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Original Article

Examining the factors associated with disabilities among hypertensive patients in India

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Abstract

Hypertension is a major contributor to disability and mortality in India. The aim of this study was to examine the factors associated with activities of daily living (ADL) and instrumental activities of daily living (IADL) disabilities among patients with hypertension in India using secondary data from the longitudinal aging study in India (LASI) wave-1, encompassing a sample of 4,618 respondents. The disablement process model was adopted to categorize the variables into risk, intra-individual, and extra-individual factors. A zero-inflated negative binomial model was employed to identify factors associated with the absence of disabilities and those contributing to their progression. The results indicate that the risk and intra-individual factors had a larger variance in explaining disabilities than the extra-individual factor. Variables such as age, sex, depressive symptoms, psychosomatic symptoms, and physical activity were significantly associated with ADL and IADL disabilities. The findings highlight the need for targeted interventions addressing modifiable risk factors, promoting physical activity, managing depressive symptoms, and enhancing social support to reduce the disability burden in this population and improve the quality of life of hypertensive patients in India.

Keywords: Hypertension, India, ADL, IADL, disablement process

Introduction

According to the World Health Organization (WHO), one is deemed hypertensive (high blood pressure) when the pressure in the blood vessels reaches above 140 mmHg (systolic) or below 90 mmHg (diastolic) [1]. WHO indicated that there are 220 million hypertensive patients in India, with only 15% of them under control, indicating a high risk of vulnerability [2]. In India, hypertension is attributed to more than 400,000 to 500,000 deaths per year and 34 million disability-adjusted life years, which is higher than that of any other non-communicable disease in 2018 [3]. Approximately 15–30% of middle-aged individuals in India are prone to hypertension, and many are unaware that they have high blood pressure [4]. Even those who are aware of their diagnosis are very likely not to adhere to medications, as the median non-adherence rate among patients with hypertension in the country, according to a recent systematic report, was 50% [5]. Patients with hypertension in India are at greater risk of functional limitations and disabilities. This is substantiated by the latest longitudinal aging study in India (LASI) wave-1 data, where hypertensive patients in the country are twice as likely to experience activities of daily living (ADL) disability, and 1.5 times more likely to develop instrumental activities of daily living (IADL) disability compared to non-hypertensive patients [6]. Disability is defined as a person's inability to perform basic or complex activities of daily living [7].

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The present study was adapted from the theoretical model known as the disablement process, which lists how comorbidities and impairments moderated by individual and environmental factors affect disabilities [7]. The model was proposed by Verbrugge and Jette in 1994, who categorized the variables that can affect disabilities in an individual into five categories: risk, intra-individual, extra-individual, pathology, impairments, and functional limitations. The main pathway consists of pathology, impairments, and functional limitations, whereas the rest are moderators [7]. This study assessed the direct effects of the external pathway—risk, intra-, and extra-individual factors—on ADL and IADL disabilities. The aim of this study was to understand the role of an individual's pre-existing, modifiable, and external environmental factors in shaping their disabilities [7]. As previous studies have focused on the role of pathologies and impairments in disabilities, much less focus has been given to the role of individual and external factors in disabilities [8-10]. The theoretical framework is illustrated in **Figure 1**.

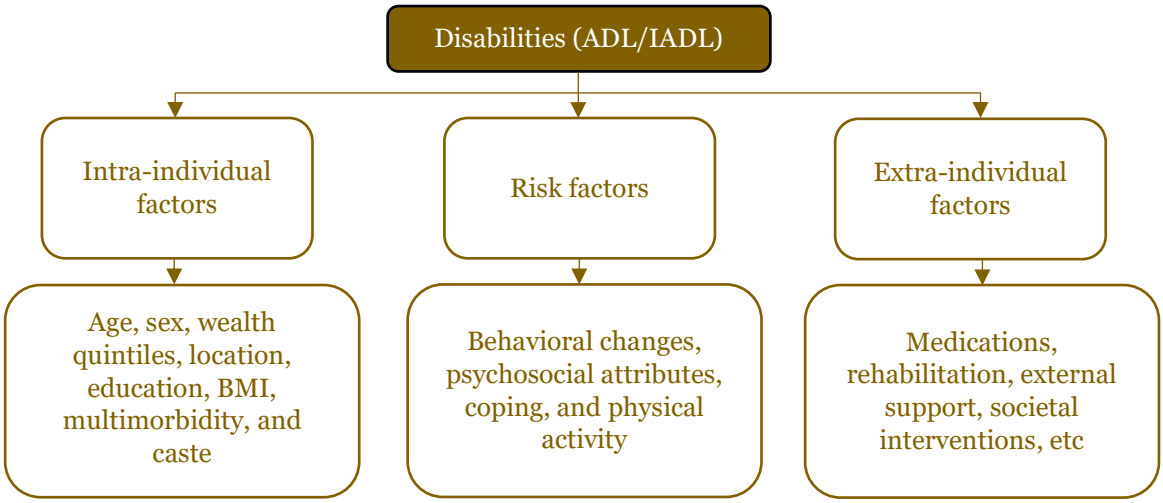

Figure 1. Conceptual framework adapted from the disablement process [7]. ADL: activities of daily living; BMI: body mass index; IADL: instrumental activities of daily living.

The rising incidence of hypertension and poor management have increased the vulnerabilities associated with the condition, warranting further investigation. ADL and IADL are two popular scales used for measuring vulnerabilities among patients because of their comprehensibility and adaptability [11,12]. The ADL and IADL are robust and standardized tools for measuring disabilities, as they are sensitive to health indicators, especially among the elder generation and poor health status [11,12]. This study is a secondary study based on LASI wave-1 data, which is a nationally representative survey conducted by the International Institute for Population Sciences, Harvard T. H. Chan School of Public Health [HSPH] and University of Southern California [USC], similar to that of a health and retirement study conducted in the United States [6]. Despite the higher burden of functional limitations among hypertensive patients in India, there remains a gap in understanding how individual and environmental factors affect disabilities among them [8,13-15]. This study employed a zero-inflated negative binomial model, which provides insights into factors associated with the odds of having no disabilities (ADL/IADL=0) and which factors are associated with further worsening of these diseases (ADL/IADL>0) [16]. To the best of our knowledge, no study has examined the incidence of disabilities among hypertensive patients in India, and no other research has comprehensively attempted to understand the factors related to disability by using the external pathway of the disablement process. The aim of this study was to examine the factors affecting ADL and IADL disabilities among patients with hypertension in India, which can inform clinical and policy recommendations at the individual and environmental levels that could reduce the incidence of disabilities among these patients.

Methods

Data source and sampling design

This study adopted a cross-sectional design utilizing the wave-1 datasheet of the LASI. The data were collected from 2017 to 2019, and the latest version of the datasheet (Version A.3) was released in April 2023. LASI is a joint project of three institutions: the International Institute for Population Sciences (IIPS) and Harvard T. H. Chan School of Public Health (HSPH), University of Southern California (USC), funded by the Ministry of Health and Family Affairs and the National Institute of Aging [6]. LASI adopts a multistage cluster sampling technique consisting of three stages in rural areas and four stages in urban areas. The LASI gives more preference to samples aged 65 and above and respondents from megacities such as New Delhi and Mumbai [6]. Wave-1 of LASI consisted of 72,250 respondents, of whom 20,320 were identified as having hypertension. After removing the missing data, the final sample size was 4,618 respondents. The sampling process is explained in **Figure 2**.

Figure 2. Sample selection criteria.

Measures

The dependent and independent variables for this study were selected based on Verbrugge and Jette's disablement process [7]. The disablement process divides factors affecting disabilities into five categories: pathology, impairment, risk factors, intra-individual factors, and extra-individual factors. This study's focus was limited to the last three factors. The dependent variables were ADL and IADL. ADL refers to basic activities of life, such as bathing, dressing, eating, and getting in/out of bed, and is measured on a scale of 0 to 6, where 0 indicates no disability and 6 indicates disability in all activities [8,9]. The IADL consists of more complex activities, such as shopping for groceries, making telephone calls, and managing medications, and is measured on a scale of 0 to 7, where 0 indicates no disability and 7 indicates disability in all activities [8,9].

The independent variables were categorized into three categories based on the disablement process: risk, intra-individual, and extra-individual factors. Risk factors include demographic, biological, social, and environmental factors that can affect disability [7]. These characteristics exist in a person prior to the onset of disability, that is, predisposing factors including age, sex, wealth quintiles, place of residence, education, body mass index (BMI), multimorbidity, and caste (scheduled caste [SC], scheduled tribes [ST], other backward castes [OBC], and general). Demographic aspects were explained by age, sex, and literacy, while biological aspects were captured by age, multimorbidity, and BMI. Social factors included caste, literacy, and wealth, whereas environmental factors were captured by location [7]. The BMI was measured based on the WHO classification, where a BMI less than 18.5 is categorized as underweight, between 18.5 and 24.9 is normal, between 25 and 29.9 is overweight, between 30 and 34.9 is obesity class 1, between 35 and 40 is obesity class 2, and above 40 is obesity class 3 [6]. All variables except for age were categorical. Multimorbidity was defined as the presence of two or more chronic conditions in a patient. In this study, researchers included cardiovascular, oncological, orthopedic, dental, ophthalmological, gastrointestinal, neurological, and otolaryngological diseases as a part of multimorbidity [9,10].

Intra-individual factor is defined as a factor that operates within a patient and is reversible or modifiable [7]. These factors include lifestyle and behavioral changes, psychosocial attributes, coping mechanisms, and physical activity. This study included the presence of four or more depressive symptoms according to the Center for Epidemiologic Studies Depression (CESD) scale, self-rated health status, psychosomatic symptoms, satisfaction with life, drinking and

smoking frequency, and moderate exercise. Four or more depressive symptoms, psychosomatic symptoms, life satisfaction, and self-rated health status represented psychosocial attributes and coping. The CESD scale is a 20-item self-report questionnaire covering six areas of depression: worthlessness, helplessness, psychomotor retardation, loss of appetite, and sleep disturbance. The score ranges from 0 to 60. Patients who scored more than 16 were considered to have depression [6]. The variable 'four or more depressive symptoms' is a dichotomous variable, showing whether the selected patient has scored over the threshold in any four of the mentioned areas. Psychosomatic symptoms include the positive and negative emotions experienced by patients, such as happiness, excitement, frustration, sadness, loneliness, boredom, anger, and pain. The score ranges from 0 to 78, and a score above 11 for females and 10 for males is considered to indicate psychosomatic symptoms [6]. Satisfaction with life is another variable measured as an average of the following items: whether leading an ideal life, whether life conditions are excellent, and whether important things are achieved in life [6]. All variables were measured using a five-point Likert scale [6]. The diseases and impairments reported by patients with hypertension are self-reported and can be biased because they can either overestimate or underestimate their diagnosis. The frequency of exercising, drinking alcohol, and smoking cigarettes can be considered both lifestyle and behavioral aspects of intra-individual factors [7]. Verbrugge and Jette defined extra-individual factors as an external intervention either performed on or inserted into the body [7]. These can be medications, rehabilitation, external support, societal interventions, etc. This study incorporated the variables of a six-item discrimination score, any weekly contact with relatives/friends in person, type of insurance, hospital stay, doctor visits, and medication use. The six-item discrimination score and type of insurance represent the built-in social environment, and any weekly contact with relatives/friends in person shows the external support systems. Staying in hospitals, visiting doctors, and taking medications cover the medication and rehabilitation aspects of extra-individual factors [7]. The six-item discrimination score is a composite score measuring aspects such as lack of respect, poor service at restaurants, people treating them poorly, getting harassed, poor service from hospitals, and people being scared of them [6].

Data analysis

Zero-inflated negative binomial model

RStudio and Microsoft Excel 2019 were used for the analysis. The zero-inflated negative binomial (ZINB) model was selected after comparing the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values of the six-count regression models. Kuiper suggested selecting the model with the lowest AIC and BIC values for analysis as it provides the best fit [17]. These criteria are used to balance the sensitivity and specificity in the models to minimize overfitting by integrating the goodness-of-fit and penalty for redundant parameters [18]. AIC is a more lenient metric compared to BIC, as it focuses more on the model's predictive capacity over parsimony. Therefore, it may prefer a complex model over a simple one because of the presence of more predictors and better predictive power in the former. In contrast, BIC prefers a simpler model over a complex model (albeit higher-predictive) by imposing a heavier penalty on additional parameters than AIC [18]. The AIC and BIC values of the ADL and IADL models are compared in the **Supplementary file**. For the ADL model, the ZINB model had the lowest AIC and BIC values; however, for the IADL model, Hurdle NB had a marginal edge over ZINB. The researchers decided to use ZINB for the analysis because it is more capable of handling zero inflation, as more than 60% of the population does not have ADL or IADL, sampling zeroes (people who did not have ADLs and IADLs at the time of the survey but are at risk of getting one), and structural zeroes (those who are completely independent of ADLs and IADLs) [18]. The formula for the ZINB is as follows:

$$P(Y_i = y_i) = \begin{cases} \pi_i + (1 - \pi_i)\left[\left(\frac{r}{(\mu_i + r)}\right)^r\right] & if\ y_i = 0 \\ (1 - \pi_i)\left(\frac{\Gamma(y_i + r)}{(\Gamma(r)y_{i!})}\right)\left(\frac{\mu_i}{(\mu_i + r)}\right)^{y_i}\left(\frac{r}{(\mu_i + r)}\right)^r & if\ y_i > 0 \end{cases}$$

where Y_i is a random variable, y_i is the observed value, π_i is the probability of a structural zero, μ_i is the mean of the negative binomial (NB) model, r is the dispersion parameter, and Γ is the gamma function [18]. A sensitivity analysis was also conducted on the hurdle model to determine how the model fit varied when each factor was removed from the model and to identify, screen, and rank the factors according to their effect on disabilities [19].

Results

Respondent characteristics

The respondent characteristics, which contain 4,618 samples, are presented in **Table 1**. Almost half of the respondents (48.9%) were aged between 60 and 80, while 44.02% were aged 40–60. Approximately 62.41% were females, and 87.59% had multimorbidity. In this study, 56% of the respondents were from urban areas and 56.52% were literate. Almost 10% of the respondents were underweight, 31.12% were overweight, and 12.91% were obese. Of the 4,618 respondents, 37.57% were from the OBC category, 32.6% were from the general category, and 15.29% and 13.79% identified as SC and ST, respectively. Eighty percent of the respondents were free from ADLs, 61.65% were free from IADLs, almost 10% had severe IADLs, and only 2% had severe ADLs.

Table 1. Respondent characteristics

Variable	Frequency	Percentage	95%CI
Age			
20–40	62	1.34	1.01–1.67
40–60	2,033	44.02	42.59–45.46
60–80	2,258	48.9	47.45–50.34
>80	265	5.74	5.07–6.41
Sex			
Male	1,736	37.59	36.2–39
Female	2,882	62.41	61–63.8
Wealth			
Poor	941	20.38	19.2–21.6
Lower middle	944	20.44	19.3–21.6
Middle	938	20.31	19.2–21.5
Upper middle	921	19.94	18.8–21.1
Rich	873	18.9	17.8–20.1
NA	1	0.02	0–0.1
Place of residence			
Rural	2,032	44	42.6–45.4
Urban	2,586	56	54.6–57.4
Education			
Illiterate	2,007	43.46	42–44.9
Literate	2,610	56.52	55.1–58
NA	1	0.02	0–0.1
Body mass index (BMI)			
Underweight	456	9.87	9–10.8
Normal	2,129	46.1	44.7–47.6
Overweight	1,437	31.12	29.8–32.5
Obesity class 1	463	10.03	9.2–10.9
Obesity class 2	114	2.47	2–3
Obesity class 3	19	0.41	0.2–0.6
Has multimorbidity			
No	522	11.3	10.4–12.3
Yes	4,045	87.59	86.6–88.5
NA	51	1.1	0.8–1.4
Caste			
Scheduled castes (SC)	706	15.29	14.3–16.4
Scheduled tribes (ST)	637	13.79	12.8–14.8
Other backward castes (OBC)	1,735	37.57	36.2–39
General	1,505	32.59	31.2–34
NA	35	0.76	0.5–1.1
Activities of daily living (ADL)			
0	3,763	81.49	80.37–82.61
1–2	586	12.69	11.73–13.65

Variable	Frequency	Percentage	95%CI
3–4	153	3.31	2.8–3.83
5–6	116	2.51	2.06–2.96
Instrumental activities of daily living (IADL)			
0	2,847	61.65	60.25–63.05
1–2	872	18.88	17.75–20.01
3–4	473	10.24	9.37–11.12
5–7	426	9.22	8.39–10.06

NA: Not available

The zero-inflated negative binomial model

The results of the zero-inflated negative binomial model are presented in **Table 2**, where the odds ratio (OR) represents the chance of obtaining at least one ADL/IADL; if OR>1, then the chance of obtaining one ADL/IADL is low, and vice versa. The incidence rate ratio (IRR) indicates the chance of worsening ADL/IADL; if IRR>1, then the chances of aggravating ADL/IADL are high, and vice versa. Among the risk factors, all except location and caste were significant. Age was associated with both ADL and IADL, as patients aged, the chances of getting an ADL (OR: 0.96) and IADL (OR: 0.96) increased, along with a higher incidence of worsening IADL (IRR: 1.02). Female patients with hypertension were more vulnerable to ADL (OR: 0.63) and IADL (IRR: 1.19; OR: 0.59) compared to males. Middle-class patients with hypertension had higher odds of not getting at least one ADL (OR: 1.44) compared to poor patients. Literate patients were less likely to have IADL and had higher odds of not getting them compared to illiterate hypertensive patients (IRR: 0.83; OR:2.07). However, they were more likely to have an ADL disability, even though they had a lower incidence of worsening it (IRR: 0.81; OR: 0.74). Body mass index (BMI) was associated with a lower incidence of IADLs, as the overweight and obesity class 1 patients were less likely to develop IADLs than underweight patients (IRRs: 0.85, 0.85). Patients with multimorbidity were more likely to get an ADL and IADL than those who do not have any (ORs: 0.65, 0.75).

Among intra-individual factors, all variables except drinking and smoking were associated with ADLs and IADLs. Patients who were somewhat satisfied and not very satisfied with their lives (OR: 0.75, 0.52) and those who rated their health status as fair and poor (OR: 0.35, 0.33) were more likely to have an IADL disability compared to their respective reference categories. When compared to patients who exercise daily, those who do it more than once weekly (OR: 0.72) were more like to get an IADL disability, while those who never exercised were more likely to worsen their ADL and IADL (IRR: 1.46, 1.21). Patients who had higher psychosomatic symptom scores were more likely to have ADL and IADL (OR: 0.72. 0.82), and aggravate their IADLs (IRR: 1.06). Additionally, patients who had more than 4 symptoms of depression as per the CESD scale were more vulnerable to developing an ADL and IADL (OR: 0.71, 0.58).

Among extra-individual factors, the variables of taking blood pressure (BP) medications and having insurance were not associated with either ADL or IADL. Patients who scored higher on the six-item discrimination score had a higher incidence of both ADLs and IADLs (IRR: 1.14 and 1.11, respectively), whereas patients who visited an allopathic doctor were less likely to aggravate their ADLs and IADLs (IRRs: 0.79 and 0.90, respectively). Patients who frequently contacted relatives and friends were less likely to get an IADL (OR: 1.31) and were more capable of managing their ADLs (IRR: 0.67). Patients who had inpatient stays at hospitals were more likely to have increased ADLs than those who had not stayed (IRR: 1.30).

Sensitivity analysis

The results of the sensitivity analysis, in which each factor was removed from the full model to check the explained variance of each factor in the ADL and IADL models, are presented in **Table 3**. In the ADL model, the removal of both risk factors and intra-individual factors had similar effects on ADL, as R^2 decreased by 30.85% and 34.04%, respectively, and AIC values increased by 3.2–3.5%.

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Table 2. The zero-inflated negative binomial model for factors affecting ADL and IADL

Variable (reference)	Activities of daily living (ADL)		Instrumental activities of daily living (IADL)	
	IRR (95%CI)	OR (95%CI)	IRR (95%CI)	OR (95%CI)
Intercept	0.32 (0.11–0.98) *	167.77 (37.42–752.10) ***	0.69 (0.44–1.07)	98.99 (39.92–245.46) ***
Age (years)	1.01 (1.00–1.02) *	0.96 (0.95–0.97) ***	1.02 (1.01–1.02) ***	0.96 (0.95–0.97) ***
Sex				
Male (*ref*)				
Female	0.83 (0.68–1.01)	0.63 (0.48–0.84) **	1.19 (1.09–1.30) ***	0.59 (0.49–0.71) ***
Wealth quintiles				
Poor (*ref*)				
Lower middle	1.12 (0.87–1.45)	1.28 (0.89–1.84)	1.03 (0.93–1.15)	0.93 (0.73–1.19)
Middle	1.13 (0.88–1.45)	1.44 (1.00–2.07) *	1.08 (0.97–1.21)	0.93 (0.73–1.19)
Upper middle	0.93 (0.70–1.22)	1.19 (0.80–1.77)	1.06 (0.95–1.18)	0.81 (0.63–1.05)
Rich	1.04 (0.79–1.38)	1.43 (0.95–2.13)	1.03 (0.91–1.16)	0.99 (0.76–1.29)
Place of residence				
Rural (*ref*)				
Urban	0.92 (0.77–1.11)	1.18 (0.91–1.52)	1.03 (0.95–1.11)	0.88 (0.74–1.04)
Education				
Illiterate (*ref*)				
Literate	0.81 (0.67–0.98) *	0.74 (0.56–0.98) *	0.83 (0.76–0.90) ***	2.07 (1.73–2.46) ***
Body mass index				
Underweight (*ref*)				
Normal weight	1.19 (0.90–1.57)	1.31 (0.84–2.04)	0.91 (0.83–1.01)	1.14 (0.88–1.49)
Overweight	1.31 (0.96–1.80)	1.33 (0.82–2.16)	0.85 (0.76–0.95) **	1.12 (0.84–1.49)
Obesity class 1	1.33 (0.91–1.94)	1.03 (0.58–1.83)	0.85 (0.73–1.00) *	1.01 (0.70–1.45)
Obesity class 2	1.22 (0.74–2.01)	0.48 (0.20–1.15)	0.90 (0.72–1.14)	0.60 (0.34–1.07)
Obesity class 3	0.86 (0.22–3.34)	0.35 (0.03–4.75)	0.69 (0.36–1.33)	0.67 (0.16–2.90)
Have multimorbidity [a]				
No (*ref*)				
Yes	0.86 (0.60–1.22)	0.65 (0.43–0.98) *	0.92 (0.81–1.04)	0.75 (0.58–0.97) *
Caste [a]				
Scheduled castes (*ref*)				
Scheduled tribes	1.31 (0.95–1.82)	1.13 (0.73–1.75)	1.13 (0.99–1.29)	1.17 (0.87–1.57)
Other backward castes	1.04 (0.81–1.34)	1.01 (0.70–1.44)	1.07 (0.97–1.19)	1.02 (0.80–1.30)
General	0.97 (0.74–1.27)	0.90 (0.61–1.32)	1.05 (0.94–1.17)	1.11 (0.86–1.43)
Depression symptoms				
No (*ref*)				
Yes	1.19 (0.97–1.47)	0.71 (0.54–0.95) *	1.05 (0.97–1.14)	0.58 (0.48–0.70) ***
Moderate exercise				
Daily (*ref*)				
More than once a week	1.17 (0.81–1.68)	1.14 (0.70–1.88)	1.04 (0.90–1.20)	0.72 (0.51–1.00) *
Once a week	0.72 (0.43–1.22)	0.69 (0.31–1.52)	1.12 (0.94–1.35)	0.89 (0.59–1.33)
One to three times a month	1.30 (0.76–2.24)	1.09 (0.55–2.19)	1.13 (0.90–1.41)	0.94 (0.58–1.52)
Hardly or never	1.46 (1.19–1.78) ***	0.84 (0.64–1.10)	1.21 (1.12–1.31) ***	0.92 (0.77–1.10)
Self–rated health				

Variable (reference)	Activities of daily living (ADL)		Instrumental activities of daily living (IADL)	
	IRR (95%CI)	OR (95%CI)	IRR (95%CI)	OR (95%CI)
Excellent (*ref*)				
Very good	1.71 (0.70–4.19)	1.05 (0.35–3.17)	0.86 (0.61–1.21)	0.76 (0.42–1.37)
Good	1.64 (0.69–3.91)	0.84 (0.28–2.48)	0.89 (0.64–1.23)	0.59 (0.33–1.05)
Fair	1.73 (0.73–4.11)	0.46 (0.15–1.34)	1.02 (0.73–1.41)	0.35 (0.19–0.62) ***
Poor	2.02 (0.86–4.79)	0.36 (0.12–1.07)	1.16 (0.83–1.62)	0.33 (0.18–0.61) ***
Average score of experienced psychosomatic symptoms	1.08 (0.98–1.19)	0.72 (0.61–0.84) ***	1.06 (1.02–1.11) **	0.82 (0.74–0.92) ***
Satisfied with life				
Completely satisfied (*ref*)				
Very satisfied	0.90 (0.68–1.19)	0.98 (0.67–1.42)	1.01 (0.89–1.14)	0.89 (0.69–1.14)
Somewhat satisfied	0.99 (0.74–1.32)	1.07 (0.73–1.58)	1.04 (0.92–1.18)	0.75 (0.58–0.96) *
Not very satisfied	0.90 (0.64–1.27)	0.58 (0.34–1.00)	1.00 (0.86–1.17)	0.52 (0.36–0.75) ***
Not at all satisfied	1.06 (0.68–1.66)	0.52 (0.23–1.18)	0.98 (0.80–1.21)	0.55 (0.29–1.02)
Frequency of alcohol drinking				
Never (*ref*)				
Less than once a month	1.14 (0.46–2.84)	1.70 (0.62–4.60)	1.07 (0.79–1.45)	0.92 (0.51–1.66)
One to three times a month	1.04 (0.56–1.94)	0.62 (0.28–1.38)	0.87 (0.60–1.25)	1.05 (0.56–1.98)
One to four days a week	0.91 (0.39–2.12)	0.71 (0.22–2.25)	0.89 (0.58–1.37)	0.73 (0.33–1.63)
Five or more days a week	1.06 (0.25–4.50)	2.01 (0.45–8.97)	0.83 (0.54–1.28)	0.65 (0.29–1.44)
Number of cigarettes	0.98 (0.95–1.02)	1.02 (0.98–1.06)	0.99 (0.98–1.00)	0.99 (0.97–1.02)
Six-item discrimination score	1.14 (1.01–1.29) *	1.04 (0.87–1.25)	1.11 (1.05–1.18) ***	1.09 (0.94–1.26)
Any weekly contact with relative/friend in person [a]				
No (*ref*)				
Yes	0.67 (0.47–0.96) *	1.21 (0.76–1.91)	0.92 (0.81–1.04)	1.31 (1.03–1.68) *
Have insurance [a]				
No (*ref*)				
Government insurance	0.91 (0.72–1.15)	0.91 (0.66–1.26)	0.96 (0.88–1.06)	1.07 (0.87–1.31)
Employer	2.12 (0.46–9.73)	2.42 (0.39–14.94)	1.28 (0.58–2.81)	1.25 (0.32–4.83)
Others	1.06 (0.61–1.83)	1.14 (0.54–2.42)	1.21 (0.94–1.57)	1.54 (0.87–2.72)
Either or all	0.76 (0.32–1.84)	0.80 (0.21–3.11)	0.84 (0.57–1.24)	0.50 (0.18–1.38)
Whether hospitalized [a]				
No (*ref*)				
Yes	1.30 (1.03–1.63) *	0.88 (0.62–1.26)	1.07 (0.96–1.19)	0.85 (0.65–1.10)
Visited doctor				
No (*ref*)				
Yes	0.79 (0.64–0.98) *	0.98 (0.75–1.30)	0.90 (0.83–0.98) *	0.91 (0.75–1.09)
Taking BP medications				
No (*ref*)				
Yes	1.21 (0.98–1.51)	0.91 (0.68–1.22)	0.98 (0.90–1.06)	0.96 (0.80–1.15)
Log (theta)	2.11 (1.30–3.45) **		12.24 (7.47–20.06) ***	

IRR: incidence rate ratios; OR: odds ratio

McFadden's Adjusted Pseudo R^2: 0.094 (ADL), 0.114 (IADL)

The multicollinearity of the variables was checked, and all the variables had VIF<5, indicating very low multicollinearity (**Supplementary file**)

[a] indicates the presence of missing cases of nearly 0.1–1.1%; * Statistically significant at p=0.05; ** Statistically significant at p=0.01; *** Statistically significant at p=0.001

In the IADL model, risk factors had a higher effect than intra-individual factors, as the adjusted R^2 decreased by half when the former was removed, while R^2 decreased by 21.05% when intra-individual factors were removed. Extra-individual factors had the lowest variance in either model, as the change in R^2 was marginal compared to other factors, with an R^2 change of 5–6.3% in either model. The detailed ZINB model when each factor was removed is presented in the **Supplementary file**.

Table 3. Sensitivity analysis

Model	Activities of daily living (ADL)		Instrumental activities of daily living (IADL)	
	AIC (% change)	Adjusted R^2 (% change)	AIC (% change)	Adjusted R^2 (% change)
Full model	6428.454	0.094	11410.19	0.114
No risk factors	6635.576 (3.2%)	0.065 (-30.85%)	12168.99 (6.65%)	0.055 (-51.75%)
No intra-individual factors	6658.278 (3.5%)	0.062 (-34.04%)	11722.61 (2.73%)	0.09 (-21.05%)
No extra-individual factors	6471.728 (0.67%)	0.088 (-6.38%)	11492.35 (0.72%)	0.108 (-5.26%)

AIC: Akaike information criteria; BIC: Bayesian information criteria
R^2 is calculated using McFadden pseudo-R^2

Discussion

This study examined the risk, intrapersonal, and external factors affecting ADL and IADL disabilities in Indian patients with hypertension. The findings indicate that 18.51% of hypertensive patients have one or more ADL disabilities, and 38.35% have one or more IADL disabilities. When compared to other diseases, hypertensive patients are twice as likely to get an ADL disability, and 1.5 times more likely to develop an IADL disability compared to non-hypertensive patients in India [6]. This is validated by similar studies conducted in the United States, Iran, and China, as they suggest that hypertensive patients are at a higher risk of developing white matter hyperintensities in their brain, which can affect their control of mobility, cognition, and mood [9,20,21]. The variables affecting disability were divided into three categories: risk, intra-individual, and extra-individual factors. The sensitivity analysis revealed that intra-individual and risk factors had a higher variance in ADLs and IADLs than extra-individual factors. The findings highlight that direct clinical interventions on modifiable risk factors and intra-individual factors, such as BMI and depressive symptoms, are more effective in treating hypertension-related disabilities than environmental factors [22].

Among the risk factors, all selected variables, except location and caste, were significant predictors of ADLs, IADLs, or both. The risk of developing ADLs and IADLs disabilities increases by one to four percentage points each year, usually associated with physiological decline and multimorbidity associated with aging [13,20,23,24]. Female patients with hypertension had higher odds of having an ADL disability and a higher odds and incidence of IADL disabilities, which is consistent with the findings of Chauhan *et al*. among elderly individuals in India, who cited sex segregation and cultural barriers while receiving treatment for morbidities as potential reasons for the higher incidence of ADL and IADL disabilities in women [13]. Sex differences in ADL and IADL disabilities are observable worldwide among patients with various noncommunicable diseases [9,20,24]. Literate patients with hypertension were less vulnerable to developing IADL disabilities; however, they were more likely to have an ADL disability, which contradicts the existing literature [9,13,14]. Despite the higher odds, they were more proficient in managing ADLs as the incidence of ADL disabilities was lower because of their greater health and social literacy and associated socioeconomic advantages, enabling them to manage their disabilities better than illiterate patients with hypertension [9,24]. The odds of having an ADL disability were lower among people belonging to higher wealth quintiles, especially among the middle class, compared to poor patients, indicating wealth-related disparities in acquiring care for hypertension and related disabilities [13,14]. Underweight patients were more likely to develop IADL disabilities than other weight classes, which can be attributed to their lack of muscle mass and improper nutrition, which hampered their cognitive and physical function [25]. Multiple comorbidities and hypertension can increase the odds of developing an ADL or IADL

disability. Comorbidities such as stroke, arthritis, and Alzheimer's disease are often associated with impairments such as hemiplegia, aphasia, agnosia, and dementia, which would often lead to ADL and IADL disabilities among patients with hypertension [8,9]. When intra-individual factors were removed from the analysis, previously insignificant variables such as location and caste became significant (**Supplementary file**). This suggests that social and geographical factors affecting disabilities in hypertensive patients are confounded by intra-individual factors, particularly lifestyle and psychosocial variables. This hypothesis aligns with previous studies that have shown that rural and socially disadvantaged patients are more vulnerable to psychosocial disorders, which in turn may influence the manifestation of disabilities in patients with hypertension [26,27].

Among intra-individual factors, patients who rated their health as poor or fair were more likely to get an IADL than others, indicating high self-awareness of their health status. However, this may not always be ideal, as Shandra *et al*. reported that increased awareness of poor health status can lead to depression [28]. Patients with hypertension who were diagnosed with at least four symptoms of depression on the CESD scale had increased odds of having ADL and IADL. Depression has been identified as a precursor to several physical and cognitive impairments that can cause or increase the severity of disabilities [29,30]. The prevalence of depressive symptoms increases with age in hypertensive patients because of increased stress due to chronic illnesses, social factors, and medications. Thus, a stable mental state is essential for managing disabilities [31]. The incidence of both ADL and IADL disabilities was greater among patients who never or rarely exercised; therefore, the promotion of exercise to reduce functional limitations among hypertensive patients would enable them to reduce their functional limitations [32]. The existence of psychosomatic symptoms can increase the risk of having an ADL and IADL by more than 20–30% among hypertensive patients, and it can also worsen their IADLs. The existence of psychosomatic symptoms and depression can overlap in many patients, which medical professionals may not detect and may worsen functional impairment [33]. Hypertensive patients who were less satisfied with their lives had higher odds of achieving ADL and IADL, suggesting a bidirectional relationship between the two. Patient life satisfaction can worsen with disabilities and complications from hypertension, and psychological distress caused by low life satisfaction can cause further disability [33-35].

Extra-individual factors, such as facing discrimination, having a social support group, visiting doctors, and hospitalizations, were significantly associated with ADL and IADL disabilities. Patients admitted to hospitals for more than one night were more likely to develop ADL disabilities. There could be multiple reasons for this, as the intensity of the disease and associated impairments can worsen disability rather than the hospitalization itself [36]. Another reason could be patient safety incidents, including adverse drug reactions, which lead to longer hospital stays and increased health risks for patients [37]. Routine doctor visits have been associated with a lower incidence of both ADLs and IADLs, indicating better management of diseases [38]. Social and medical discrimination faced by hypertensive patients is associated with aggravating ADL and IADL [39]. Discrimination faced at the neighborhood level would result in reduced physical advantage, leading to the worsening of pre-existing disabilities [39,40]. Therefore, having a social support system is crucial in managing disabilities, as our study found that maintaining contact with friends and family on a regular basis would help reduce the odds of getting IADLs and developing ADLs. A positive social environment with a supportive family would reduce mental stress, which would further protect against disabilities [24].

Major implications from this study are: (1) It was found that the factors at an individual level (risk and intra-individual) had a higher variance in disabilities than extra-individual factors. Therefore, when treating disabilities among hypertensive patients, physicians should focus on modifiable individual-level factors such as BMI and smoking, rather than controlling their external environment [22]; (2) physical inactivity and depressive symptoms were predictors of both ADL and IADL disability. These two predictors are also correlated because lack of exercise is often considered a precursor to depression. Thus, doctors should recommend moderate exercise to patients with hypertension to reduce the risk of disability [28]. Along with exercise, doctors should screen their patients for psychosomatic and depressive symptoms as they have a greater impact on impairments and disabilities than other factors [31,33]; (3) our findings

highlight that illiterate and poor women are at a higher risk of developing and worsening ADL and IADL disabilities. Subsequently, their vulnerability increased with age, highlighting the gaps and disparities in the treatment received by socially marginalized populations. Care for patients with hypertension in disadvantaged positions should be personalized and targeted, and providing health education would enable them to reduce their disabilities [13,14]; (4) patients with hypertension who have been hospitalized for more than a night experience greater ADL disability, which could be due to the bidirectional relationship between hospitalization and disabilities or patient safety incidents at the hospital itself. Further research focusing on the effects of hospital stay on disabilities would add more context [36,37]; (5) Comorbidities, especially stroke and arthritis, had a greater direct effect on disability. Therefore, hypertensive patients with these comorbidities should take the necessary precautions to prevent their disabilities from aggravating [8,9]; and (6) having an amiable environment, with routine contact with friends, family, and doctors can help in reducing the disabilities among the hypertensive patients by improving their mental state and quality of life [24,34,38,39].

Although our study was comprehensive, it has several limitations. The data were cross-sectional; therefore, evidence of associations should be validated using a longitudinal study to establish causal effects. The diseases and impairments reported by patients with hypertension are self-reported and can be biased because they can either overestimate or underestimate their diagnosis. Owing to variable limitations, the original disablement process model could not adapt to the main pathway of the model or feedback loops in the study. Additionally, this study was conducted among patients with hypertension in India; thus, the findings cannot be generalized to other countries. Owing to the use of secondary data, further inquiry into unexpected findings cannot be conducted. Future studies should focus on the causal effects of external pathways adapted by the model through a longitudinal study. A more comprehensive cross-sectional study incorporating the main pathway of the disablement process would provide more insights.

Conclusion

The findings highlight the role of modifiable risk factors, including physical inactivity, symptoms of depression, and socioeconomic factors such as sex and wealth on disabilities in hypertensive patients. Intra-individual and risk factors contribute more significantly to disabilities than extra-individual factors. Targeted interventions emphasizing lifestyle changes and mental health support are essential to reduce disabilities among patients with hypertension. Clinicians should encourage physical activity and mental health assistance for their patients, while policymakers should address healthcare access disparities to reduce ADL and IADL prevalence. Future studies should incorporate longitudinal data to explore causal relationships between the selected factors and functional disabilities, as well as examine pathways and feedback loops within disablement. This study offers recommendations to inform clinical practice and policymaking, aiming to alleviate disability burden among hypertensive patients.

Ethics approval

This study was conducted using secondary data, and all required approval was obtained from the original data source. We hereby declare that we had no access to the sensitive information like names, addresses, etc. of the respondents.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

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Declaration of artificial intelligence use

We hereby declare that we have used Paperpal for language assistance, and we confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

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