SSM - Population Health 23 (2023) 101489

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Examining the impact of spatial accessibility to rehabilitation facilities on the degree of disability: A heterogeneity perspective☆

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ARTICLE INFO

Keywords:
Spatial accessibility of rehabilitation facilities
Monetization of travel costs
Degree of disability
Diversity of disability
Application programming interface
Barrier-free facilities

ABSTRACT

The positive effect of healthcare facilities on residents' health has been extensively studied. However, few studies have focused on the role of rehabilitation services as unique healthcare services for persons with disabilities. This study aimed to examine the relationship between the spatial accessibility of rehabilitation facilities and the degree of disability. To this end, an approach of measuring the spatial accessibility of rehabilitation facilities to persons with disabilities was proposed. This approach integrates multiple key elements including the characteristics of facilities (i.e., the capacity, frequency of use and service radius), characteristics of the mobility of persons with disabilities (i.e., the mode of travel, escort support, transportation fee and barrier-free environment requirements) and travel time obtained from a routing application programme interface. The accessibility of rehabilitation facilities was calculated at the neighbourhood level within the Central Urban Area of Tianjin Municipality. The ordinal logistic regression analysis revealed that higher accessibility to rehabilitation facilities generally corresponded to lower severity of disability. However, the impact varied depending on the type of disability. Increased accessibility was associated with greater severity of intellectual disability, whereas it was linked to reduced severity of visual, hearing, limb, mental and speech disabilities. It is suggested to incorporate disability diversity and the accessibility of rehabilitation facilities into spatial planning and governance.

1. Introduction

The degree of disability is a comprehensive measure used to assess the extent of an individual's disability (Mitra, 2006). The World Health Organization (WHO) developed the International Classification of Functioning, Disability and Health, which serves as a universally acknowledged conceptual framework merging medical and social perspectives (WHO, 2001). Typically, governments formulate specific technical criteria to ascertain the degree of disability and establish assessment and guidance teams comprising professionals such as doctors, psychologists, and social assistants (WHO, 2011).

The determinants of the degree of disability have attracted significant attention in the medical and social sciences (Alarcón et al., 2015; Fong, 2019; Nov-Klaiman et al., 2022). Disability, caused directly by diseases, injuries, or other health conditions, poses ongoing challenges for individuals. Consequently, the interaction between disability and healthcare has become a prominent area of study (Iezzoni et al., 2021; Mitra, 2006). Earlier research in the 1960s confirmed the importance of clinic proximity in outpatient treatment requests, influencing the degree of disability (Dworin, Green, & Young, 1964). Recent studies have further supported these findings. For acute stroke, Sheth et al. (2015) found that an early time to surgery improved the disability outcome and reduced the degree of disability. Similarly, Santos et al. (2015) identified inadequate treatment, often due to a lack of professional knowledge, as a significant factor contributing to the high disability rate among leprosy patients. Disability rehabilitation services specifically accommodate the particular health needs of persons with disabilities (Iezzoni & Agaronnik, 2020, pp. 15–31). Early identification of impairments, basic interventions, and referral to specialized services offering physical, occupational, and speech therapy, as well as prosthetics, orthotics, and corrective surgeries, are of utmost importance (Jacob et al., 2022). However, while numerous studies have explored the spatial accessibility of medical facilities (Jia et al., 2022), limited research has investigated the accessibility of disability rehabilitation, including the specific travel

☆ All authors have reviewed and approved the manuscript before submission.
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https://doi.org/10.1016/j.ssmph.2023.101489
Received 23 June 2023; Received in revised form 6 August 2023; Accepted 7 August 2023
Available online 9 August 2023
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barriers faced by persons with disabilities (Bezyak et al., 2020), and the utilization patterns of rehabilitation facilities (Al Imam et al., 2022). Moreover, empirical research on the impact of access to rehabilitation services on the degree of disability is limited and yields inconsistent results across different types of disabilities (Angerova et al., 2020).

This paper represents one of the pioneering empirical studies on disability in Chinese cities, building upon previous research (Qiu, Cheng, & Zhang, 2022) to further explore the heterogeneous effects of accessibility to different disability rehabilitation services on the degree of disability. To achieve this, an innovative approach to measuring spatial accessibility was developed by monetizing travel costs. The study not only reaffirms existing evidence but also generates new insights into the relationships between accessibility and varying severity of diverse disabilities. Following the introduction, section two presents a conceptual framework by reviewing the current literature on facility-based rehabilitation and the accessibility of persons with disabilities. Section three focuses on explaining and justifying the data sets and analytical methods employed in the study. In section four, the analytical results and findings are presented. These findings contribute to the existing knowledge base on disability geography and rehabilitation geography. Finally, section five discusses the contributions and implications of this empirical study.

2. Literature review

2.1. Improvement effect of rehabilitation facilities on disabilities

The relationship between healthcare facilities and health status has been extensively confirmed. Evidence includes differences in infant mortality rates, birth weight, vaccination status, complications from diseases, late-stage cancer diagnosis, and quality patient care and survival (Jafari et al., 2010; Wang, 2012). It has been shown that the health status of persons with disabilities is associated with the accessibility of preventive healthcare services, which follows patterns similar to the general population (Fortney & Tassé, 2021).

Many scholars have explored the positive effects of disability rehabilitation, a specific form of healthcare (Fig. 1). For individuals with physical disabilities resulting from conditions such as spinal cord injuries, amputations, or musculoskeletal disorders, rehabilitation facilities offer physical therapy, occupational therapy, and mobility training. These interventions can help restore or improve physical functioning, enhance strength and coordination, and reduce pain and discomfort (Jiang et al., 2023; Tarakci et al., 2020). With regular therapy, individuals can regain mobility, learn adaptive techniques, and increase their overall independence (McGlinchey et al., 2020).

Similarly, cognitive rehabilitation also reduces the degree of disability (Nevala et al., 2019). suggested that the employment of people with intellectual disability is improved through secondary education involving proper teaching methods and personal support services, the adoption of supported work, workplace accommodations and support from the person's family and employer. (Chen et al., 2020; Qiu et al., 2023) explored the improvement in cognition, mobility and participation of people with schizophrenia disability in Taiwan after receiving routine treatments within the current mental healthcare system. Through cognitive rehabilitation programs, individuals receive specialized therapies to enhance memory, attention, problem-solving skills, and executive functions. These interventions can significantly improve cognitive abilities, allowing individuals to better manage daily tasks, improve communication skills, and regain vocational and educational capabilities (Cicerone et al., 2019).

Sensory rehabilitation programs encompass a range of interventions, including vision or hearing therapies, assistive technology training, and orientation and mobility training, with the use of aids to address visual and hearing impairments in disability rehabilitation. Silva et al. (2014), for example, demonstrated the benefits of optical aids, non-optical aids, and environmental adaptations in enhancing visual functionality, underscoring the impact of external factors on functionality. Additionally, a significant proportion of individuals with hearing disabilities benefit from hearing aids and specialized interventions (Vestergaard Knudsen et al., 2010). By utilizing adaptive strategies and technologies, individuals can enhance their remaining sensory abilities, improve communication, and navigate their environment more effectively.

Rehabilitation facilities also promote the psychological and emotional well-being of disabled individuals. Coping with a disability can be emotionally challenging, and rehabilitation facilities often provide counselling, psychological support, and peer support groups. These services help individuals develop coping mechanisms, boost self-esteem, manage anxiety or depression, and improve overall mental health (Perna & Harik, 2020).

However, it is important to note that not all studies have consistently demonstrated positive effects of rehabilitation across all types of disabilities. Angerova et al. (2020), for example, found that the cost and cost-effectiveness of early rehabilitation following a stroke were positively associated with the degree of motor disability but not cognitive

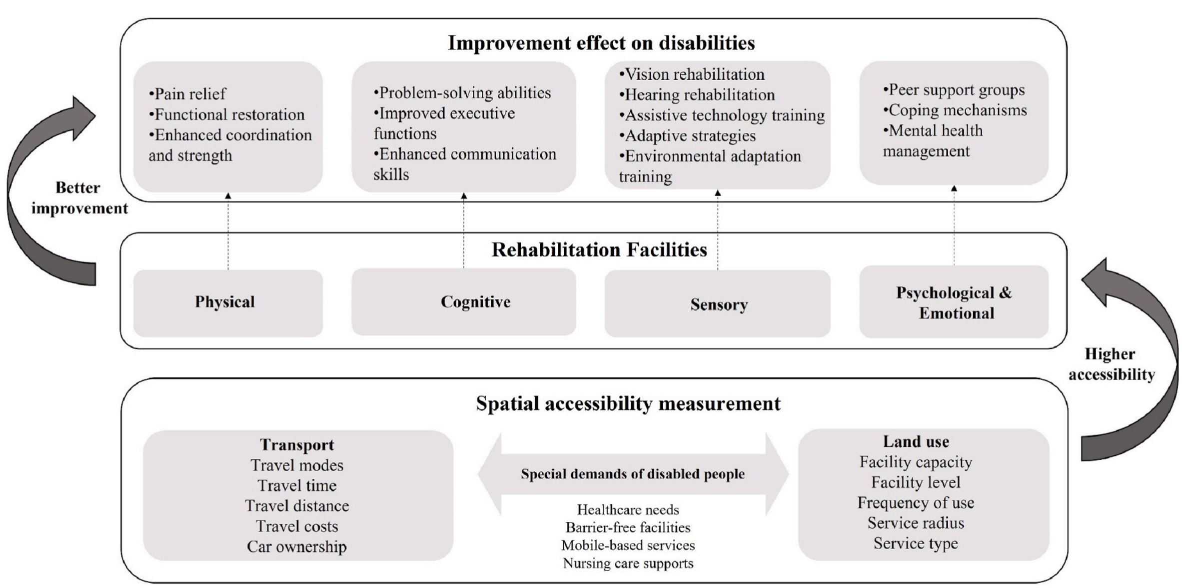

Fig. 1. Theoretical framework for spatial accessibility to rehabilitation facilities and the improvement effect.

disability. Previous research has often focused on specific types of disabilities, limiting comparisons across multiple disabilities. Furthermore, most studies have relied on survey data and lacked a quantitative measure of the accessibility of rehabilitation facilities and its effect on the degree of disability (Brick et al., 2022; Silva et al., 2014).

2.2. Spatial accessibility of healthcare to persons with disabilities

Spatial accessibility of healthcare refers to the ease of reaching medical services and facilities, considering factors like distance, travel time, and cost (Hewko et al., 2002). Traditional studies use Geographic Information Systems (GIS) for location-based accessibility analysis (Langford & Higgs, 2006). Measures include travel distance and time to the nearest health service (Brabyn & Skelly, 2002). More sophisticated methods include the use of the gravity model (Joseph & Bantock, 1982), the two-step floating catchment area method (Luo & Wang, 2003) and their variants (Cheng & Bertolini, 2013; Shatnawi et al., 2022; Wang, 2012). In general, these methods formulate distance-dependent interactions between healthcare services and population demands, while representing competition among populations for limited resources. In recent years, measurements of the spatial accessibility of healthcare have turned to specific facilities, such as special epidemic disease services (Kang et al., 2020) and emergency medical services (Xia et al., 2019), and target population groups, such as older adults (Zhang et al., 2019), groups of low socioeconomic status (Burger & Christian, 2020) and refugees (Gokalp Aras et al., 2021). These studies have refined the supply of healthcare providers and the demand of the population to maximise the accuracy of service coverage, limit the number of facilities, reduce travel barriers and improve the health of vulnerable groups. Moreover, with the rapid development of spatial perception and positioning technology, the integration of different travel modes in traditional accessibility models and the use of spatial big data algorithms to calculate time or distance costs have become new trends of research (Langford et al., 2016). Routing application programming interfaces (APIs) from online mapping services like Google and Baidu Maps offer convenient options (Wang & Xu, 2011).

Spatial accessibility measurement for individuals with disabilities considers not only land use and transportation factors but also incorporates the special demands of people with disabilities. With regard to land use, the capacity, level, use frequency and service radius of facilities should be more accurately estimated, as the services are used only by persons with disabilities or even by certain types of persons with disabilities, such as those requiring disability rehabilitation (Angerova et al., 2020), assistive technologies (McNicholl et al., 2021) and daily care (Naruse et al., 2020). In terms of transport, long-term physical, mental, intellectual or sensory impairments of persons with disabilities result in a resistance to travel that is much greater than that for people without disabilities, and differences in travel preference and barriers between different types of disability cannot be ignored (Bezyak et al., 2020). Therefore, the travel modes for persons with disabilities are different from those for people without disabilities, because public transport is not always accessible to or inclusive for persons with disabilities, whereas cars and/or taxis offer freedom, independence and mobility to persons with disabilities (Behrens & Görgens, 2019; Dejeammes, 2000). However, the travel costs and car ownership should be considered in low- and middle-income countries (Kett et al., 2020). As examples of differences between groups, people with visual and limb disabilities need mobile-based services and barrier-free facilities (Wu et al., 2020), people with mental and intellectual disabilities need nursing care supports (Yamada & Arai, 2020), and there is little difference in travel between people with hearing and speech disabilities and those without disabilities.

In summary, there is a need for an integral approach to measure the spatial accessibility of healthcare facilities to persons with disabilities that considers the specific match between the provision of healthcare services and the transport demands of persons with disabilities. Considering the heterogenous needs of different types of persons with disabilities, differences in the accessibility of rehabilitation facilities to the different types of persons with disabilities should also be considered in this approach. Furthermore, accurately measuring the accessibility of rehabilitation facilities for different disability types can help validate the social diversity in the impact of rehabilitation facility accessibility on the degree of disability. Therefore, a theoretical framework is proposed to assess the accessibility of specialized healthcare services for individuals with disabilities, followed by an examination of whether higher accessibility level contributes to the improvement effect of rehabilitation facilities on disabilities (Fig. 1).

3. Data and methods

3.1. Study area

Tianjin, an important industrial megacity in China, is situated to the southeast of Beijing. This study focused on the Central Urban Area within the Tianjin Outer Ring Road, which is its political, economic and social centre (Fig. 2). The study area had a land area of 576 km^2, accounting for 13.3% of the total land area in Tianjin. The Tianjin Disability Database had 129,833 certified persons with disabilities in the study area, accounting for 50.6% of the total disabled population in Tianjin. The study included 2484 neighbourhoods, with an average area of 0.042 km^2 per neighbourhood. Each neighbourhood had an average of 11 residential buildings and 855 tenements. The number of individuals with disabilities in a neighbourhood ranged from 0 to 2,005, with an average of 54.

3.2. Data sources

Data were collated from three sources. First, the Tianjin Disability Database (Qiu, Cheng, & Zhang, 2022), provided social and health attributes of 129,833 certified persons with disabilities in the study area. Six types of disabilities were considered: visual, hearing, limb, mental, intellectual, and speech disabilities (spatial distribution showed in Figure A1). Second, Data on 94 disability rehabilitation facilities were collected from the Database of Disabled Facilities in Tianjin. The facilities were categorized into four types: visual, hearing and speech, limb, and mental and intellectual facilities (spatial distribution and service capacities showed in Figure A2). Thirdly, the data of 2484 neighborhoods are drawn from the second-hand housing information of *Fang.com.*[1] Fourth, travel time data were collected using Python 3.7 from the Gaode Maps API, which was utilized instead of a traditional network solution in a desktop GIS. Fifth, the locations and prevalence of 100,000 barrier-free facilities were taken from the Rongchang application[2] (spatial distribution showed in Figure A3). Finally, data on the mobility characteristics of persons with disabilities were obtained from a comprehensive survey conducted by the Tianjin Disabled People's Federation in spring 2020. Information on the mode of travel, requirements for escort support, and barriers to accessibility for different disability types were processed from the survey data.

3.3. Measuring the spatial accessibility of rehabilitation facilities to persons with disabilities

This study proposed an accurate approach to derive a measure of accessibility of rehabilitation facilities. This approach integrates multiple key elements including the characteristics of facilities (i.e., the

[1] Fang.com, founded in 1999, is a professional online platform for the real estate home industry covering the areas of new, used, rental, home, and real estate research, with current data for 24 countries and 658 cities worldwide.

[2] The Rongchang application is a barrier-free signage system based on an Internet navigation map.

Fig. 2. Study area.

capacity, frequency of use and service radius), characteristics of the mobility of persons with disabilities (i.e., the mode of travel, cost of an escort, transportation fee and barrier-free environment requirements) and travel time obtained from the routing API. In general, both landuse and transport systems contributing to the accessibility should be considered. In terms of the mobility of persons with disabilities, only people with mental and intellectual disabilities need to consider the cost of an escort, whereas people with visual and limb disabilities need to consider the barrier-free environment requirements.

First, the service radius for rehabilitation facilities was determined based on the maximum travel time and facility use frequency (Table A1) as reported by the Tianjin Disabled People's Federation. The maximum travel time allowed for individuals with visual, hearing, speech, and limb disabilities was 1.5 h for over 80% of them (Table A2), while it was 1 h for individuals with mental and intellectual disabilities (Table A3). Second, according to the survey conducted by the Tianjin Disabled People's Federation, persons with different types of disability had different travel preferences. The model of travel is given in Table A4. The travel time to rehabilitation facilities was generally long in contrast with non-disabled people, and a car or taxi and public transport were taken as the two modes of travel. Third, the levels of barrier-free environment requirements of people with visual and limb disabilities are given in Table A5. Barrier-free facilities included blind sides, barrier-free passageways, barrier-free street sounds, barrier-free signage, handrails, barrier-free elevators, barrier-free toilets, wheelchair ramps, barrier-free parking and edge stone ramps (Table 1).

A gravity-based model was proposed to measure the spatial accessibility of rehabilitation facilities for individuals with disabilities, incorporating a distance decay function as a crucial component. Previous studies have shown that the inverse power function is suitable for low-frequency travel interactions, while the negative exponential function is better suited for high-frequency travel (De Vries et al., 2009). Since individuals with disabilities may visit rehabilitation facilities on a monthly basis, the inverse power function was chosen due to its lower sensitivity. The formula used for most calculations is as follows.

Table 1
Integral accessibility measurement.

Element		Visual	Hearing & speech	Limb	Mental & intellectual
Characteristics of rehabilitation facilities	Use frequency	1–2 times/ month or year	1–2 times/ month or year	1–2 times/ month or year	3-4 times/ week
	Service radius (h)	1.5 h	1.5 h	1.5 h	1 h
Mobility of persons with disabilities	Mode of travel (car/ taxi; public transport)	27%; 73%	12%; 88%	47%; 53%	35%; 65%
	Cost of escort	–	–	–	✓
	Barrier-free environment	✓	–	✓	–
Formula selection		(1)(2)(3)(4)(5)(6)	(1)(2)(3)(4)	(1)(2)(3)(4)(5)(6)	(1)(2)(3)(4)(7)

$$A_i = \sum_{j=1}^{n} \frac{S_{ij} M_j}{C_{ij}^{\beta} P_i} \quad (1)$$

Here, A_i is the accessibility of a disability rehabilitation facility for neighbourhood i; S_{ij} is the travel-time influence factor of disability rehabilitation facility j for neighbourhood i; T_{ij} is the trave time from neighbourhood i to facility j; M_j is the number of physicians at facility j; P_i is the size of the disabled population in neighbourhood i; C_{ij} is the cost of travel to facility j from neighbourhood i; and β is the travel impedance. To calculate impedance values for each mode, survey conducted by the Tianjin Disabled People's Federation were used to fit inverse power curve that provided a continuous approximation to the shape of trip length distribution, using data of trave time. The same functional form was used for both car/taxi and public transport to ensure consistency of application across modes. The impedance functions for car/taxi and public transport were 1.5 and 1.7 respectively. S_{ij} is calculated as follows.

$$S_{ij} = 1 - \left(\frac{T_{ij}}{T_j}\right)^{\beta} \tag{2}$$

Here, T_j is the maximum travel time. When the travel time exceeds the maximum travel time (i.e., $T_{ij}/T_j \geq 1$; $S_{kj} \leq 0$), persons with disabilities do not choose this rehabilitation facility.

The cost of travel to facility j from neighbourhood i, C_{ij}, is obtained by dividing the monetary cost of accessing a facility by the minimum wage in neighbourhood i (Table A6) as expressed in the following formula.

$$C_{ij} = \frac{\mathrm{D_{ij}} + f_{ij} + e_{ij}}{Mw_i} \tag{3}$$

Here, D_{ij} is the monetary cost of the travel time from neighbourhood i to facility j, and f_{ij} is the round-trip transportation fee from neighbourhood i to facility j. For the group with mental and intellectual disabilities, e_{ij} is the cost of an escort from neighbourhood i to facility j. The study, which for the first time adds the cost of escort and translates the monetary cost of travel time, plays an important role in improving the accuracy of accessibility calculations. D_{ij} is the product of the total travel time, round-trip time ($2T_{ij}$) and minimum hourly wage (Mhw) (see Table A6), expressed as follows.

$$\mathrm{D_{ij}} = Mhw \times 2T_{ij} \times \left(1 + B_i + B_j\right) \tag{4}$$

For the group with visual and limb disabilities, the coefficient of barrier-free impedance B_i is calculated as follows.

$$B_i = 1 - \frac{N_i}{N_{i(max)}} \tag{5}$$

$$N_i = \sum \left[a_1 \times E_{i(\text{Blind side})} + a_2 \times E_{i(\text{passway})} + \ldots + a_n \times E_{i(\text{ramp})}\right] \tag{6}$$

Here, N_i/N_j is the number of barrier-free facilities within 500 m of the buffer zone for neighbourhood i/facility j. According to the survey conducted by the Tianjin Persons with disabilities Federation, 500 m is usually a comfortable distance for people with visual and physical disabilities to travel by foot or change transportation vehicle. N_{max} is the maximum number of barrier-free facilities in a neighbourhood, i.e., $N_i/N_{max} \leq 1$. A larger value of N_i indicates that the neighbourhood has more barrier-free facilities and less barrier-free impedance B_i. E_i is the number of different types of barrier-free facilities within 500 m of the buffer zone for neighbourhood i/facility j., and a_1, a_2 and a_3 are the different needs provided for by the various types of barrier-free facility (Table A3).

The cost of an escort, e_{ij}, from neighbourhood i to facility j, is expressed as the product of the total travel time, round-trip time ($2T_{ij}$) and use of facilities (h), and minimum hourly wage (Mhw) as follows.

$$e_{ij} = Mhw \times \left(2T_{ij} + \mathrm{h}\right) \tag{7}$$

3.4. *Modeling the effect of the accessibility of rehabilitation facilities on the degree of disability*

The degree of disability refers to the extreme, severe, moderate or mild severity of the disability on a numerical scale. This study applied an ordinal logistical regression model to obtain a reliable estimate of the degree of disability and avoid the loss of information. The ordinal logistical regression can be written as follows.

$$p_j = p\left(y \leq j \middle| X = \frac{\exp\left(a_j + \sum_{i=1}^{n}\beta_i x_i\right)}{1 + \exp\left(a_j + \sum_{i=1}^{n}\beta_i x_i\right)}\right) \tag{8}$$

where, y is the degree of disability, which was classified into four ordinal categories according to Chinese disability classification standards. The degrees of disability of 129,833 certified persons with disabilities were captured from registration information in the Tianjin Disability Database for 2020. $j = 1, 2, 3$ and 4 correspond to extreme, severe, moderate and mild levels of disability, respectively. a_j is the constant term regression factor. β_i correspond to regression coefficient for the respective independent variables. x_i are i_{th} explanatory variable (i = 1, 2, …n).

There were two sets of independent variables. First, our main independent variable of interest was the accessibility to rehabilitation facilities by disabled individuals measured at the neighbourhood level. Second, the study controlled for the individual-and neighbourhood-level variables (Table 2).

4. Results

4.1. *Spatial accessibility of rehabilitation facilities to persons with disabilities*

Fig. 3 shows the spatial accessibility of the four types of rehabilitation facilities to persons with disabilities, which were comprehensive calculated based on the ratio of two mode of travels (car/taxi; public transport). Global spatial autocorrelation was adopted to test the overall trend of the spatial clustering between adjacent neighbourhoods across the study area. The global Moran I index in Table 3 indicates that accessibility was significantly and positively spatially auto-correlated.

There were 21 rehabilitation facilities for visual disability, including hospital-based outpatient ophthalmology clinics, ophthalmology specialist hospitals and visual aid centres. Fig. 3(a) shows that accessibility was lower in the central district and higher in the surrounding districts, in particular in the north-western neighbourhoods. The accessibility of rehabilitation facilities then declined to a minimum in peripheral districts.

There were 23 rehabilitation facilities for hearing and speech disability, including a hospital-based outpatient otolaryngology clinic, otolaryngology specialist hospitals and hearing aid centres. Fig. 3(b) shows that accessibility was highest in the eastern district and generally lowest in southern and northern neighbourhoods.

There were 16 rehabilitation facilities for limb disability, including rehabilitation departments in hospitals and service centres for the disabled. Fig. 3(c) shows that the accessibility pattern of rehabilitation facilities for limb disability was similar to that of rehabilitation facilities for visual disability in that it tapered off away from the central districts. In general, the accessibility of the first three types of rehabilitation facility for persons with disabilities had a circular pattern, reflecting the centralisation of healthcare facilities and the marginalisation of some groups of persons with disabilities.

There were 29 rehabilitation facilities for mental and intellectual disabilities, including an autism rehabilitation centre, kindergartens and schools for children with disabilities, a psychiatric specialist hospital and a hospital-based outpatient psychiatric clinic. Fig. 3(d) shows that the accessibility had an obvious pattern of being high in the northwest and low in the southeast and was higher in peripheral neighbourhoods than in central neighbourhoods. This result was due to there being far more mental and intellectual rehabilitation facilities and a smaller disabled population in peripheral areas than in central areas. Additionally, the inclusion of the cost of an escort for the group with mental and intellectual disabilities reduced accessibility in areas where the cost of an escort was high.

4.2. *Factors affecting the degree of disability*

We constructed seven ordinal logistical regression models to investigate the effects of the accessibility of rehabilitation facilities and the demographic characteristics of persons with disabilities on the degree of disability using Equation (8). Table 4 lists the odds ratios of the two ordinal logistical regression models, with both models demonstrating

Table 2
Descriptive statistics of variables.

Variable		Description	Mean	Std. Dev
Dependent variable				
Degree of disability		Severity of disability (Mild = 1; Moderate = 2; Severe = 3; Extreme = 4)	2.85	0.98
Independent variable				
Rehabilitation facilities accessibility		Spatial accessibility of rehabilitation facilities to persons with disabilities	3.40	1.93
Individual-level variables				
Disability types	Visual	Dummy variable whether or not he/she is visual disability (1 = yes, 0 = no)	0.10	0.30
	Hearing	Dummy variable whether or not he/she is hearing disability (1 = yes, 0 = no)	0.09	0.28
	Limb	Dummy variable whether or not he/she is limb disability (1 = yes, 0 = no)	0.63	0.48
	Mental	Dummy variable whether or not he/she is mental disability (1 = yes, 0 = no)	0.10	0.30
	Intellectual	Dummy variable whether or not he/she is intellectual disability (1 = yes, 0 = no)	0.07	0.26
	Speech	Dummy variable whether or not he/she is speech disability (1 = yes, 0 = no)	0.01	0.09
Gender	Female	Gender dummy variable (1 = yes, 0 = no)	0.48	0.50
	Male	Gender dummy variable (1 = yes, 0 = no)	0.52	0.50
Age		Age of persons with disabilities (years)	58.84	13.76
Education years		Years of education for persons with disabilities (years)	11.01	3.45
Marital status	Married	Marital dummy variable whether or not he/she is married (1 = yes, 0 = no)	0.69	0.46
	Unmarried	Marital dummy variable whether or not he/she is unmarried (1 = yes, 0 = no)	0.14	0.35
	Divorced	Marital dummy variable whether or not he/she is divorced (1 = yes, 0 = no)	0.08	0.28
	Widowed	Marital dummy variable whether or not he/she is widowed (1 = yes, 0 = no)	0.08	0.28
Household registration type	Agriculture	Dummy variable representing agricultural household (1 = yes, 0 = no)	0.02	0.14
	Non-agricultural	Dummy variable representing non-agricultural household (1 = yes, 0 = no)	0.98	0.14
Employment status	Yes	Dummy variable whether or not he/she is employed (1 = yes, 0 = no)	0.36	0.48
	No	Dummy variable whether or not he/she is employed (0 = yes, 1 = no)	0.64	0.48
Neighbourhood-level variables				
Housing price		Average housing price per square meter (RMB/m2)	28,946	13,934
Property management fee		Average management fee per square meter (RMB/m2)	1.07	1.02
Plot ratio		Percentage of the total building area of the land area occupied by the building	1.89	0.72
Greenery cover		Percentage of total green space (%)	25.6	8.67
Transport		Number of public transport stations within 3 km	88	50.22
Education		Number of education services within 3 km	71	24.28
Medical		Number of health services within 3 km	36	19.66
Shopping		Number of commercial services within 3 km	860	371.89
Park		Number of parks within 3 km	22	14.49

similar Log likelihood and Pseudo R square values, indicating a good fit for the data. In Model 1, individual- and neighbourhood-level variables were included as control variables. Model 2 introduced 6 interaction variables for accessibility and disability types to examine and analyse the variations in accessibility to rehabilitation facilities among individuals with six different types of disabilities.

4.2.1. Effects of the spatial accessibility of rehabilitation facilities

The disability type dummy variables showed positive and significant effects in both Model 1 and Model 2 (significance level of 0.01), indicating a generally lower degree of speech disability compared to other types of disabilities. Furthermore, there were notable differences in the degree of disability among the six types, with visual disability exhibiting the highest degrees, followed by physical and intellectual disabilities, while mental disability had a relatively lower degree of disability.

In both Model 1 and Model 2, the spatial accessibility of rehabilitation facilities had a strongly significant negative effect on the degree of disability (significance level of 0.01). Higher accessibility thus corresponded to a lower severity of disability. In Model 2, the inclusion of accessibility and disability type interactions reveals heterogeneous effects of rehabilitation facilities on the degrees of the six disability types. Among the six disability types, except for intellectual disability, the severity of other disabilities significantly decreased with increased accessibility to rehabilitation facilities. Regarding the coefficients, the decrease in the severity of hearing disability was most influenced by the enhanced accessibility of rehabilitation facilities, followed by speech and mental disabilities, while the impact was relatively lower for visual and limb disabilities. Notably, intellectual disability demonstrated a notable trend of increased disability severity with improved accessibility to rehabilitation facilities.

4.2.2. Effects of individual-level variables

All individual-level variables demonstrated a highly significant effect (significance level of 0.01) on the degree of disability among individuals with disabilities. Firstly, women generally exhibited a lower degree of disability compared to men among individuals with disabilities. Secondly, the severity of disability significantly increased with age, indicating a positive correlation between age and disability severity. Thirdly, higher levels of education were strongly associated with a lower degree of disability across all disability types. Fourthly, marital status influenced the degree of disability, with married and divorced individuals generally displaying lower disability severity compared to widowed individuals, while unmarried individuals did not exhibit a significant effect on the degree of disability. Fifthly, non-agricultural household registration had a strongly significant negative effect on the degree of disability, providing evidence of urban-rural disparities in disability severity among different types of individuals with disabilities. Finally, employment status significantly impacted the degree of

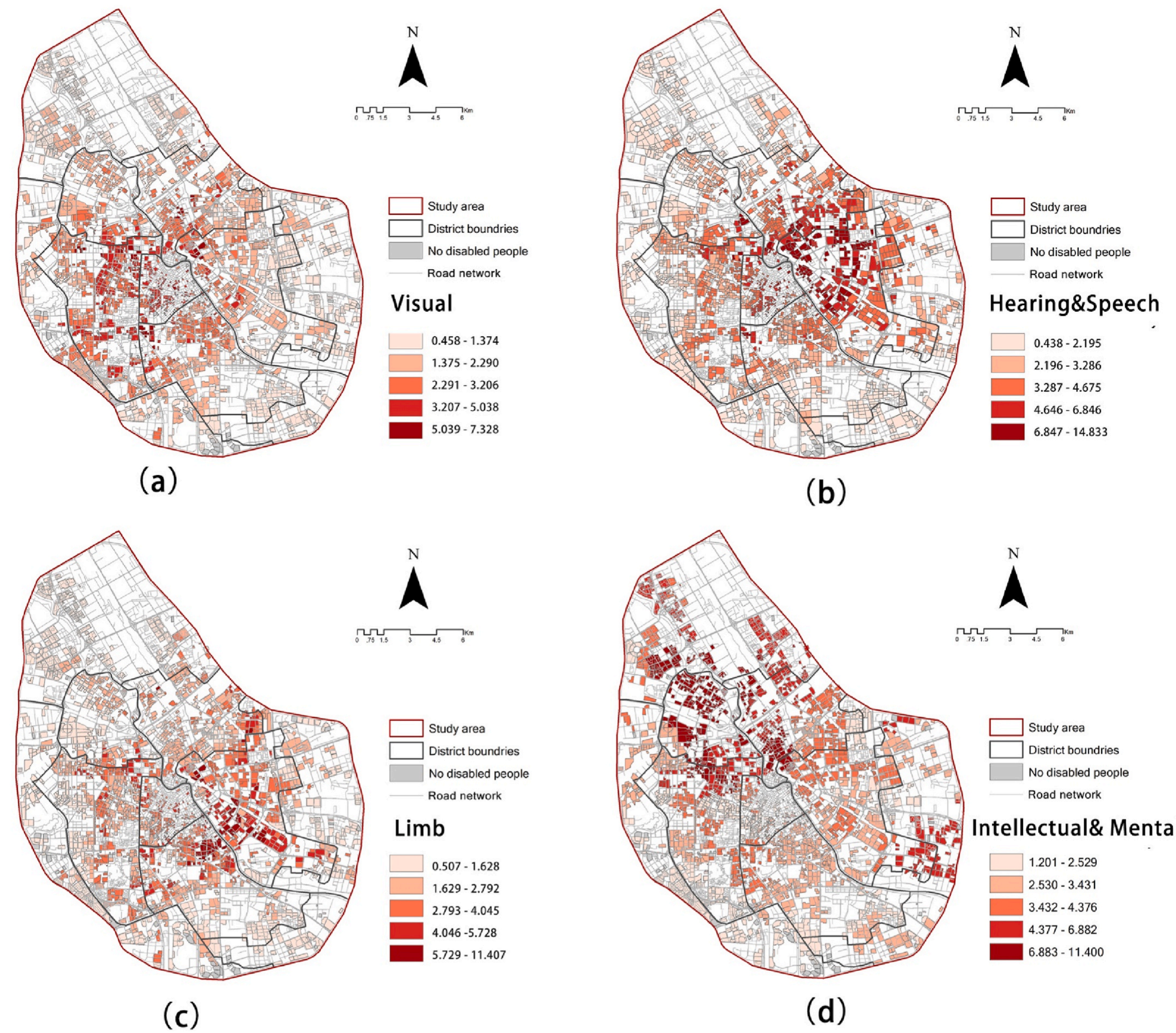

Fig. 3. Spatial accessibility of rehabilitation facilities to persons with disabilities.

Table 3
Moran's I of the spatial accessibility of rehabilitation facilities to persons with disabilities.

Type of disability	Visual	Hearing & speech	Limb	Mental & intellectual
Moran's I	0.235	0.378	0.198	0.405
z-score	7.289	10.216	5.182	6.399
p-value	<0.01	<0.01	<0.01	<0.01

disability, as individuals with regular employment demonstrated reduced disability severity.

4.2.3. Effects of neighbourhood-level variables

Among neighbourhood-level variables, both Model 1 and Model 2 results indicated that increasing housing prices had a significant positive impact on the severity of disability (significance level of 0.05). Conversely, an increase in plot ratio and greenery cover were found to significantly reduce the severity of disability. Among different types of public services, neighbourhoods with concentrated educational facilities exhibited significantly lower degrees of disability, while areas with concentrated commercial facilities showed significantly higher degrees of disability.

4.3. Robustness test

To assess the robustness of the effects of rehabilitation facility accessibility on the degree of disability, ordinary least squares (OLS) regression was employed as an alternative to the previously described ordinal logistical regression. The empirical results, presented in Table A7, demonstrate that while the coefficient estimates differ, the significance and direction of the explanatory variables remain consistent with the previous study, affirming the reliability and robustness of the effects observed for each variable.

5. Discussion

This study provides empirical evidence and investigates the influence of rehabilitation facility accessibility and demographic factors on

Table 4
Model results for the degree of disability.

Independent variable	Model 1		Model 2	
	Coef.	Std. Err	Coef.	Std. Err
Rehabilitation facility accessibility	−0.306***	0.019	−0.302***	0.054
Rehabilitation facility accessibility and disability types interactions				
Rehabilitation facility accessibility*Visual			−0.640***	0.086
Rehabilitation facility accessibility*Hearing			−5.959***	0.881
Rehabilitation facility accessibility*Limb			−0.480***	0.059
Rehabilitation facility accessibility*Mental			−1.486***	0.073
Rehabilitation facility accessibility*Intellectual			3.112***	0.505
Rehabilitation facility accessibility*Speech			−2.796***	0.258
Individual-level variables				
Disability type (ref. speech)				
Visual	1.708***	0.065	1.673***	0.075
Hearing	1.026***	0.065	0.967***	0.077
Limb	1.433***	0.063	1.417***	0.072
Mental	0.231***	0.064	0.205**	0.074
Intellectual	1.286***	0.066	0.255***	0.076
Gender (ref. male)				
Female	−0.697***	0.010	0.679***	0.010
Age	0.014***	0.010	0.020***	0.002
Education level	−0.237***	0.004	−0.235***	0.004
Marital status (ref. widowed)				
Married	−0.367***	0.020	−0.283***	0.056
Unmarried	0.485***	0.027	0.556***	0.094
Divorced	−0.107***	0.026	−0.092c	0.084
Household registration type (agricultural)				
Non-agricultural	−0.354***	0.037	−0.371***	0.037
Employment (No)				
Yes	−0.113***	0.011	−0.114	0.011
Neighbourhood-level variables				
Housing price	0.120**	0.000	0.131**	0.000
Property management fee	−0.003	0.005	−0.006	0.005
Housing age	0.000	0.001	−0.001	0.001
Plot ratio	−0.017**	0.009	−0.018**	0.009
Greenery cover	−0.171*	0.090	−0.090**	0.089
Transport	0.000	0.000	0.000	0.000
Education	−0.004***	0.001	−0.004***	0.001
Medical	0.000	0.001	−0.001	0.001
Shopping	0.001***	0.000	0.001***	0.000
Park	0.000	0.001	0.001	0.001
Model fitting information	Chi-square = 14,835.16 *p*-value: 0.000		Chi-square = 14,845.95 *p*-value: 0.000	
Model summary	Log likelihood = −161276.61 Pseudo R square = 0.105		Log likelihood = −161271.21 Pseudo R square = 0.044	

Standard errors in parenthesis: ***p < 0.01, **p < 0.05, *p < 0.1.

the degree of disability in urban areas of China. These findings offer robust evidence from a large database regarding the relationship between spatial accessibility and disability rehabilitation within the fields of disability geography (Crooks et al., 2008) and rehabilitation geography (Martin et al., 2005), which shed light on a new research agenda that emphasizes considering the spatial and social effects of disability rehabilitation in local planning and governance. Further exploration of these effects and their interplay with other elements of the built environment can provide deeper insights into tailored intervention approaches for specific disabilities, thereby enhancing overall rehabilitation outcomes and improving the quality of life for individuals with disabilities.

First of all, our study findings confirm the existing body of research, showing that higher accessibility is associated with a reduction in the severity of disability, which aligns with previous studies (Chen et al., 2020). The correlation between accessibility and disability severity has been established through modeling; however, the absence of longitudinal data on disability levels poses challenges in proving causation. To mitigate this issue and eliminate the possibility of inverse causality between the two, we propose adopting a dual approach to interpretation. Firstly, it is essential to clarify the logic behind the planning, management and construction of rehabilitation facilities for persons with disabilities. Currently, in China, the establishment of such facilities is often based on administrative divisions or existing medical and healthcare facilities rather than being directly related to the distribution of persons with disabilities. This is very much dependent on the top-down planning process in the context of China. As a result, in our case study, the endogenous problem concerning the provision of rehabilitation capacity access on the extent of disability is relatively small. Secondly, it is essential to consider the assessment of disabilities degree and the sequencing of rehabilitation activities. In order to fully comprehend the concept of degree of disability, it is important to recognize that in many countries, including China, there is a requirement for disabilities to persist for a specific duration, often spanning months or years, before they are assessed. This means that disability is not immediately assessed following its onset. Instead, rehabilitation activities are initiated prior to the disability rating process, which is considered a golden period for disability rehabilitation (Liu, Yin, & Cai, 2022; Aasdahl & Fimland, 2020). Improved (spatial and socio-economic) accessibility of rehabilitation facilities often leads to increased frequency of visits and enhanced affordability for rehabilitation services (Anderson et al., 2021), as demonstrated in the accessibility model used in this study. These factors likely significantly contribute to the reduction and even disappearance of disabilities.

Importantly, our study provides new insights into the heterogeneous effects of accessibility to specific rehabilitation facilities on different types of disabilities. Specifically, we found that the negative effects of the accessibility of rehabilitation facilities were significant for visual, hearing limb and speech disabilities, which are mainly the result of geriatric diseases. According to *Data of the second national sample survey of persons with disability* of *Tianjin* (DSNSS), the main causes of visual disability are cataracts and retinal and pigment membrane lesions; the main causes of hearing disability are presbycusis, otitis media and systemic disease; the main causes of limb disability are cerebrovascular diseases and osteoarthrosis and the main causes of limb disability are cerebral infarction and cerebral haemorrhage. These age-related diseases have increased in prevalence as life expectancy has extended and are now well treated and alleviated by medical and rehabilitation means (Finger et al., 2022). Thus, rehabilitation measures have the greatest effect in reducing the degree of disability severity. Among these facilities, hearing rehabilitation facilities have a significant impact on improving hearing grades, driven by inspiring advancements in science and technology, particularly in hearing aids. These aids enhance sound reception and transmission, leading to the recovery or improvement of hearing function in individuals with hearing disabilities. Unlike some other disabilities, certain hearing issues can be corrected or improved through appropriate treatment and rehabilitation measures. Similarly, speech disability benefits from early speech therapy, training, and modern rehabilitation techniques, resulting in a reduction in its severity. However, visual and physical disabilities present unique challenges due to their diverse types and complicated causes, requiring comprehensive and ongoing rehabilitation processes that may lead to less effective outcomes compared to other disabilities.

In the case of mental disabilities, increased accessibility to rehabilitation facilities allows for earlier, more integral, and effective interventions and treatments, ultimately contributing to a reduction in the severity of mental disabilities. Moreover, the community integration efforts and educational campaigns conducted by these facilities play a crucial role in diminishing social discrimination and prejudice. By creating a more inclusive and supportive environment for individuals with mental disabilities, the severity of their condition is also alleviated (Iemmi et al., 2016). Conversely, individuals with disabilities resulting from congenital genetic diseases, such as intellectual disabilities, showed a positive correlation between the availability of rehabilitation services and the severity of their intellectual disability. There are two possible reasons for this correlation. First, the main causes of intellectual disability are brain disease and genetic inheritance according to DSNSS. China's rehabilitation for intellectual disabilities presently focuses on the early rehabilitation and cognitive training of children with disabilities. Such rehabilitation services and training are more effective for mild disabilities and less effective for severe disabilities, resulting in a higher rate of severe disability (Wu et al., 2010). Second, the medical facilities and education and rehabilitation institutions for people with intellectual disabilities have long struggled to meet the tremendous needs of people with intellectual disability for care and services (Sonnander & Claesson, 1997). The location of rehabilitation services is therefore determined according to the level of concentration of children with disabilities, and facilities in regions with many people having a severe degree of disability are thus better equipped.

Our study revealed significant associations between the degree of disability and various demographic attributes of individuals with disabilities, which generally align with previous findings on factors such as age (Fong, 2019), education level (Brigola et al., 2019), marital status (Defar et al., 2023), and employment status (Nevala et al., 2019). First, as we age, natural processes of organ and system degradation occur in the body. This, combined with the potential worsening of certain chronic diseases such as arthritis, heart disease, diabetes, and neurodegenerative diseases, can contribute to an increase in the severity of existing disabilities or the development of new ones (Fong, 2019). Second, highly educated individuals often possess better health knowledge and awareness of preventive measures, enabling them to take proactive steps in reducing the risk of illness and disability. They also tend to have improved access to medical resources and early treatment. Additionally, their educational background may provide them with easier access to rehabilitation skills, treatment plans, and self-care strategies. Thirdly, marital relationships play a crucial role in providing social and emotional support, which can have a positive impact on mental health and the recovery process (Liu et al., 2019). Individuals with disabilities who are married or divorced often receive additional support and care from their spouse, family, and close relationships. Spouses, in particular, frequently assume the role of caregivers, offering daily support and assistance to their partners with disabilities (Mont & Nguyen, 2018). Fourth, employment can lead to positive psychosocial and economic benefits for persons with disabilities, including a sense of purpose, opportunities for new friendships (Howarth et al., 2006), better health (Dean et al., 2018) and a better quality of life (Kober & Eggleton, 2005). Employment thus contributes to the rehabilitation of people with disability, especially those with intellectual disabilities (Nevala et al., 2019). On the other hand, people with mild disabilities are more likely to have more job opportunities than people with severe disabilities (Vornholt et al., 2018). However, our study also uncovered a gendered variation that diverged from evidence found in other studies (Helvik et al., 2008). New evidence from this Chinese city that men with disabilities tend to experience a higher degree of disability, emphasized the need to explore gender differences among individuals with disabilities across different countries (Qiu, Cheng, & Zhang, 2022). More comparative international evidence can contribute to the understanding of gender disparities in healthcare access and inform gender-sensitive healthcare planning and design within the field of health geography (Shantz & Elliott, 2021).

The neighbourhood-level variables indicated a potential correlation between neighbourhoods with high housing prices and a high concentration of commercial facilities. High housing costs can pose financial challenges for individuals with disabilities, leading to limited access to quality healthcare, rehabilitation, and support services (Kondo et al., 2009). This limited access, especially in communities with a significant number of commercial facilities, can further hinder their ability to access appropriate rehabilitation and support services, potentially contributing to higher levels of disability. On the contrary, increased greening rates can have a positive impact on persons with disabilities by offering accessible outdoor spaces, promoting physical activity, facilitating social interaction, and supporting natural therapy, ultimately reducing disability levels (Du & Zhang, 2020; Yen et al., 2021).

Finally, the proposed methodology offers the primary advantage of monetizing travel costs when measuring spatial accessibility for individuals with disabilities. This approach enables the systematic integration of various spatial and costing factors, including travel time, transport expenses, and escort costs. The ability to incorporate these costs is particularly beneficial in situations where high travel expenses pose a significant concern. Therefore, the potential for widespread adoption and implementation of this methodology in healthcare accessibility studies should be seriously considered. It can effectively address the specific needs of individuals with visual and limb disabilities, such as those met by mobile-based services and barrier-free facilities (Grisé et al., 2019), as well as the requirements for nursing care among individuals with mental and intellectual disabilities (Yamada & Arai, 2020). Moreover, by including escort costs in the accessibility measurements, this approach extends its applicability beyond persons with disabilities and has the potential to encompass individuals in need of care, such as the elderly and children, in the future.

This study has several limitations that should be acknowledged. Firstly, while our accessibility methods accounted for the specific requirements of persons with disabilities, certain elements (e.g., cost of rehabilitation) could not be included due to data unavailability. Secondly, the model results demonstrate a correlation rather than a causal relationship between the improved accessibility of rehabilitation institutions and the severity of disability. To explore the interdependence between accessibility to specific facilities and the degree of disability in future research, the collection of panel and spatio-temporal data will be indispensable. Lastly, there may be differences in travel impedance (obstacles or difficulties encountered during travel) among individuals with different types of disabilities. Further research should explore and incorporate these variations in travel impedance to provide a more comprehensive understanding of accessibility challenges faced by individuals with different types of disabilities.

6. Conclusions

The empirical study's primary findings and contributions can be threefold as summarized as follows. Firstly, we propose an approach to measure the spatial accessibility of rehabilitation facilities for individuals with disabilities, incorporating facility characteristics and the mobility profiles of individuals. The calculation of accessibility varies based on the specific disability type. Secondly, our findings demonstrate that higher accessibility to rehabilitation facilities generally corresponds to a lower severity of disability, with the exception of intellectual disability. However, the longitudinal data will enable a more comprehensive and robust analysis of the dynamic relationship between accessibility and disability severity, helping to establish a more nuanced understanding of their association. Furthermore, our study emphasizes the impact of individual- and community-level indicators on the disability degrees. The findings of our study contribute to a better understanding of the prevalence and severity of disability and hold important policy implications for disability planning and governance.

Credit author statement

Ning Qiu: Conceptualization, Methodology, Writing - original draft preparation, Funding acquisition, Tianjie Zhang: Conceptualization, Methodology, Writing review and editing, Jianquan Cheng: Conceptualization, Supervision, Co-draft preparation, Writing review and editing.

Ethical statement

The study does not contain any personally identifiable information. All authors of this study do not have any financial disclosures to report.

Financial statement

All authors report no financial funding was associated with this study.

Funding

This study was funded by Natural Science Foundation of Shandong Province, China (grant number: ZR2023QE242) (CN).

Data availability

The authors do not have permission to share data.

Acknowledgment

We express our gratitude to the anonymous referees for their valuable and constructive comments, which significantly contributed to improving the paper, particularly regarding the Endogeneity and robustness of the model. Additionally, we extend our thanks to Yulan Lv for providing valuable comments on the modified version of this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101489.

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