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Multimorbidity combinations and their association with functional disabilities among Indian older adults: evidence from Longitudinal Ageing Study in India (LASI)

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ABSTRACT

Objective This study aims to identify the unique multimorbidity combinations (MMCs) and their associations with the functional disability of Indian older adults. Moreover, the population attributable fractions (PAFs) were calculated to assess the potential impact of additional diseases in the nested groups on disability.

Design A cross-sectional data were analysed in this study.

Setting and participants The present study uses data from the first wave of the Longitudinal Ageing Study in India (2017–2018). The sample for the study consists of 27 753 aged 60 years and over.

Primary and secondary outcome measures The primary outcome variable was functional disability, measured by the combined activities of daily living (ADL)-instrumental activities of daily living (IADL) index.

Results Out of 197 uniquely identified MMCs, the combination of hypertension and high depressive symptoms (HDS) was the most prevalent (10.3%). Overall, all MMCs were associated with increased functional limitation. Specifically, the combination of hypertension, arthritis and HDS was associated with greater ADL-IADL disability than any other MMC. The addition of HDS in group 3 (hypertension and arthritis) (incidence rate ratios (IRR)=1.44; 95% CI 1.26 to 1.64) and the addition of arthritis in group 1 (hypertension, HDS) (IRR=1.48; 95% CI 1.28 to 1.71) and group 2 (hypertension, diabetes) (IRR=1.49; 95% CI 1.22 to 1.82) significantly increases the rates of ADL-IADL disability. The estimated PAFs of the group 1 (hypertension and HDS), group 3 (hypertension and arthritis) and group 4 (arthritis and HDS) for ADL-IADL disability were 22.5% (19.2–25.5), 21.6% (18.7–24.4) and 23.5% (20.6–26.3), respectively.

Conclusion The findings from this study underscore the importance of addressing the morbidity combinations which are more disabling than the others in older adults. Understanding the somatic and psychological relevance of the morbidities in functional health is necessary and can help reduce disabilities among older adults.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ First study that estimated the different multimorbidity combinations (MMCs) and their association with the functional disabilities in India.
⇒ The usage of the national representative sample of older adults is a strength of the study.
⇒ Population attributable fractions were derived to assess the potential impact of additional diseases.
⇒ The inability to establish the causal relationship between variables of interest is the limitation of the study.
⇒ The inclusion of self-reported chronic diseases may underestimate the true prevalence of these diseases, therefore, may alter the MMCs.

BACKGROUND

Multimorbidity, generally defined as the presence of two or more chronic ailments in an individual,[1] is considered as the significant predictor of poor quality of life,[2 3] lower self-rated health,[4 5] greater likelihood of disability[6 7] and hence, mortality.[8–11] The average rise in life expectancy due to improvement in healthcare, rapid urbanisation and lifestyle changes have increased the likelihood of proportion of individuals with multiple chronic diseases.[12] Multimorbidity is increasingly common with advancing age, possibly attributable to common pathophysiological and aetiological pathways of some age-related conditions.[13] A recent systematic review of seventy community-based studies in both high-income countries and low/middle-income countries found that more than 50% of individuals aged 65 and over had multimorbidity, and it further increases with increasing age.[14] Moreover, a recent systematic analysis based on South Asian countries reported a range of prevalence of multimorbidity between 24% and 83%, where hypertension, arthritis, diabetes, skin diseases, and cardiac problems were the leading chronic diseases.[15]

Multiple studies have investigated the association between single diseases and disability[16–18]; however, recent clinical guidelines have advocated the shifting of research and clinical practice from single diseases to multimorbidity.[19 20] Rather than merely counting the number of chronic diseases, an investigation of the impact of different combinations of chronic health diseases on health-related outcomes such as disability have been recommended.[6 7 21] Specific chronic diseases are strongly associated with disability than others, and individuals with particular combinations of chronic diseases become more functionally impaired than individuals with fewer chronic diseases.[22]

The importance of studying the chronic diseases in terms of forms of combination has been mentioned as different combinations of chronic diseases impact disability differently.[6 21] For instance, a study based on US older adults,[6] after including nine chronic diseases, found 291 unique combinations of these chronic diseases, and reported that arthritis and hypertension were most prevalent and as compared with individuals with no chronic disease has associated with higher disability than any other combinations. Study based on older adults in European countries[21] found 380 unique combinations based on 10 chronic diseases, and suggested that those multimorbidity combinations, including depressive symptoms, were associated with increased rates of disability. However, depression is considered as a comorbid condition associated with other chronic diseases. Multiple studies have included depressive symptoms in the operational definition of multimorbidity and shown significant impact on health-related outcomes.[21 23 24]

In recent decades, India experienced an unprecedented change in the demographic structure characterised by increasing share of the older adults. The number of individuals aged over 60 years is expected to grow from 8% in 2011 to 19% by 2050 in India.[25] Also, India is experiencing an epidemiological transition from predominant infectious diseases to non-communicable diseases (NCDs).[26 27] This transition in the disease patterns along with population ageing poses new challenges for the policymakers and public health experts. A study showed that more than half of the burden on NCDs occurred in the individuals aged 45 years and older in India.[28] Changing lifestyles and rapid urbanisation may be contributed to the high burden of NCDs in India.[29] With increasing prevalence of the chronic conditions, there is an urgent need of understanding the pattern of morbidities in older people in India to develop effective responses for the upcoming challenges and requirements of the healthcare services.[30]

A study found that the prevalence of multimorbidity in Indian older adults was 24%.[31] The same study reported that arthritis, high blood pressure and cataract were the most prevalent diseases in the older people. Another study based on selected Indian states found that hypertension and arthritis were the most common cluster of morbidities followed by cataract and arthritis, and hypertension and diabetes.[30] However, inferences based on some states of India cannot be generated at national level, therefore, by overcoming this limitation and this study used the national representative sample to derive the national-level estimates of the multimorbidity combinations (MMCs).

A recent study based on Indian older adults has found that increase in the number of pre-existing chronic conditions significantly positively associated with the functional limitations.[32] However, the study focused largely on the association between the number of chronic diseases and disability.[32] Considering chronic diseases as a count and deriving a measure of multimorbidity by adding the number of chronic diseases may be inadequate for clinical purposes because the patients in these indices may not exhibit all or most diseases or disease combinations. Therefore, to determine the predictors of disability, recent studies started focusing on the clustering or co-occurrence of the diseases in population. A higher number of chronic diseases lead to disability in older adults.[33 34] Measurement of disability often performed by considering the restriction in functional activities i.e. activities of daily living (ADL) and instrumental activities of daily living (IADL) in the surveys despite several models of disability evoke different dimensions of measurement.[35]

Previously, most studies examining the relationship between combination of multimorbid conditions and disability were conducted in high-income countries.[6 21] There is a lack of understanding of the association between combinations of multimorbidity conditions and disability in Asian countries, especially in India. Thus, the study aims to examine the association of different multimorbidity patterns with ADL and IADL disability among older adults in India. Moreover, we investigated how each MMC impacts ADL/IADL disability relative to healthy older adults (with no disease) and those with a single chronic disease. Furthermore, we examined the marginal contribution of specific chronic diseases. Finally, population attributable fractions (PAFs) were calculated to assess the potential impact of additional diseases in the nested groups on disability.

METHODS

Data source

We have used the first wave of Longitudinal Ageing Study in India (LASI) conducted during 2017–2019, which is available on public forum. LASI is a nationally representative longitudinal survey that collects vital information on the physical, mental and social well-being of older adults in India. It collects data of over 72 000 individuals aged 45 years and over, and their spouses across all states and union territories of India (excluding Sikkim). LASI adopted the multistage stratified cluster sampling design for collecting the unit-level data, including three stages in rural areas and four stages in urban areas. The details of the sample design, survey questionnaires, fieldwork, data collection and processing were published in the

LASI report.[36] The Indian Council of Medical Research extended the ethical approval and necessary guidelines for conducting the LASI survey. In the fieldwork, all participants were provided with information brochures explaining the purpose of the survey and the safety of health assessments. Moreover, the consent forms were also administered to each participant.

Our initial sample size consists of 31 464 older adults aged 60 years and over. We excluded 1094 respondents with one or more missing chronic disease responses. Moreover, 42 and 2575 respondents were excluded with missing data on ADL and selected covariates, respectively. Our final analysis sample included 27 753 older adults.

Variable description

Outcome variable

Assessment of the disability

In LASI, the participants were asked if they had any limitations in the ADL with a duration longer than 3 months. The participants reported about six basic and seven instrumental ADLs. The six basic ADLs included dressing, bathing, walking across the room, eating difficulties, getting in or out of bed, and using the toilet. The seven instrumental ADLs included telephone use, taking medications, shopping for groceries, preparing a hot meal (cooking and serving), doing housework, managing money and getting around or finding an address in unfamiliar place. Our study created ADL and IADL summary indices by summing the number of basic ADLs (0–6) and instrumental IADLs (0–7), respectively. Moreover, the ADL-IADL summary index ranging from 0 to 13 was assessed by adding both ALDs and IADL disability counts.[37] The higher number indicates a greater ADLs disability.

Explanatory variables

Chronic diseases

Participants were asked about the diagnosis of nine chronic health diseases by asking the question: 'Has any health professional ever diagnosed you with the following chronic diseases or diseases?'. We have used nine health diseases associated with disability: hypertension, diabetes, cancer, chronic lung disease, chronic heart disease, stroke, arthritis, neurological problems and high cholesterol. As per suggestions by the previous studies,[6 21] we also included a mental health condition—depression. In our study, depressive symptoms were assessed using a 10-item Centre for Epidemiologic Studies Depression (CES-D) scale with four option categories. The 10-items included seven negative symptoms (feeling depressed, low energy, trouble concentrating, feeling alone, bothered by things, fear of something and everything is an effort) and three positive symptoms (feeling happy, satisfied and hopeful). The possible responses included rarely or never (less than 1 day), sometimes (1 or 2 days), often (3 or 4 days) and most or all the time (5–7 days) in the last 7 days before the interview. For analysis, for negative symptoms, rarely or never (<1 day) and sometimes (1 or 2 days) were scored as 0, and often (3 or 4 days) and most or all the time (5–7 days) categories were scored as 1. Scoring was reversed for positive symptoms. The overall score lies between 0 and 10. The respondents with four or more responses indicating the depressive symptom on the 10-item CES-D instrument were considered as having high depressive symptoms (HDS).[38]

Sociodemographic factors

We have included selected individual characteristics including, age (60–69, 70–79 and 80+ years), sex (male, female), education (no education, primary, secondary and higher), marital status (currently married, widowed, divorced/separated/deserted) and working status (never worked, currently working and not currently working) in the analysis. LASI provides information about the current use of smoke or smokeless tobacco (1=current smoke or chew tobacco). Body mass index (BMI) was calculated by using the formula (weight (kg)/height^2 (m^2)). Moreover, various household-level factors were also included, such as religion (Hindu, Muslim, Christian and others), caste (Scheduled Tribe, Scheduled Caste, Other Backward Class and others) and place of residence (rural and urban). Moreover, we classified India into six broad geographical regions—North, Central, East, Northeast, West and South.

Statistical analysis

To examine the association between multimorbidity and ADL-IADL disability, we determined the prevalence of combinations of two or more chronic diseases. Most prevalent combinations were rank ordered according to their proportions. We have used the criterion of ≥2% prevalence of multimorbidity group in the study population, to ensure a sufficient sample size in each multimorbidity group which can allow for the valid regression estimates. Mean ADL, IADL and ADL-IADL indices were calculated for each multimorbidity group. Since the dependent variables, disability indices (ADL, IADL and ADL-IADL), were over-dispersed (when the variance exceeds the mean), we employed negative binomial regression analysis. Negative binomial regression models are used when the count data is over-dispersed, and their parameter estimates in terms of rate ratios can be interpreted as the relative difference in incidence rates between groups. We reported the incidence rate ratios (IRR) and 95% CIs, and a p value of <0.05 was considered significant. We had three dependent variables: ADL (0–6), IADL (0–7) and ADL-IADL (0–13). In the regression analysis, across all three dependent variables, we have examined two different reference groups: (1) healthy participants with no chronic disease (n=9597) and (2) participants who reported having only one chronic disease (n=9065). Also, we evaluated these associations among the nested groups (one additional chronic disease to the existing combination) to assess the marginal impact of the additional chronic disease between groups. For instance, a multimorbidity group that includes both hypertension, diabetes and HDS would

be compared with the group that includes only diabetes and HDS to examine the marginal impact of hypertension on the combination.

Both unadjusted and adjusted regression models were determined to assess the association between multimorbidity and ADL-IADL disability. We considered various explanatory variables including sex, age, smoking status, education, working status, marital status, BMI, wealth index, residence, religion, caste and region were used as the controlling variables in all adjusted regression models. Moreover, while conducting statistical analysis, we used the 'svyset' command in Stata accounting for the complex survey design of LASI.

For quantifying the potential impact of additional diseases in the nested groups on ADL-IADL disability, the PAF was calculated. PAF accounts for both the prevalence of exposure and strength of association and estimates the proportion of cases with disease attributable to exposure of interest in the population. PAFs were estimated from the multivariable logistic regression models using the maximum likelihood estimates method.[39] The PAFs reflect the proportional reduction in ADL-IADL disability would occur if the exposure to the risk would reduce to counterfactual scenario (elimination of the additional disease from the nested disease groups).

The PAF was calculated as:

$$\text{PAF} = \frac{\text{P}\times(\text{RR}-1)}{\text{P}\times(\text{RR}-1)+1}$$

Here, P is the population distribution of exposure, and RR is the relative risk in the exposed compared with the unexposed group. The greater magnitudes of PAFs indicate greater potential reduction in the ADL-IADL disability. PAFs were calculated from the final regression model using the '*punaf* Stata command. We conducted a sensitivity analysis to check the robustness of the findings. For instance, we compared the characteristics of the individuals who were included in the final analytical sample of the study with those who were excluded because of missing information on the explanatory variables using the χ^2 test (online supplemental table S1).

Patient and public involvement

No patient was involved.

RESULTS

The final sample size consists of 27 753 older adults aged 60 years and above. Table 1 summarises the sample characteristics of the selected participants. Just over half of the sample are women (51.9%). Around 60% of the individuals were in the age group 60–69 years. Around 34% of the participants currently smoke or chew tobacco products, more than half were with no education (56.1%), nearly 42% were not currently working and 35% were widowed at the time of the survey. The mean BMI, mean difficulties in ADLs and mean difficulties in IADLs were 21.8 (SD=4.8), 0.5 (SD=1.2) and 1.6 (SD=2.2), respectively. Self-reported

Table 1 Sample characteristics of the study population, Longitudinal Ageing Study in India, 2017–2018

Characteristics	N* (%†)/mean† (SD)
Individual factors	
Sex, N (%)	
Male	13 360 (48.1)
Female	14 393 (51.9)
Age groups, N (%)	
60–69 years	17 067 (59.7)
70–79 years	7990 (29.4)
80+ years	2696 (10.9)
Currently smoke/chew tobacco, N (%)	
No	18 842 (66.0)
Yes	8911 (34.0)
Education level, N (%)	
No education	14 809 (56.1)
Primary	6784 (22.7)
Secondary	4100 (13.6)
Higher	2060 (7.6)
Working status, N (%)	
Never worked	7710 (26.4)
Currently working	8420 (32.1)
Not currently working	11 623 (41.5)
Marital status, N (%)	
Currently married	17 778 (63.3)
Widowed	9277 (34.5)
Others‡	698 (2.2)
Body mass index, mean (SD)	21.8 (4.8)
ADLs (0–6), mean (SD)	0.5 (1.2)
IADLs (0–7), mean (SD)	1.6 (2.2)
ADLs and IADLs (0–13), mean (SD)	2.1 (3.0)
Chronic diseases, N (%)	
Hypertension	9616 (32.4)
Diabetes	4256 (14.2)
Cancer	202 (0.6)
Chronic lung disease	2089 (8.1)
Chronic heart disease	1397 (5.2)
Stroke	628 (2.3)
Arthritis	4918 (18.8)
Neurological problem	674 (2.6)
High cholesterol	1060 (2.9)
High depressive symptoms**	7638 (29.5)
Household factors	
Wealth index, N (%)	
Poorest	5656 (21.5)
Poorer	5744 (21.5)
Middle	5714 (21.6)
Richer	5469 (18.7)
Richest	5170 (16.6)

Continued

Table 1 Continued

Characteristics	N* (%†)/mean† (SD)
Place of residence, N (%)	
Rural	18484 (72.3)
Urban	9269 (27.7)
Religion, N (%)	
Hindu	20317 (82.6)
Muslim	3279 (10.8)
Christian	2799 (2.9)
Others§	1358 (3.7)
Caste, N (%)	
SC	4540 (18.8)
ST	4576 (8.1)
OBC¶	10575 (45.6)
Others	8062 (27.4)
Regions, N (%)	
North	5177 (13.1)
Central	3750 (21.4)
East	5225 (24.6)
Northeast	3319 (2.8)
West	3661 (15.8)
South	6621 (22.3)
Total	27753 (100.0)

*Values are unweighted counts.
†Values are weighted percentages.
‡Divorced, separated and deserted.
§Includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others.
¶Other Backward Classes.
**Based on the Centre for Epidemiologic Studies Depression scale,.
ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

hypertension was the most prevalent chronic diseases (32.4%), followed by HDS (29.5%), arthritis (18.8%) and diabetes (14.2%). Moreover, cancer (0.6%), stroke (2.3%) and neurological problems (2.6%) were among the least reported chronic health conditions. Around one-fourth of participants lived in urban areas (27.4%).

Out of total 1013 combinations, we identified 197 unique morbidity combinations with varying numbers of participants ranging from 1 to 2820. Out of these, we kept the top 13 morbidity combinations with at least 2% of the respondents. Table 2 presents the prevalence of morbidity combinations ranked from 1 to 13 and average ADL-IADL disability in these groups. Among chronic diseases, the combination of hypertension and HDS (10.3%) was the most prevalent, followed by hypertension and diabetes (9.7%), hypertension and arthritis (8.3%), and arthritis and HDS (6.7%). Eight of the thirteen most prevalent groups included hypertension, six included either depressive symptoms or arthritis and five included diabetes. None included cancer, stroke, neurological problem or high cholesterol. Mean ADL-IADL disability was highest in the 10th group (hypertension, arthritis and HDS) (mean=4.27), followed by the 4th group (arthritis and HDS) (mean=4.04) and 13th group (chronic lung diseases and arthritis) (mean=3.71). Moreover, the mean ADL-IADL disability in the 10th group is 6%–101% higher than any other morbidity combination group. Mean ADL-IADL disability according to background characteristics is presented in online supplemental table S2. Figure 1 shows the top 13 morbidity combinations according to different regions of India. Older adults in southern India represented most of the individuals in 10 out of 13 morbidity combinations, and older adults in eastern India represented most of the participants in 3 out of 13 groups. Overall, northeast India had low representations across all the MMCs.

Table 3 presents the unadjusted and adjusted negative binomial regression results of ADL-IADL disability on multimorbidity groups. By keeping healthy older adults (with no chronic disease) as a reference, all 13 MMCs were associated with higher rates of ADL-IADL disability in unadjusted and adjusted models. Various background characteristics, including sex, age, smoking status, education, working status, marital status, BMI and wealth index, were controlled in all the models. After keeping individuals with exactly one chronic disease as a reference, all multimorbidity groups except 2, 5 and 9 were related to higher rates of ADL-IADL disability. Even after adjusting for selected covariates, except for group 2 (hypertension, diabetes), different morbidity combinations were significantly at the risk of an increase in the rates of ADL-IADL disability relative to individuals with a single chronic disease. All MMCs were associated with increased rates of ADL-IADL disability when compared with participants with only one chronic disease, except for group 2. Similar results were obtained for ADL and IADL disability indices.

Table 4 presents the head-to-head adjusted and unadjusted results from the nested group comparisons. In the nested comparisons, we examine the marginal effect of additional chronic disease in the base MMC. The inclusion of hypertension in different dyads of chronic diseases, including group 9 (diabetes, HDS), group 10 (arthritis, HDS) and group 12 (diabetes, arthritis) does not exert any significant impact on the ADL-IADL disability. Relative to having only hypertension and diabetes (group 2), in the adjusted model, the inclusion of HDS to hypertension and diabetes (group 9) was significantly associated with increased rates of ADL-IADL disability (IRR=1.30; 95% CI 1.05 to 1.61); however, the results were not statistically significant in the unadjusted model. Moreover, the addition of HDS in group 3 (hypertension and arthritis) significantly increases the rates of ADL-IADL disability in unadjusted (IRR=1.61; 95% CI 1.39 to 1.87) and adjusted (IRR=1.44; 95% CI 1.26 to 1.64) models. The inclusion of diabetes in group 1 (hypertension, HDS) and group 3 (hypertension, arthritis) was not significantly associated with the ADL-IADL disability. Assessing the added contribution of diabetes with comparison to group 1 (hypertension, HDS) and group 3 (hypertension, arthritis), the result shows that the inclusion of diabetes in these groups

Table 2 Most prevalent multimorbidity combination groups and mean ADL-IADL, Longitudinal Ageing Study in India, 2017–2018

Group	Morbidity combination	N*	%†	ADLs Mean (95% CI)	IADLs Mean (95% CI)	Mean (ADLs and IADLs) Mean (95% CI)
1	Hypertension+HDS	2800	10.3	0.90 (0.84, 0.96)	2.23 (2.14, 2.32)	3.13 (2.99, 3.26)
2	Hypertension+diabetes	2820	9.7	0.57 (0.52, 0.62)	1.54 (1.47, 1.62)	2.12 (2.00, 2.23)
3	Hypertension+arthritis	2273	8.3	0.98 (0.91, 1.04)	2.27 (2.17, 2.36)	3.24 (3.10, 3.39)
4	Arthritis+HDS	1642	6.7	1.28 (1.20, 1.37)	2.76 (2.64, 2.88)	4.04 (3.86, 4.22)
5	Diabetes+HDS	1166	4.3	0.73 (0.64, 0.82)	1.74 (1.62, 1.87)	2.48 (2.28, 2.67)
6	Hypertension+chronic lung disease	890	3.5	0.65 (0.56, 0.74)	2.18 (2.03, 2.33)	2.83 (2.62, 3.04)
7	Hypertension+heart disease	941	3.5	0.73 (0.64, 0.82)	2.07 (1.93, 2.21)	2.80 (2.60, 3.00)
8	Diabetes+arthritis	957	3.5	0.76 (0.67, 0.86)	2.20 (2.06, 2.34)	2.96 (2.76, 3.16)
9	Hypertension+diabetes+HDS	803	3.2	0.76 (0.65, 0.87)	1.72 (1.56, 1.87)	2.48 (2.24, 2.72)
10	Hypertension+arthritis+HDS	785	3.0	1.43 (1.30, 1.57)	2.84 (2.67, 3.01)	4.27 (4.00, 4.55)
11	Chronic lung disease+HDS	722	2.8	1.06 (0.93, 1.19)	2.57 (2.39, 2.76)	3.63 (3.36, 3.91)
12	Hypertension+diabetes+arthritis	661	2.5	0.78 (0.67, 0.90)	2.27 (2.11, 2.44)	3.06 (2.81, 3.30)
13	Chronic lung disease+arthritis	517	2.4	0.99 (0.86, 1.13)	2.71 (2.53, 2.90)	3.71 (3.42, 3.99)

HDS is based on the Centre for Epidemiologic Studies Depression scale.
*Values are unweighted counts.
†Values are weighted percentages.
ADL, activities of daily living; HDS, high depressive symptoms; IADL, instrumental activities of daily living.

does not exert any significant impact on the ADL-IADL disability. The addition of arthritis in group 1 (hypertension, HDS) and group 2 (hypertension, diabetes) was significantly associated with an ADL-IADL count 1.48 times greater (IRR=1.48; 95% CI 1.28 to 1.71) and 1.49 times greater (IRR=1.49; 95% CI 1.22 to 1.82) in adjusted models, respectively.

The PAF of the added chronic diseases in different groups for ADL-IADL disability are given in table 5. The estimated PAF of HDS in group 9 (hypertension, HDS and diabetes) and group 10 (hypertension, arthritis and HDS) was 8.9% (95% CI 1.2 to 16.0) and 14.6% (95% CI 9.3 to 19.7) for ADL-IADL disability. In other words, nearly 9% and 15% of older adults would have been prevented from ADL-IADL disability if HDS was eliminated from groups 9 and 10, respectively. Moreover, around 13.5% and 12.7% of older adults would have been averted from ADL-IADL disability if arthritis was eliminated from group 10 (hypertension, arthritis and HDS) and group 12 (hypertension, diabetes and arthritis). Moreover, PAF of the different morbidity combinations relative to healthy older adults for ADL-IADL disability is shown in online supplemental

Morbidity combinations	North	Central	East	Northeast	West	South
Hypertension + HDS	14.6	15.6	25.8	1.8	10.6	31.5
Hypertension + Diabetes	10.7	10.8	16.7	1.8	19.1	40.9
Hypertension + Arthritis	12.6	8.3	26.2	1.3	18.7	32.8
Arthritis + HDS	10.9	13.6	32.3	0.7	13.4	29.1
Diabetes + HDS	9.5	14.8	20.3	0.7	9.9	44.7
Hypertension + Chronic lung disease	18.4	12.3	19.4	1.9	14.8	33.3
Hypertension + Heart disease	14.5	9.5	25.4	1.7	19.6	29.4
Diabetes + Arthritis	8.9	9.4	19.5	0.7	17.8	43.8
Hypertension + Diabetes + HDS	9.4	13.2	19.3	0.6	9.3	48.0
Hypertension + Arthritis + HDS	13.1	10.1	33.2	0.8	13.3	29.6
Chronic lung disease + HDS	16.6	21.1	30.3	1.3	10.1	20.6
Hypertension + Diabetes + Arthritis	7.8	7.2	18.2	0.9	17.0	48.9
Chronic lung disease + Arthritis	11.7	10.2	20.3	0.6	17.3	39.9

Note. HDS: high depressive symptoms; Red color represents high prevalence and green color represents low prevalence.

Figure 1 Prevalence of different multimorbidity combinations according to different Indian regions, Longitudinal Ageing Study in India, 2017–2018, reported as weighted percentages.

Table 3 Unadjusted and adjusted negative binomial regression of ADL-IADL index on multimorbidity group, Longitudinal Ageing Study in India, 2017–2018

	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)
	No chronic disease (n=9597)		One chronic disease (n=9065)	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*
ADLs/IADLs (0–13)				
1: Hypertension+HDS	2.20† (1.93 to 2.50)	2.17† (1.96 to 2.39)	1.48† (1.24 to 1.78)	1.52† (1.32 to 1.75)
2: Hypertension+diabetes	1.49† (1.30 to 1.70)	1.80† (1.58 to 2.04)	1.00 (0.84 to 1.20)	1.23 (1.00 to 1.46)
3: Hypertension+arthritis	2.28† (2.06 to 2.53)	2.31† (2.08 to 2.56)	1.54† (1.36 to 1.74)	1.64† (1.48 to 1.80)
4: Arthritis+HDS	2.84† (2.54 to 3.18)	2.60† (2.35 to 2.88)	1.92† (1.67 to 2.20)	1.84† (1.67 to 2.03)
5: Diabetes+HDS	1.74† (1.35 to 2.23)	2.17† (1.81 to 2.59)	1.17 (0.86 to 1.60)	1.43† (1.10 to 1.86)
6: Hypertension+chronic lung disease	1.99† (1.75 to 2.26)	1.89† (1.67 to 2.15)	1.34† (1.18 to 1.53)	1.36† (1.21 to 1.53)
7: Hypertension+heart disease	1.97† (1.63 to 2.38)	2.46† (2.09 to 2.89)	1.33† (1.07 to 1.65)	1.66† (1.44 to 1.91)
8: Diabetes+arthritis	2.08† (1.84 to 2.35)	2.43† (2.08 to 2.83)	1.40† (1.23 to 1.60)	1.67† (1.46 to 1.92)
9: Hypertension+diabetes+HDS	1.74† (1.26 to 2.41)	2.22† (1.78 to 2.76)	1.18 (0.80 to 1.73)	1.46† (1.05 to 2.02)
10: Hypertension+arthritis+HDS	3.00† (2.64 to 3.42)	2.92† (2.56 to 3.33)	2.03† (1.74 to 2.35)	2.05† (1.82 to 2.32)
11: Chronic lung disease+HDS	2.55† (2.23 to 2.92)	2.23† (1.96 to 2.55)	1.72† (1.46 to 2.03)	1.59† (1.39 to 1.83)
12: Hypertension+diabetes+arthritis	2.15† (1.88 to 2.45)	2.45† (2.07 to 2.90)	1.45† (1.25 to 1.68)	1.71† (1.48 to 1.97)
13: Chronic lung disease+arthritis	2.61† (2.28 to 2.99)	2.64† (2.31 to 3.03)	1.76† (1.47 to 2.10)	1.91† (1.66 to 2.19)
ADLs (0–6)				
1: Hypertension+HDS	3.33† (2.80 to 3.96)	3.18† (2.73 to 3.71)	1.90† (1.57 to 2.31)	1.99† (1.74 to 2.27)
2: Hypertension+diabetes	2.12† (1.66 to 2.72)	2.36† (1.94 to 2.86)	1.21 (0.94 to 1.57)	1.51† (1.27 to 1.78)
3: Hypertension+arthritis	3.62† (3.02 to 4.33)	3.59† (3.04 to 4.23)	2.07† (1.68 to 2.54)	2.34† (2.02 to 2.71)
4: Arthritis+HDS	4.76† (3.93 to 5.75)	4.34† (3.65 to 5.15)	2.72† (2.19 to 3.38)	2.73† (2.33 to 3.20)
5: Diabetes+HDS	2.71† (2.02 to 3.63)	3.21† (2.52 to 4.09)	1.55† (1.15 to 2.09)	1.93† (1.54 to 2.41)
6: Hypertension+chronic lung disease	2.41† (1.77 to 3.30)	2.08† (1.61 to 2.70)	1.38† (0.99 to 1.92)	1.35† (1.07 to 1.69)
7: Hypertension+heart disease	2.70† (1.93 to 3.78)	2.99† (2.24 to 3.98)	1.54† (1.08 to 2.20)	1.82† (1.45 to 2.29)
8: Diabetes+arthritis	2.83† (2.11 to 3.80)	3.13† (2.39 to 4.09)	1.62† (1.19 to 2.20)	2.08† (1.65 to 2.61)
9: Hypertension+diabetes+HDS	2.82† (1.96 to 4.05)	3.30† (2.50 to 4.36)	1.61† (1.11 to 2.33)	2.02† (1.57 to 2.60)
10: Hypertension+arthritis+HDS	5.30† (4.34 to 6.48)	5.15† (4.16 to 6.36)	3.03† (2.43 to 3.78)	3.31† (2.77 to 3.96)
11: Chronic lung disease+HDS	3.92† (3.16 to 4.88)	3.37† (2.73 to 4.17)	2.24† (1.74 to 2.90)	2.00† (1.59 to 2.53)
12: Hypertension+diabetes+arthritis	2.91† (1.99 to 4.25)	3.12† (2.26 to 4.30)	1.66† (1.12 to 2.46)	2.11† (1.61 to 2.75)
13: Chronic lung disease+arthritis	3.68† (2.50 to 5.42)	3.49† (2.50 to 4.87)	2.11† (1.38 to 3.21)	2.29† (1.68 to 3.12)
IADLs (0–7)				
1: Hypertension+HDS	1.93† (1.70 to 2.20)	1.94† (1.77 to 2.13)	1.36† (1.12 to 1.66)	1.40† (1.21 to 1.62)
2: Hypertension+diabetes	1.34† (1.19 to 1.51)	1.65† (1.46 to 1.85)	0.94 (0.81 to 1.10)	1.14 (0.96 to 1.36)
3: Hypertension+arthritis	1.97† (1.77 to 2.18)	1.99† (1.80 to 2.20)	1.39† (1.25 to 1.54)	1.44† (1.31 to 1.58)
4: Arthritis+HDS	2.39† (2.17 to 2.64)	2.19† (2.00 to 2.40)	1.69† (1.48 to 1.92)	1.59† (1.46 to 1.74)
5: Diabetes+HDS	1.51† (1.18 to 1.94)	1.94† (1.65 to 2.29)	1.07 (0.77 to 1.48)	1.30 (1.00 to 1.69)
6: Hypertension+chronic lung disease	1.89† (1.63 to 2.19)	1.84† (1.61 to 2.10)	1.33† (1.20 to 1.48)	1.35† (1.20 to 1.51)
7: Hypertension+heart disease	1.80† (1.46 to 2.21)	2.28† (1.95 to 2.67)	1.27† (1.04 to 1.55)	1.57† (1.37 to 1.80)
8: Diabetes+arthritis	1.91† (1.65 to 2.20)	2.25† (1.94 to 2.61)	1.34† (1.21 to 1.49)	1.56† (1.37 to 1.76)
9: Hypertension+diabetes+HDS	1.49† (1.08 to 2.06)	1.99† (1.62 to 2.43)	1.05 (0.70 to 1.57)	1.31 (0.94 to 1.83)
10: Hypertension+arthritis+HDS	2.46† (2.19 to 2.78)	2.42† (2.14 to 2.74)	1.74† (1.50 to 2.01)	1.73† (1.54 to 1.95)
11: Chronic lung disease+HDS	2.23† (1.97 to 2.53)	2.02† (1.79 to 2.28)	1.57† (1.35 to 1.83)	1.49† (1.32 to 1.69)
12: Hypertension+diabetes+arthritis	1.97† (1.69 to 2.31)	2.31† (1.94 to 2.76)	1.39† (1.25 to 1.54)	1.60† (1.39 to 1.84)
13: Chronic lung disease+arthritis	2.35† (2.08 to 2.66)	2.45† (2.12 to 2.84)	1.66† (1.48 to 1.86)	1.78† (1.57 to 2.02)

HDS is based on the Centre for Epidemiologic Studies Depression scale
*Adjusted for sex, age, smoking status, education, working status, marital status, body mass index, wealth index, residence, religion, caste and region.
†p<0.05.
ADL, activities of daily living; HDS, high depressive symptoms; IADL, instrumental activities of daily living; IRR, incidence rate ratios.

Table 4 Nested comparisons: negative binomial models of ADL-IADL index on multimorbidity groups, Longitudinal Ageing Study in India, 2017–2018

		ADLs/IADLs (0–13)		ADLs (0–6)		IADLs (0–7)	
		Unadjusted	Adjusted*	Unadjusted	Adjusted*	Unadjusted	Adjusted*
Comparison group	Reference group	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)
Addition of hypertension to the combination							
9: Hypertension+diabetes+HDS	5: Diabetes+HDS	1.01 (0.69 to 1.46)	0.98 (0.72 to 1.33)	1.17 (0.75 to 1.84)	1.07 (0.71 to 1.61)	0.95 (0.65 to 1.38)	1.01 (0.78 to 1.31)
10: Hypertension+arthritis+HDS	4: Arthritis+HDS	1.11 (0.98 to 1.26)	1.12 (0.99 to 1.27)	**1.23† (1.01 to 1.51)**	1.22 (1.00 to 1.48)	1.06 (0.94 to 1.18)	1.09 (0.98 to 1.23)
12: Hypertension+diabetes+arthritis	8: Diabetes+arthritis	1.12 (0.89 to 1.42)	1.02 (0.80 to 1.31)	1.10 (0.68 to 1.78)	1.06 (0.70 to 1.60)	1.13 (0.87 to 1.47)	1.02 (0.82 to 1.26)
Addition of HDS to the combination							
9: Hypertension+diabetes+HDS	2: Hypertension+diabetes	1.28 (0.87 to 1.88)	**1.30† (1.05 to 1.61)**	**1.58† (1.17 to 2.13)**	**1.73† (1.34 to 2.23)**	**1.18 (0.76 to 1.82)**	**1.23† (1.01 to 1.50)**
10: Hypertension+arthritis+HDS	3: Hypertension+arthritis	**1.61† (1.39 to 1.87)**	**1.44† (1.26 to 1.64)**	**2.00† (1.53 to 2.61)**	**1.78† (1.45 to 2.18)**	**1.46† (1.26 to 1.71)**	**1.34† (1.18 to 1.52)**
Addition of diabetes to the combination							
9: Hypertension+diabetes+HDS	1: Hypertension+HDS	0.73 (0.52 to 1.01)	0.88 (0.74 to 1.04)	0.79 (0.55 to 1.15)	0.93 (0.74 to 1.16)	**0.70† (0.51 to 0.97)**	0.88 (0.75 to 1.03)
12: Hypertension+diabetes+Arthritis	3: Hypertension+arthritis	0.92 (0.80 to 1.06)	1.02 (0.88 to 1.17)	0.74 (0.50 to 1.09)	0.81 (0.63 to 1.03)	1.00 (0.85 to 1.18)	1.11 (0.97 to 1.28)
Addition of arthritis to the combination							
10: Hypertension+arthritis+HDS	1: Hypertension+HDS	**1.61† (1.33 to 1.95)**	**1.48† (1.28 to 1.71)**	**2.11† (1.64 to 2.72)**	**2.03† (1.66 to 2.40)**	**1.44† (1.20 to 1.73)**	**1.29† (1.14 to 1.47)**
12: Hypertension+diabetes+arthritis	2: Hypertension+diabetes	**1.71† (1.38 to 2.11)**	**1.49† (1.22 to 1.82)**	**1.57† (1.13 to 2.19)**	**1.59† (1.19 to 2.13)**	**1.76† (1.33 to 2.32)**	**1.43† (1.18 to 1.73)**

HDS is based on the Centre for Epidemiologic Studies Depression scale.
*Adjusted for sex, age, smoking status, education, working status, marital status, body mass index, wealth index, residence, religion, caste and region
†p<0.05.
ADL, activities of daily living; HDS, High Depressive Symptoms; IADL, instrumental activities of daily living; IRR, incidence rate ratios.

Table 5 Estimated population attributable fraction (PAF) of added hypertension, HDS, diabetes and arthritis for ADL-IADL index in Indian older adults, Longitudinal Ageing Study in India, 2017–2018

Comparison group	Reference group	Population attributable fraction (PAF) (95% CI)		
		ADLs/IADLs (0–13)	ADLs (0–6)	IADLs (0–7)
Addition of hypertension to the combination				
9: Hypertension+diabetes+HDS	5: Diabetes+HDS	−1.4 (−26.1 to 18.4)	4.8 (−28.2 to 29.4)	0.6 (−20 to 17.8)
10: Hypertension+arthritis+HDS	4: Arthritis+HDS	5.0 (−0.8 to 10.5)	9.1 (−0.6 to 17.8)	4.0 (−1.3 to 9.0)
12: Hypertension+diabetes+arthritis	8: Diabetes+arthritis	1.7 (−17.2 to 17.6)	3.8 (−28.6 to 28.0)	1.4 (−15.5 to 15.8)
Addition of HDS to the combination				
9: Hypertension+diabetes+HDS	2: Hypertension+diabetes	**8.9* (1.2 to 16.0)**	**17.9* (8.6 to 26.2)**	**7.1* (−0.2 to 13.8)**
10: Hypertension+arthritis+HDS	3: Hypertension+arthritis	**14.6* (9.3 to 19.7)**	**24.0* (14.9 to 32.1)**	**11.7* (6.5 to 16.5)**
Addition of diabetes to the combination				
9: Hypertension+diabetes+HDS	1: Hypertension+HDS	−3.2 (−7.3 to 0.8)	−2.0 (−7.8 to 3.6)	−3.1 (−7.0 to 0.6)
12: Hypertension+diabetes+arthritis	3: Hypertension+arthritis	0.4 (−3.6 to 4.3)	−5.4 (−11.4 to 0.3)	3.0 (−1.0 to 6.9)
Addition of arthritis to the combination				
10: Hypertension+arthritis+HDS	1: Hypertension+HDS	**13.5* (8.1 to 18.5)**	**24.7* (17.2 to 31.5)**	**8.7* (4.1 to 13.1)**
12: Hypertension+diabetes+arthritis	2: Hypertension+diabetes	**12.7* (5.8 to 19.0)**	**13.5* (3.8 to 22.3)**	**11.6* (4.9 to 17.8)**

*p<0.05;.HDS is based on the Centre for Epidemiologic Studies Depression scale; PAF (per cent of cases in the population attributable to exposure) of addition of diseases (hypertension, HDS, diabetes and arthritis) was estimated based on negative binomial regression models for the cases of ADL/IADL index, adjusted for sex, age, smoking status, education, working status, marital status, body mass index, wealth index, residence, religion, caste and region.
ADL, activities of daily living; HDS, high depressive symptoms; IADL, instrumental activities of daily living; IRR, incidence rate tatio.

table S3. The estimated PAF of the group 1 (hypertension and HDS), group 3 (hypertension and arthritis), group 4 (arthritis and HDS), group 10 (hypertension, arthritis and HDS) for ADL-IADL disability were 22.5% (19.2–25.5), 21.6% (18.7–24.4), 23.5% (20.6–26.3) and 15.4% (12.8–17.8), respectively.

Sensitivity analysis

The results from the sensitivity analysis suggest that the characteristics were significantly different each other except gender, mean BMI, diabetes, cancer, chronic lung disease, chronic heart disease, arthritis and religion. Moreover, the inclusion of the participants who were excluded due to incomplete data in the final sample had minimal effect on the results (online supplemental table S4).

DISCUSSION

This study investigated the prevalence of MMCs and their association with functional limitations in the national representative sample of Indian older adults aged 60 years and over. We identified 197 unique MMCs among the people who reported at least two chronic diseases. Using the criterion of ≥2% prevalence of the multimorbidity group, we identified the 13 most prevalent groups. Multimorbidity is highly prevalent among older adults in India, with around 55% of the sample reporting two chronic diseases and 9% of the reported three chronic diseases. We found that the combination of hypertension and HDS was the most prevalent MMC. Moreover, hypertension, HDS and arthritis were present in most of the multimorbidity groups separately. Overall, all MMCs were associated with increased functional limitation. Specifically, the combination of hypertension, arthritis and HDSs was associated with greater ADL-IADL disability than any other MMC. The pattern for chronic diseases and their effect on the functional restrictions in this study has been consistent with studies done in Europe and the USA.[6 21] Interestingly, the risks for functional restrictions are much higher for the ADL than IADL found in the study.

A regional pattern for the nesting of multimorbidity conditions is recognised in this study. These are concentrated in the southern and eastern regions of the country, reflecting a demographic and epidemiological relevance to the disease outcome. States in the southern and few in the eastern region have a higher share of the older adult population than other regions,[40] hence, possibly contributing to a higher burden of diseases. In our study, in the eastern region, group 10 (hypertension, arthritis, HDS), group 11 (chronic lung diseases, HDS) and group 4 (arthritis, HDS) are more prevalent multimorbid clusters. While in the southern region, almost all multimorbidity groups are highly prevalent except group 11 (chronic lung disease, HDS).

The result from the nested comparison of multimorbid conditions suggests that there is a commonality in the disease pattern among older adults in India. Particularly in combinations with hypertension, few diseases such as diabetes and arthritis are occurring most frequently. The accumulation of cardiometabolic risk factors results into metabolic syndrome in the body. It further encourages the incidence of higher rates of oxidative stress at the younger ages and hence, the pathophysiological changes led to faster ageing.[41] There are several life-style factors such as food habits, stressful life situations, lack of exercise, etc increases the multiple metabolic risk factors among individuals. It has a linear and significant

association with the functional restrictions. With an increase in urbanisation, the metabolic risk factors are multiplying to great extent. The presence of higher share of increase triglyceride found among rural elderly living in Southern India is evident. Since two-thirds of the population in India is rural, therefore, high burden of hypertension can be a cause of concern.[42] Along with those other diseases like diabetes, which is highly undiagnosed, is a prime disease to form a cluster. Additionally, ageing is associated with several physiological changes that trigger the multimorbidity to develop once an individual reaches 40 years[43] and that grows up to the age 70 years and later odds of multimorbidity remains stagnant.[44] Metabolic abnormalities at early ages and neglect to that impart a long-term effect on the individuals. Metabolic diseases can aggravate the loss of serotonergic innervations as the individual ages, which increases the chances of depression as well.[45] Our study has mainly considered hypertension in the disease clustering to understand the probable effect of other diseases on the functional activities among older adults (table 4). Hypertension with other combination of chronic diseases is occurring frequently and shows a higher likelihood for declining functions, however, combination such as arthritis and HDSs are no less. It is highly strong in declining functional activities among elderly than any other clustering of diseases. In a study among elderly in China, clustering of hypertension with other diseases are found most frequently.[46] The literatures investigating on the association between depressive symptoms and functional limitations suggests an existence of a bidirectional relationship.[47–50] People with depression generally face retarding effects, due to less physical activity and lower compliance with treatment recommendations, which increases the risk of functional limitations.[51 52] Alternatively, the experience of functional limitations may aggravate the stress level, as a result, increases the risk of depression.[53] On the other hand, arthritis poses persistent difficulties in ADLs or mobility.[54] Controlling all other demographic, health and socioeconomic factors, introduction of arthritis in the disease combination of hypertension and arthritis, and hypertension and diabetes show a higher PAF among elderly in India. Though study claims that an addition of depressive symptoms in the disease clusters are affecting the functional restriction more than addition of somatic conditions.[21] However, this pattern is not followed among older adults in India. Perhaps, there is a significant regional difference in the epidemiological and lifestyle transitions in India, which led to mixed outcome on the functional activities. A study supports a regional difference exists in India in terms of burden of metabolic disorders.[55] Sheridan *et al*[21] also find the odds for functional restrictions due to multimorbidities are much higher in the case of ADL than IADL. It explains that more restrictions in performing the basic activities at the later ages when instrumental activities can be performed by the support of caregivers in case of their inabilities.

The higher share of older adults in the population shows a higher likelihood for clustering of dyad and triad of multimorbid conditions. Very few studies estimated the combinations of the most prevalent clusters of diseases at a national level. However, the presence of arthritis and hypertension with other combinations is distinguishable from the study conducted at the local level.[56] This commonality of clustering of specific diseases is explained by the fact that risk factors for metabolic pathways are similar for diseases like diabetes and cardiovascular diseases.

This study found that older adults with HDSs have a greater odds of functional limitations at all levels of multimorbidity.[57] Our study presents evidence that the combinations of arthritis, HDS and hypertension are the most severe in nature, resulting in higher restrictions in ADL and IADL. Depressive symptoms can be developed independently of other chronic diseases; however, the development of depression along with chronic morbidities is less clinically recognised, though often found to a large extent. Schäfer *et al*[58] find that vascular problems such as cardiac insufficiency affects the development of vascular dementia. The same study also mentioned that the presence of anxiety or depression could be found in 30% of the cases having any somatic condition. It is commonly found that diabetes and arthritis together occur due to a similar risk factor.

Previously, multiple studies have reported the positive association between multiple chronic illnesses and disability.[6 59] The present study is an extension because it associates the most prevalent MMCs with functional limitations. The study has several limitations worth mentioning. First, all the diseases except HDS were diagnosed in the past. We assessed HDSs with the help of the CES-D scale. The nine out of ten chronic diseases (except depressive symptoms) included in the study were self-reported, therefore, subject to recall bias. Clinical diagnosis of the depression would provide a better chance to identify the depression among the targeted population. Second, it has also been seen that population-based data sources have a subjective bias to the intensity of the functional restriction one suffers. The severity of chronic diseases on the functional limitations (ADL/IADL) cannot be measured by the present source of data and the method followed to identify the disease. Third, this dataset does not offer an analysis to differentiate on mild, acute/chronic, early, or advanced stage of disease, degenerative diseases. A detailed study must be recommended across different population clusters to measure the burden of disease or disability in the context of a particular population subset. Fourth, we excluded the clinically diagnosed neurological diseases (ie, neurological, or psychiatric problems such as depression, Alzheimer's/Dementia, unipolar/bipolar disorders, convulsions and Parkinson's) from the analysis due to a very low prevalence (0.89%) in the dataset. LASI also provides information on measured cognition, and since there is no well-established algorithm that can determine the clinical cognitive impairment in the

Indian scenario, we have not included cognitive impairment in the chronic diseases. Finally, due to unavailability of information on other causes of disability including, instability, immobility, incontinence, polypharmacy and iatrogenic disease in LASI data, the incorporation of such risk factors was not possible. Since a high degree of variation is observed across regions of India due to their relative position of demographic, epidemiological and economic transitions, putting together all those contexts would be comprehensive to fathom the impact of disease clustering. The future studies must highlight the other health indicators such as medications, therapeutic intervention, caregiving support to understand the severity of multimorbidity. Moreover, these studies can also address the causal linkage between the clusters of diseases considering similar risk factors. Though different studies on a similar issue have highlighted the utility of longitudinal survey in regard to the progress of the diseases, buffer effects, and protective effects.[6 21] However, we also suggest including the verbatim of other diseases influence the risk factors for functional restrictions among older adults. Moreover, analysis based on gender, age groups, educational and wealth categories would capture a more vivid picture of incidence and clustering of certain kinds of disease.

CONCLUSIONS

The study aims to determine the combinations of chronic morbidities and their association with functional health among older adults in India. We find that MMCs are highly prevalent in India and are associated with an increased risk of disability. Chronic diseases like hypertension, HDS and arthritis were present in majority of the MMCs. Moreover, the addition of arthritis and HDS in different MMCs can be more disabling. The incidence of these kinds of degenerative diseases requires in-depth and long-term analysis considering the somatic and psychological relevance of the morbidities on the well-being of older adults. This study portrays the importance of studying the combinations of the chronic diseases with respect to functional disability rather than focusing on merely one or two chronic diseases. In clinical settings, priority should be placed on identifying the HDSs in older adults with other chronic diseases, particularly hypertension and arthritis. Also, arthritis coupled with hypertension and diabetes is significantly positively associated with functional disability in older adults. Future research may use longitudinal data to study morbidity transitions and to establish the causal association between different morbidity combinations and functional disability.

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REFERENCES

1 Fortin M, Bravo G, Hudon C, *et al*. Prevalence of multimorbidity among adults seen in family practice. *Ann Fam Med* 2005;3:223–8.
2 Makovski TT, Schmitz S, Zeegers MP, *et al*. Multimorbidity and quality of life: systematic literature review and meta-analysis. *Ageing Res Rev* 2019;53:100903.
3 Williams JS, Egede LE. The association between multimorbidity and quality of life, health status and functional disability. *Am J Med Sci* 2016;352:45–52.
4 Perruccio AV, Katz JN, Losina E. Health burden in chronic disease: multimorbidity is associated with self-rated health more than medical comorbidity alone. *J Clin Epidemiol* 2012;65:100–6.
5 Galenkamp H, Braam AW, Huisman M, *et al*. Somatic multimorbidity and self-rated health in the older population. *J Gerontol B Psychol Sci Soc Sci* 2011;66:380–6.
6 Quiñones AR, Markwardt S, Botoseneanu A. Multimorbidity combinations and disability in older adults. *J Gerontol A Biol Sci Med Sci* 2016;71:823–30.
7 Su P, Ding H, Zhang W, *et al*. The association of multimorbidity and disability in a community-based sample of elderly aged 80 or older in shanghai, china. *BMC Geriatr* 2016;16:178.
8 Rivera-Almaraz A, Manrique-Espinoza B, Ávila-Funes JA, *et al*. Disability, quality of life and all-cause mortality in older mexican adults: association with multimorbidity and frailty. *BMC Geriatr* 2018;18:236.
9 Willadsen TG, Siersma V, Nicolaisdóttir DR, *et al*. Multimorbidity and mortality: a 15-year longitudinal registry-based nationwide danish population study. *J Comorb* 2018;8.
10 Emerging Risk Factors Collaboration, Di Angelantonio E, Kaptoge S, *et al*. Association of cardiometabolic multimorbidity with mortality. *JAMA* 2015;314:52–60.
11 Zheng DD, Loewenstein DA, Christ SL, *et al*. Multimorbidity patterns and their relationship to mortality in the US older adult population. *PLoS One* 2021;16:e0245053.
12 Habib SH, Saha S. Burden of non-communicable disease: global overview. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* 2010;4:41–7.
13 Pefoyo AJK, Bronskill SE, Gruneir A, *et al*. The increasing burden and complexity of multimorbidity. *BMC Public Health* 2015;15:415.
14 Nguyen H, Manolova G, Daskalopoulou C, *et al*. Prevalence of multimorbidity in community settings: a systematic review and meta-analysis of observational studies. *J Comorb* 2019;9.

15 Pati S, Swain S, Hussain MA, *et al*. Prevalence and outcomes of multimorbidity in South Asia: a systematic review. *BMJ Open* 2015;5:e007235.
16 Heiland EG, Welmer A-K, Wang R, *et al*. Cardiovascular risk factors and the risk of disability in older adults: variation by age and functional status. *J Am Med Dir Assoc* 2019;20:208–12.
17 Werfalli M, Kassanjee R, Kalula S, *et al*. Diabetes in south african older adults: prevalence and impact on quality of life and functional disability-as assessed using SAGE wave 1 data. *Glob Health Action* 2018;11:1449924.
18 Friedrich MJ. Depression is the leading cause of disability around the world. *JAMA* 2017;317:1517.
19 Norris SL, High K, Gill TM, *et al*. Health care for older Americans with multiple chronic conditions: a research agenda. *J Am Geriatr Soc* 2008;56:149–59.
20 Boyd CM, Ritchie CS, Tipton EF, *et al*. From bedside to bench: summary from the American geriatrics society/national Institute on aging research conference on comorbidity and multiple morbidity in older adults. *Aging Clin Exp Res* 2008;20:181–8.
21 Sheridan PE, Mair CA, Quiñones AR. Associations between prevalent multimorbidity combinations and prospective disability and self-rated health among older adults in europe. *BMC Geriatr* 2019;19:198.
22 Dunlop DD, Lyons JS, Manheim LM, *et al*. Arthritis and heart disease as risk factors for major depression: the role of functional limitation. *Med Care* 2004;42:502–11.
23 Park SJ, Rim SJ, Kim CE, *et al*. Effect of comorbid depression on health-related quality of life of patients with chronic diseases: a south korean nationwide study (2007-2015). *J Psychosom Res* 2019;116:17–21.
24 Quiñones AR, Markwardt S, Thielke S, *et al*. Prospective disability in different combinations of somatic and mental multimorbidity. *J Gerontol A Biol Sci Med Sci* 2018;73:204–10.
25 Giridhar G, James KS, Kumar S. Caring for our elders: early responses. 2017. Available: https://india.unfpa.org/sites/default/files/pub-pdf/India Ageing Report- 2017 %28Final Version%29.pdf
26 Quigley MA. Commentary: shifting burden of disease -- epidemiological transition in India. *Int J Epidemiol* 2006;35:1530–1.
27 Yadav S, Arokiasamy P. Understanding epidemiological transition in India. *Glob Health Action* 2014;7:23248.
28 Chatterji S, Kowal P, Mathers C, *et al*. The health of aging populations in China and India. *Health Aff (Millwood)* 2008;27:1052–63.
29 Chakma JK, Gupta S. Lifestyle and non-communicable diseases: a double edged sword for future india. *Indian J Community Heal* 2014;26:325–32. Available: https://www.iapsmupuk.org/journal/index.php/IJCH/article/view/434
30 Mini GK, Thankappan KR. Pattern, correlates and implications of non-communicable disease multimorbidity among older adults in selected Indian states: a cross-sectional study. *BMJ Open* 2017;7:e013529.
31 Talukdar B, Himanshu H. Prevalence of multimorbidity (chronic NCDS) and associated determinants among elderly in india. *Demogr India* 2017:69–76. Available: https://www.cabdirect.org/globalhealth/abstract/20203499974
32 Sharma P, Maurya P, Muhammad T. Number of chronic conditions and associated functional limitations among older adults: cross-sectional findings from the longitudinal aging study in india. *BMC Geriatr* 2021;21:664.
33 Garin N, Olaya B, Moneta MV, *et al*. Impact of multimorbidity on disability and quality of life in the Spanish older population. *PLoS One* 2014;9:e111498.
34 Boeckxstaens P, Vaes B, Legrand D, *et al*. The relationship of multimorbidity with disability and frailty in the oldest patients: a cross-sectional analysis of three measures of multimorbidity in the BELFRAIL cohort. *Eur J Gen Pract* 2015;21:39–44.
35 Barberger-Gateau P, Rainville C, Letenneur L, *et al*. A hierarchical model of domains of disablement in the elderly: a longitudinal approach. *Disabil Rehabil* 2000;22:308–17.
36 International Institute for Population Sciences (IIPS). Longitudinal ageing study in india (LASI) wave 1, 2017-18, india report; 2020. 2017–8.Available: https://iipsindia.ac.in/sites/default/files/LASI_India_Report_2020_compressed.pdf
37 Spector WD, Fleishman JA. Combining activities of daily living with instrumental activities of daily living to measure functional disability. *J Gerontol B Psychol Sci Soc Sci* 1998;53:S46–57.
38 Irwin M, Artin KH, Oxman MN. Screening for depression in the older adult: criterion validity of the 10-item center for epidemiological studies depression scale (CES-D). *Arch Intern Med* 1999;159:1701–4.
39 Greenland S, Drescher K. Maximum likelihood estimation of the attributable fraction from logistic models. *Biometrics* 1993;49:865–72.
40 Rajan IS, Aliyar S. Population ageing in india. institutional provisions care aged. 2008:39–54.
41 Bonomini F, Rodella LF, Rezzani R. Metabolic syndrome, aging and involvement of oxidative stress. *Aging Dis* 2015;6:109–20.
42 Sundarakumar JS, Stezin A, Menesgere AL, *et al*. Rural-urban and gender differences in metabolic syndrome in the aging population from southern india: two parallel, prospective cohort studies. *EClinicalMedicine* 2022;47:101395.
43 Mercer S, Salisbury C, Fortin M. *ABC of multimorbidity*. John Wiley & Sons, 2014.
44 Barnett K, Mercer SW, Norbury M, *et al*. Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet* 2012;380:37–43.
45 Liaw F-Y, Kao T-W, Wu L-W, *et al*. Components of metabolic syndrome and the risk of disability among the elderly population. *Sci Rep* 2016;6:22750.
46 He K, Zhang W, Hu X, *et al*. Relationship between multimorbidity, disease cluster and all-cause mortality among older adults: a retrospective cohort analysis. *BMC Public Health* 2021;21:1080.
47 Dunlop DD, Manheim LM, Song J, *et al*. Incidence of disability among preretirement adults: the impact of depression. *Am J Public Health* 2005;95:2003–8.
48 Hybels CF, Pieper CF, Blazer DG, *et al*. Trajectories of mobility and IADL function in older patients diagnosed with major depression. *Int J Geriatr Psychiatry* 2010;25:74–81.
49 Hajek A, König H-H. Longitudinal predictors of functional impairment in older adults in Europe -- evidence from the survey of health, ageing and retirement in Europe. *PLoS One* 2016;11:e0146967.
50 Callahan CM, Kroenke K, Counsell SR, *et al*. Treatment of depression improves physical functioning in older adults. *J Am Geriatr Soc* 2005;53:367–73.
51 Farmer ME, Locke BZ, Mościcki EK, *et al*. Physical activity and depressive symptoms: the NHANES I epidemiologic follow-up study. *Am J Epidemiol* 1988;128:1340–51.
52 Elliott R, Sahakian BJ, McKay AP, *et al*. Neuropsychological impairments in unipolar depression: the influence of perceived failure on subsequent performance. *Psychol Med* 1996;26:975–89.
53 Mazure CM, Maciejewski PK, Jacobs SC, *et al*. Stressful life events interacting with cognitive/personality styles to predict late-onset major depression. *Am J Geriatr Psychiatry* 2002;10:297–304.
54 Covinsky KE, Lindquist K, Dunlop DD, *et al*. Effect of arthritis in middle age on older-age functioning. *J Am Geriatr Soc* 2008;56:23–8.
55 Krishnamoorthy Y, Rajaa S, Murali S, *et al*. Prevalence of metabolic syndrome among adult population in India: a systematic review and meta-analysis. *PLoS One* 2020;15:e0240971.
56 Kshatri JS, Palo SK, Bhoi T, *et al*. Prevalence and patterns of multimorbidity among rural elderly: findings of the AHSETS study. *Front Public Health* 2020;8:582663.
57 Fisher K, Griffith LE, Gruneir A, *et al*. Functional limitations in people with multimorbidity and the association with mental health conditions: baseline data from the Canadian longitudinal study on aging (CLSA). *PLoS One* 2021;16:e0255907.
58 Schäfer I, von Leitner E-C, Schön G, *et al*. Multimorbidity patterns in the elderly: a new approach of disease clustering identifies complex interrelations between chronic conditions. *PLoS One* 2010;5:e15941.
59 Stenholm S, Westerlund H, Head J, *et al*. Comorbidity and functional trajectories from midlife to old age: the health and retirement study. *J Gerontol A Biol Sci Med Sci* 2015;70:332–8.