable of self-regulating to adapt to emotional disturbances as they often do not know where to seek professional support and do not have a good coping approach (71, 72). In addition, lacking family companionship could contribute to poor mental well-being as families often act as the resource to help people navigate mood changes, extending support to anxiety and frustration (73). Furthermore, the study showed that cancer patients with disability had an overall low satisfaction in their social life. As they became less engaged with other people and got disconnected from relationships, it intensified their negative moods and also reduced the chances for them to receive emotional support from families and friends. Being physically inactive could also contribute to the disruption of self-esteem, confidence, creativity, sense of self-worth and the ability to handle challenges since they lack the experience of setting objectives and fulfilling goals.

Limitations and future directions

Whilst this study provided new insights into the inequalities experienced by cancer patients living with disability, there are some key drawbacks. The main disadvantage was the use of self-reported surveys. The participants might have provided biased responses unintentionally because of a misinterpretation of the survey question. It was also possible that they hesitated to share personal details, or they answered the questions in a way they thought would be correct theoretically. Second, a large database like All of Us was subject to coding bias (74). Third, the stage of cancer was unknown which may have affected the generalisability of the results. Patients present with early stages might be less likely to face as many barriers in healthcare as ones with a more advanced stage do.

Future research could examine the varying spectrum of disparities across different types of disabilities, such as sensory, mobility, cognitive and self-care impairments. By acknowledging that individuals may encounter unique challenges in accessing healthcare based on their circumstances, we can develop a more integrated approach that thoroughly addresses the disparities in this multifaceted issue.

Conclusion

This study addressed the gaps in cancer health disparities by highlighting the difficulty in accessing and affording healthcare for patients with disability. The poor health may partially be mediated by the adverse socioeconomic status in employment and income, leading to severe financial burdens that create cost-related barriers to accessing timely healthcare.

APPENDIX

Appendix 1. The overall health questionnaire

Questions	Response to the survey
In general, would you say your health is:	• Excellent • Very Good • Good • Fair • Poor
In general, would you say your quality of life is:	• Excellent • Very Good • Good • Fair • Poor
In general, how would you rate your physical health?	• Excellent • Very Good • Good • Fair • Poor
In general, how would you rate your mental health, including your mood and your ability to think?	• Excellent • Very Good • Good • Fair • Poor
In general, how would you rate your satisfaction with your social activities and relationships?	• Excellent • Very Good • Good • Fair • Poor
To what extent are you able to carry out your everyday physical activities such as walking, climbing stairs, carrying groceries, or moving a chair?	• Completely • Mostly • Moderately • A little • Not at all
In the past 7 days, how would you rate your pain on average?	On a scale from 0 to 10 where 0 means no pain and 10 means the worst possible pain
In the past 7 days, how would you rate your fatigue?	• None • Mild • Moderate • Severe • Very severe
In general, please rate how well you carry out your usual social roles. (This includes activities at home, at work and in your community, and responsibilities as a parent, child, spouse, employee, friend, etc.)	• Excellent • Very Good • Good • Fair • Poor
In the past 7 days, how often have you been bothered by emotional problems such as feeling anxious, depressed or irritable?	• Never • Rarely • Sometimes • Often • Always

Appendix 2. The healthcare access and utilisation.

	Before matching			After matching		
	Without disability	With disability	P	Without disability	With disability	P
Reasons for delayed medical care						
Insurance not accepted (during the past 12 months)	679 (7.1)	322 (11.7)	9.387e-15	130 (6.4)	210 (11.8)	6.90e-09
No transportation	264 (2.8)	349 (12.7)	< 2.2e-16	80 (3.9)	193 (10.8)	2.42e-16
Lived in a rural area where distance to the health care provider is too far	113 (1.2)	133 (4.8)	< 2.2e-16	32 (1.6)	74 (4.2)	2.06e-06
Too nervous to see a health care provider	755 (7.9)	355 (12.9)	8.553e-16	148 (7.3)	217 (12.2)	3.45e-07
Couldn't get time off work	611 (6.4)	126 (4.6)	0.0005018	86 (4.2)	92 (5.2)	0.1936
Couldn't get child care	167 (1.7)	46 (1.7)	0.857	24 (1.2)	31 (1.7)	0.1878
Couldn't get elderly care	118(1.2)	82 (3)	2.948e-10	30 (1.5)	51 (2.9)	0.004228
Couldn't afford the co-pay	327 (3.4)	208 (7.6)	< 2.2e-16	91 (4.5)	126 (7.1)	0.0006784
Couldn't afford the deductible	511 (5.3)	208 (7.6)	1.531e-05	113 (5.6)	131 (7.4)	0.02717
Couldn't afford the out of pocket for some/all of the procedure	1074 (11.2)	411 (14.9)	1.693e-07	229 (11.3)	267 (15)	0.0007125
Strategies used to reduce cost						
Skipped medication doses	285 (3)	198 (7.2)	< 2.2e-16	81 (4)	116 (6.5)	0.000543
Took less medicine	356 (3.7)	228 (8.3)	< 2.2e-16	100 (4.9)	133 (7.5)	0.001266
Delayed filling a prescription	545 (5.7)	318 (11.5)	< 2.2e-16	139 (6.8)	197 (11.1)	5.38e-06
Asked for a lower cost medication	1375 (14.4)	549 (19.9)	1.556e-12	326 (16)	359 (20.2)	0.001007
Bought prescription	214 (2.2)	72 (2.6)	0.2747	40 (2)	42 (2.4)	0.4684

drugs from another country					
Used alternative therapies	377 (3.9)	183 (6.6)	2.536e-09	87 (4.3)	109 (6.1)	0.01219
Unaffordable healthcare					
Prescription medicine	651 (6.2)	458 (14.9)	< 2.2e-16	175 (7.7)	288 (14.5)	1.428e-12
Mental health care or counselling	388 (3.7)	230 (7.5)	< 2.2e-16	89 (3.9)	140 (7.1)	7.968e-06
Emergency care	190 (1.8)	140 (4.6)	< 2.2e-16	42 (1.8)	90 (4.5)	6.986e-07
Dental care (including check-ups)	1033 (9.8)	665 (21.6)	< 2.2e-16	297 (13.1)	407 (20.5)	8.675e-11
Eyeglasses	666 (6.3)	495 (16.1)	< 2.2e-16	204 (9)	307 (15.5)	1.011e-10
To see a regular doctor or general health provider (in primary care, general practice, internal medicine, family medicine)	329 (3.1)	180 (5.9)	3.634e-12	98 (4.3)	109 (5.5)	0.08531
To see a specialist	538 (5.1)	330 (10.7)	< 2.2e-16	140 (6.2)	211 (10.6)	1.571e-07
Follow-up care	414 (3.9)	261 (8.5)	< 2.2e-16	110 (4.8)	161 (8.1)	1.656e-05

Appendix 3. Overall Health before matching

		Without disability		With disability		P
General health	Excellent	2314	(13.7)	220	(3.2)	< 2.2 e-16
	Very good	6634	(39.2)	1157	(16.8)	
	Good	5850	(34.5)	2355	(34.2)	
	Fair	1909	(11.3)	2363	(34.3)	
	Poor	229	(1.4)	797	(11.6)	
Quality of life	Excellent	4535	(26.8)	695	(10.1)	< 2.2 e-16
	Very good	7368	(43.5)	1694	(24.6)	
	Good	4115	(24.3)	2530	(36.7)	
	Fair	844	(5)	1640	(23.8)	
	Poor	74	(0.4)	333	(4.8)	
Physical health	Excellent	2058	(12.2)	190	(2.8)	< 2.2 e-16
	Very good	6277	(37.1)	1001	(14.5)	
	Good	6163	(36.4)	2254	(32.7)	
	Fair	2203	(13)	2552	(37)	
	Poor	235	(1.4)	895	(13)	
Physical activities: walking, climbing stairs, carrying groceries, moving a chair	Completely	12951	(76.5)	1840	(26.7)	< 2.2 e-16
	Mostly	2628	(15.5)	1415	(20.5)	
	Moderately	1077	(6.4)	1908	(27.7)	
	A little	255	(1.5)	1434	(20.8)	
	Not at all	25	(0.1)	295	(4.3)	
Fatigue	None	4300	(25.4)	726	(10.5)	< 2.2 e-16
	Mild	8082	(47.7)	2007	(29.1)	
	Moderate	3865	(22.8)	2813	(40.8)	
	Severe	591	(3.5)	1057	(15.3)	
	Very severe	98	(0.6)	289	(4.2)	
Mental health: Mood and ability to think	Excellent	4506	(26.6)	950	(13.8)	< 2.2 e-16
	Very good	6948	(41)	1765	(25.6)	
	Good	4301	(25.4)	2245	(32.6)	
	Fair	1094	(6.5)	1537	(22.3)	
	Poor	87	(0.5)	395	(5.7)	
Emotional problems: feel anxious, depressed or irritable	Never	4598	(27.1)	1317	(19.1)	< 2.2 e-16
	Rarely	6205	(36.6)	1614	(23.4)	
	Sometimes	4874	(28.8)	2296	(33.3)	
	Often	1095	(6.5)	1205	(17.5)	
	Always	164	(1)	460	(6.7)	
Social roles (at home/work/community,	Excellent	5911	(34.9)	987	(14.3)	< 2.2
	Very good	7036	(41.5)	1748	(25.4)	

responsibilities as a parent/child/spouse/employee/friend)	Good	3183	(18.8)	2290	(33.2)	e-16
	Fair	751	(4.4)	1490	(21.6)	
	Poor	55	(0.3)	377	(5.5)	
Satisfaction with social activities and relationships	Excellent	4055	(23.9)	921	(13.4)	< 2.2 e-16
	Very good	6794	(40.1)	1741	(25.3)	
	Good	4346	(25.7)	2203	(32)	
	Fair	1505	(8.9)	1426	(20.7)	
	Poor	236	(1.4)	601	(8.7)	
Pain, median (IQR)		2 (0, 4)		5 (2, 7)		< 2.2 e-16

Appendix 4. Overall health after matching

		Without disability		With disability		P
General health	Excellent	411	(10.3)	133	(3.3)	< 2.2e-16
	Very good	1394	(35.1)	726	(18.1)	
	Good	1505	(37.9)	1418	(35.3)	
	Fair	586	(14.7)	1316	(32.7)	
	Poor	79	(2)	428	(10.6)	
Quality of life	Excellent	856	(21.5)	423	(10.5)	< 2.2e-16
	Very good	1600	(40.3)	1093	(27.2)	
	Good	1185	(29.8)	1436	(35.7)	
	Fair	303	(7.6)	874	(21.7)	
	Poor	31	(0.8)	195	(4.8)	
Physical health	Excellent	350	(8.8)	110	(2.7)	< 2.2e-16
	Very good	1314	(33.1)	631	(15.7)	
	Good	1576	(39.6)	1375	(34.2)	
	Fair	657	(16.5)	1408	(35)	
	Poor	78	(2)	497	(12.4)	
Physical activities: walking, climbing stairs, carrying groceries, moving a chair	Completely	2785	(70.1)	1190	(29.6)	< 2.2e-16
	Mostly	740	(18.6)	858	(21.3)	
	Moderately	362	(9.1)	1057	(26.3)	
	A little	78	(2)	793	(19.7)	
	Not at all	10	(0.3)	123	(3.1)	
Fatigue	None	986	(24.8)	436	(10.8)	< 2.2e-16
	Mild	1803	(45.4)	1225	(30.5)	
	Moderate	1006	(25.3)	1631	(40.6)	
	Severe	152	(3.8)	590	(14.7)	
	Very severe	28	(0.7)	139	(3.5)	
Mental health: Mood and ability to think	Excellent	977	(24.6)	575	(14.3)	< 2.2e-16
	Very good	1554	(39.1)	1102	(27.4)	
	Good	1102	(27.7)	1272	(31.6)	
	Fair	312	(7.8)	855	(21.3)	
	Poor	30	(0.8)	217	(5.4)	
Emotional problems: feel anxious, depressed or irritable	Never	1155	(29.1)	721	(17.9)	< 2.2e-16
	Rarely	1393	(35)	1017	(25.3)	
	Sometimes	1102	(27.7)	1344	(33.4)	
	Often	283	(7.1)	686	(17.1)	
	Always	42	(1.1)	253	(6.3)	
	Excellent	1223	(30.8)	580	(14.4)	

Social roles (at home/work/community, responsibilities as a parent/child/spouse/employee/ friend)	Very good	1588	(39.9)	1080	(26.9)	< 2.2e-16
	Good	906	(22.8)	1302	(32.4)	
	Fair	236	(5.9)	838	(20.8)	
	Poor	22	(0.6)	221	(5.5)	
Satisfaction with social activities and relationships	Excellent	837	(21.1)	534	(13.3)	< 2.2e-16
	Very good	1519	(38.2)	1070	(26.6)	
	Good	1117	(28.1)	1236	(30.7)	
	Fair	424	(10.7)	822	(20.4)	
	Poor	78	(2)	359	(8.9)	
Pain, median (IQR)		2 (1,4)		5 (2,7)		< 2.2e-16

Appendix 5. Patient characteristics at baseline before PSM (imputed)

	Without disability (N=15,279)		With disability (N=15,260)		P
Age, median (IQR)	65 (55, 72)		66 (57, 74)		< 2.2e-16
Sex					
Male	4396	(28.8)	4464	(29.3)	0.3605
Female	10883	(71.2)	10796	(70.7)	
Race					
White	12267	(80.3)	10729	(70.3)	< 2.2e-16
Black	1609	(10.5)	2681	(17.6)	
Asian	297	(1.9)	224	(1.5)	
Hispanic	1099	(7.2)	1616	(10.6)	
NHPI	7	(0)	10	(0.1)	
Annual household income					
<50k	4244	(27.8)	7554	(49.5)	< 2.2e-16
50k-100k	4525	(29.6)	3816	(25)	
>100k	6510	(42.6)	3890	(25.5)	
Education					
Advanced degree	5546	(36.3)	3875	(25.4)	< 2.2e-16
College graduate	4534	(29.7)	3530	(23.1)	
Some college	3409	(22.3)	4303	(28.2)	
High school or less	1790	(11.7)	3552	(23.3)	
Marital status					
Divorced/separated/widowed	3744	(24.5)	4809	(31.5)	< 2.2e-16
Married/living with partner	9738	(63.7)	8119	(53.2)	
Never married	1797	(11.8)	2332	(15.3)	
Insurance					
Uninsured	194	(1.3)	329	(2.2)	3.13E-09
Insured	15085	(98.7)	14931	(97.8)	
Homeowner					
Rent	3103	(20.3)	4988	(32.7)	< 2.2e-16
Own	11567	(75.7)	9361	(61.3)	
Other arrangement	609	(4)	911	(6)	
Employment					
Not employed for wages	7300	(47.8)	9429	(61.8)	< 2.2e-16
Employed for wages	7979	(52.2)	5831	(38.2)	

Appendix 6. Patient characteristics-adjusted (imputed)

	Without disability (N=12,536)		With disability (N=12,536)		P
Age, median (IQR)	67 (57, 73)		66 (57, 74)		0.7351
Sex					
Male	3629	(28.9)	3747	(29.9)	0.1049
Female	8907	(71.1)	8789	(70.1)	
Race					
White	9816	(78.3)	9220	(73.5)	< 2.2e-16
Black	1471	(11.7)	1878	(15)	
Asian	225	(1.8)	216	(1.7)	
Hispanic	1019	(8.1)	1216	(9.7)	
NHPI	5	(0)	6	(0)	
Annual household income					
<50k	4224	(33.7)	5081	(40.5)	< 2.2e-16
50k-100k	4253	(33.9)	3581	(28.6)	
>100k	4059	(32.4)	3874	(30.9)	
Education					
Advanced degree	3815	(30.4)	3734	(29.8)	< 2.2e-16
College graduate	3675	(29.3)	3208	(25.6)	
Some college	3295	(26.3)	3320	(26.5)	
High school or less	1751	(14)	2274	(18.1)	
Marital status					
Divorced/separated/widowed	3451	(27.5)	3618	(28.9)	4.51e-11
Married/living with partner	7513	(59.9)	7035	(56.1)	
Never married	1572	(12.5)	1883	(15)	
Insurance					
Uninsured	186	(1.5)	276	(2.2)	2.92e-05
Insured	12350	(98.5)	12260	(97.8)	
Homeowner					
Rent	2867	(22.9)	3587	(28.6)	< 2.2e-16
Own	9147	(73)	8165	(65.1)	
Other arrangement	522	(4.2)	784	(6.3)	
Employment					
Not employed for wages	6741	(53.8)	7101	(56.6)	5.13e-06
Employed for wages	5795	(46.2)	5435	(43.4)	

Appendix 7. Health care access and utilisation (imputed)

| | Unadjusted | | | Adjusted | | |
	Without disability (N=10,461)	With disability (N=9,147)	P	Without disability (N=6,301)	With disability (N=5,666)	P
Reasons for delayed medical care						
Insurance not accepted (during the past 12 months)	759 (7.2)	875 (9.5)	3.72e-09	437 (6.9)	501 (8.8)	0.00016
No transportation	324 (3.1)	687 (7.5)	< 2.2e-16	202 (3.2)	330 (5.8)	7.94e-12
Lived in a rural area where distance to the health care provider is too far	128 (1.2)	257 (2.8)	1.54e-15	81 (1.3)	130 (2.3)	4.44e-05
Too nervous to see a health care provider	846 (8)	945 (10.3)	3.73e-08	474 (7.5)	578 (10.2)	4.28e-07
Couldn't get time off work	675 (6.4)	614 (6.7)	0.4369	390 (6.2)	441 (7.7)	0.0009009
Couldn't get child care	189 (1.8)	173 (1.9)	0.6716	87 (1.4)	114 (2)	0.00991
Couldn't get elderly care	139 (1.3)	208 (2.3)	6.00e-07	94 (1.5)	113 (2)	0.04532
Couldn't afford the co-pay	387 (3.7)	630 (6.9)	< 2.2e-16	249 (4)	382 (6.7)	1.84e-11
Couldn't afford the deductible	585 (5.5)	670 (7.3)	6.11e-07	359 (5.7)	462 (8.1)	1.96e-07
Couldn't afford the out of pocket for some/all of the procedure	1194 (11.3)	1301 (14.2)	2.35e-09	712 (11.3)	842 (14.8)	1.51e-08
Strategies used to reduce cost						
Skipped medication doses	343 (3.3)	599 (6.5)	< 2.2e-16	234 (3.7)	332 (5.8)	5.90e-08
Took less medicine	421 (4)	682 (7.4)	< 2.2e-16	276 (4.4)	381 (6.7)	3.40e-08
Delayed filling a prescription	642 (6.1)	973 (10.6)	< 2.2e-16	419 (6.7)	562 (9.9)	1.56e-10

Asked for a lower cost medication	1549 (14.7)	1856 (20.2)	< 2.2e-16	962 (15.3)	1122 (19.7)	1.65e-10
Bought prescription drugs from another country	249 (2.4)	324 (3.5)	1.40e-06	156 (2.5)	184 (3.2)	0.01474
Used alternative therapies	431 (4.1)	581 (6.3)	1.46e-12	276 (4.4)	342 (6)	6.71e-05
Unaffordable healthcare						
Prescription medicine	765 (6.7)	1214 (12.1)	< 2.2e-16	442 (6.4)	665 (10.7)	< 2.2e-16
Mental health care or counselling	445 (3.9)	592 (5.9)	6.65e-12	249 (3.6)	376 (6.1)	4.993e-11
Emergency care	213 (1.9)	337 (3.3)	4.71e-12	132 (1.9)	183 (2.9)	0.0001246
Dental care (including check ups)	1168 (10.2)	1706 (17)	< 2.2e-16	754 (10.9)	901 (14.5)	4.933e-10
Eyeglasses	770 (6.7)	1320 (13.1)	< 2.2e-16	489 (7.1)	735 (11.8)	< 2.2e-16
To see a regular doctor or general health provider (in primary care, general practice, internal medicine, family medicine)	380 (3.3)	507 (5)	1.96e-10	229 (3.3)	255 (4.1)	0.01713
To see a specialist	620 (5.4)	872 (8.7)	< 2.2e-16	378 (5.5)	482 (7.8)	1.187e-07
Follow-up care	474 (4.1)	695 (6.9)	< 2.2e-16	285 (4.1)	389 (6.3)	3.111e-08

Appendix 8: Health Outcome – Unadjusted (imputed)

		Without disability (N=18,665)		With disability (N=18,982)		P
General health	Excellent	2434	(13)	1101	(5.8)	< 2.2e-16
	Very good	7177	(38.5)	4849	(25.5)	
	Good	6411	(34.3)	6620	(34.9)	
	Fair	2310	(12.4)	4982	(26.2)	
	Poor	333	(1.8)	1430	(7.5)	
Quality of life	Excellent	4776	(25.6)	2613	(13.8)	< 2.2e-16
	Very good	8014	(42.9)	6120	(32.2)	
	Good	4671	(25)	6392	(33.7)	
	Fair	1087	(5.8)	3282	(17.3)	
	Poor	117	(0.6)	575	(3)	
Physical health	Excellent	2161	(11.6)	941	(5)	< 2.2e-16
	Very good	6778	(36.3)	4365	(23)	
	Good	6757	(36.2)	6680	(35.2)	
	Fair	2622	(14)	5422	(28.6)	
	Poor	347	(1.9)	1574	(8.3)	
Physical activities: walking, climbing stairs, carrying groceries, moving a chair	Completely	13872	(74.3)	8115	(42.8)	< 2.2e-16
	Mostly	2972	(15.9)	3777	(19.9)	
	Moderately	1345	(7.2)	3911	(20.6)	
	A little	424	(2.3)	2659	(14)	
	Not at all	52	(0.3)	520	(2.7)	
Fatigue	None	4581	(24.5)	2784	(14.7)	< 2.2e-16
	Mild	8778	(47)	6927	(36.5)	
	Moderate	4449	(23.8)	6644	(35)	
	Severe	726	(3.9)	2114	(11.1)	
	Very severe	131	(0.7)	513	(2.7)	
Mental health: Mood and ability to think	Excellent	4751	(25.5)	2721	(14.3)	< 2.2e-16
	Very good	7626	(40.9)	6454	(34)	
	Good	4812	(25.8)	5930	(31.2)	
	Fair	1344	(7.2)	3192	(16.8)	
	Poor	132	(0.7)	685	(3.6)	
Emotional problems: feel anxious, depressed or irritable	Never	4990	(26.7)	3877	(20.4)	< 2.2e-16
	Rarely	6723	(36)	5330	(28.1)	
	Sometimes	5446	(29.2)	6318	(33.3)	
	Often	1298	(7)	2619	(13.8)	
	Always	208	(1.1)	838	(4.4)	

Social roles (at home/work/community, responsibilities as a parent/child/spouse/employee/friend)	Excellent	6293	(33.7)	3785	(19.9)	< 2.2e-16
	Very good	7695	(41.2)	6150	(32.4)	
	Good	3618	(19.4)	5447	(28.7)	
	Fair	968	(5.2)	2934	(15.5)	
	Poor	91	(0.5)	666	(3.5)	
Satisfaction with social activities and relationships	Excellent	4339	(23.2)	2937	(15.5)	< 2.2e-16
	Very good	7398	(39.6)	6075	(32)	
	Good	4869	(26.1)	5826	(30.7)	
	Fair	1762	(9.4)	3045	(16)	
	Poor	297	(1.6)	1099	(5.8)	
Pain, median (IQR)		2 (0,4)		4 (1,6)		< 2.2e-16

Appendix 9: Health Outcome – Adjusted (imputed)

		Without disability (N=11,118)		With disability (N=10,160)		P
General health	Excellent	1356	(12.2)	766	(7.5)	< 2.2e-16
	Very good	4314	(38.8)	2990	(29.4)	
	Good	3903	(35.1)	3546	(34.9)	
	Fair	1352	(12.2)	2294	(22.6)	
	Poor	193	(1.7)	564	(5.6)	
Quality of life	Excellent	2794	(25.1)	1642	(16.2)	< 2.2e-16
	Very good	4897	(44)	3752	(36.9)	
	Good	2722	(24.5)	3134	(30.8)	
	Fair	644	(5.8)	1377	(13.6)	
	Poor	61	(0.5)	255	(2.5)	
Physical health	Excellent	1193	(10.7)	637	(6.3)	< 2.2e-16
	Very good	4064	(36.6)	2764	(27.2)	
	Good	4082	(36.7)	3624	(35.7)	
	Fair	1583	(14.2)	2501	(24.6)	
	Poor	196	(1.8)	634	(6.2)	
Physical activities: walking, climbing stairs, carrying groceries, moving a chair	Completely	8244	(74.2)	5136	(50.6)	< 2.2e-16
	Mostly	1793	(16.1)	2041	(20.1)	
	Moderately	806	(7.2)	1721	(16.9)	
	A little	249	(2.2)	1094	(10.8)	
	Not at all	26	(0.2)	168	(1.7)	
Fatigue	None	2747	(24.7)	1613	(15.9)	< 2.2e-16
	Mild	5293	(47.6)	4101	(40.4)	
	Moderate	2594	(23.3)	3270	(32.2)	
	Severe	415	(3.7)	946	(9.3)	
	Very severe	69	(0.6)	230	(2.3)	
Mental health: Mood and ability to think	Excellent	2831	(25.5)	1527	(15)	< 2.2e-16
	Very good	4610	(41.5)	3862	(38)	
	Good	2817	(25.3)	3018	(29.7)	
	Fair	775	(7)	1466	(14.4)	
	Poor	85	(0.8)	287	(2.8)	
Emotional problems: feel anxious, depressed or irritable	Never	2995	(26.9)	2119	(20.9)	< 2.2e-16
	Rarely	4055	(36.5)	3045	(30)	
	Sometimes	3196	(28.7)	3416	(33.6)	
	Often	761	(6.8)	1219	(12)	
	Always	111	(1)	361	(3.6)	

Social roles (at home/work/community, responsibilities as a parent/child/spouse/employee/friend)	Excellent	3750	(33.7)	2317	(22.8)	< 2.2e-16
	Very good	4570	(41.1)	3616	(35.6)	
	Good	2182	(19.6)	2662	(26.2)	
	Fair	556	(5)	1287	(12.7)	
	Poor	60	(0.5)	278	(2.7)	
Satisfaction with social activities and relationships	Excellent	2531	(22.8)	1676	(16.5)	< 2.2e-16
	Very good	4458	(40.1)	3617	(35.6)	
	Good	2889	(26)	2888	(28.4)	
	Fair	1054	(9.5)	1499	(14.8)	
	Poor	186	(1.7)	480	(4.7)	
Pain, median (IQR)		2 (1,4)		3 (1, 6)		< 2.2e-16

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