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Interaction of physical activity on the association of obesity-related measures with multimorbidity among older adults: a population-based cross-sectional study in India

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ABSTRACT

Objective To explore the associations between obesity-related measures and multimorbidity among older Indian adults and the interactive effects of physical activity in those associations.

Design A cross-sectional study was conducted using large representative survey data.

Setting and participants The present study used data from the Longitudinal Aging Study in India (LASI) conducted during 2017–2018. Participants included 15 098 male and 16 366 female older adults aged 60 years and above in India.

Primary and secondary outcome measures The outcome variable was multimorbidity among older adults coded as no and yes. Descriptive statistics along with bivariate analysis are presented in the paper. Additionally, binary logistic regression analysis was used to fulfil the study objectives.

Results About 24% of older adults in the LASI cohort suffered from multimorbidity. Older adults who were overweight/obese (adjusted OR (AOR): 1.61, CI 1.48 to 1.74), had high-risk waist circumference (AOR: 1.66, CI 1.52 to 1.80) and had high-risk waist to hip ratio (AOR: 1.45, CI 1.33 to 1.59) were significantly more likely to suffer from multimorbidity compared with their counterparts. Older adults who were obese and physically inactive had significantly increased odds of suffering from multimorbidity compared with older adults who were obese and physically active. Similarly, older adults with high-risk waist circumference (AOR: 1.30, CI 1.11 to 1.53) and high-risk waist to hip ratio (AOR: 1.32, CI 1.20 to 1.46) along with being physically inactive had significantly higher odds of suffering from multimorbidity in comparison with older adults with high-risk waist circumference and waist to hip ratio along with being physically active.

Conclusion While developing health strategies for older adults, physical activity needs to be recognised as a way of minimising comorbidities. Further, the study highlights the importance of using multiple obesity-related measures to predict chronic conditions in the older population.

Strengths and limitations of this study

- ► The study used a large nationally representative sample of older population.
- ► Objectively measured obesity-related information has been used in the study.
- ► The cross-sectional design is a limitation of the study as it is impossible to establish the observed directions of the relationships.
- ► The study used a relatively simple definition of counting diseases for measuring multimorbidity.

BACKGROUND

Considering the demographic shift towards population ageing in India, the share of people aged 60 and above is projected to increase from 8.6% in 2011 to 20% in 2050.[1] India's demographic structure is likely to shift from a young to an ageing population beyond the 2030's.[2] On the other hand, the prevalence of overweight and obesity among adults worldwide has risen from approximately 27.5% in 1980 to 39% in 2016.[3] Although the prevalence of overweight/obesity is comparatively lower among older adults than the 18–55 age groups, the increasing trend in the prevalence of overweight/obesity over the past four decades is similar among both age groups.

Traditionally healthcare delivery was built and remained typically centred on the treatment of single diseases. Over the past few decades on-site of the demographic and epidemiological transition, the growing number of elderly has become a considerable challenge to healthcare delivery as more than half of the elderly have at least two chronic conditions.[4 5] The WHO defines multimorbidity as 'the coexistence of two or more chronic conditions in the same individual'.[6] Changes in lifestyle and behavioural factors and inactivity and overeating result in impaired body systems functions and culminate in multimorbidity and increased

incidence of non-communicable diseases, including cardiovascular diseases, obesity, diabetes and cancer.[7 8]

The negative impacts of overweight/obesity on cardiovascular diseases, diabetes, hypertension and multimorbidity are well studied[9 10] and accounted for 4.0 million deaths globally.[11] Again, deprivation and health behaviours are significant predictors of multimorbidity. The public health efforts to modify the social determinants and foster healthy lifestyles can minimise the risk of multimorbidity.[12] The increased risk of multimorbidity in young adults and the growing numbers of elderly may contribute to the health and social care burden in the coming years.[13] Sufficient physical activity across the life course is the key requirement for healthy ageing and a predictor of reduced mortality.[14 15] It is widely recognised that the immune system is influenced by physical activity.[16] Increased inactivity across the lifespan due to lifestyle changes and decline in physical activity with ageing might reduce immunity in old ages.[8]

Several studies have highlighted the association between physical activity and overweight/obesity among older adults.[17–20] Physical inactivity and impaired physical mobility are the primary reasons for overweight/obesity among the elderly due to decreased metabolic rate and body composition changes.[21 22] Physical inactivity and poor health behaviours like obesity are major risk factors common to several diseases.[23] Regular physical activity is known to improve life quality, prevent various chronic diseases and reduce risk of premature death.[24–26] Studies also suggest that better physical activity could be the key to improving outcomes for older adults with multimorbidity. Physical activity should be promoted as an essential strategy to mitigate the growing burden of multimorbidity among older adults globally. Fulfilling the needs for healthcare services, physical activity, social protection for the elderly, protecting their rights and enabling them to contribute to the development process should be priorities in India's coming years.

Furthermore, previous studies revealed that multimorbidity is associated with sociodemographic characteristics such as age, sex, residence and economic status. In developed countries, multimorbidity is more prevalent among lower socioeconomic groups,[4 27] while in the context of a developing country multimorbidity is more among the wealthier.[28 29] Studies show that women and older adults have a higher chance of multimorbidity than men and younger adults.[28 30 31] Like socioeconomic status, there was an assumption that the multimorbidity burden exists only in developed and industrialised countries. Yadav and Arokiasamy[32] demonstrated the burden of multimorbidity as a major health concern especially in lower-middle-income countries, where social, behavioural and lifestyle patterns are altered with rising levels of urbanisation and industrialisation. Evidence shows the urban place of residence is associated with risk of multimorbidity.[28 33]

No previous study has looked into the interactions between physical activity, obesity measures and associated multimorbidity among older adults in the Indian context to the best of our knowledge. This study using the latest available data may provide new insights on this demanding area and highlight the relative merits of strategies to encourage physical activity among older adults. Thus, the present study explores the associations between obesity measures, physical activity and multimorbidity among older Indian adults using large nationally representative data.

MATERIALS AND METHODS

The present study used data from the Longitudinal Aging Study in India (LASI) baseline wave (wave 1) conducted during 2017–2018 in India. The survey is a joint undertaking of the Harvard TH Chan School of Public Health, the International Institute for Population Sciences and the University of Southern California. The nationally representative longitudinal survey collects vital information on the physical, social and cognitive well-being of India's older adults, which will be followed up for 25 years. The data of over 72 000 individuals aged 45 and above along with their spouses (irrespective of age) are collected across all states and union territories of India. The sample is based on a multistage stratified cluster sample design, including three and four distinct stages of rural and urban area selection, respectively. The survey provides scientific insights and facilitates a harmonised design which helps in comparing with parallel international studies. Further, the details of sample design, survey instruments, fieldwork, data collection and processing, and response rates are publicly available in the LASI report found on the LASI website.[34]

Participants of the study consist of 15 098 male and 16 366 female older adults aged 60 years and above in India. Further, the sample of overweight and high-risk waist circumference and waist to hip ratio may differ from the total sample as some of the older adults did not provide consent for measurements.[34] The survey agencies that conducted the field survey for data collection have collected prior consent from the respondents.

Variable description

Outcome description

The outcome variable was coded as binary, that is, multimorbidity (no/yes). Multimorbidity conditions refer to the presence of two or more chronic diseases, which include hypertension, chronic heart diseases, stroke, any chronic lung disease, diabetes, cancer or malignant tumour, any bone/joint disease, neurological/psychiatric disease, or high cholesterol.[34] The diseases were self-reported,[35] as assessed using the question 'Has any health professional ever diagnosed you with the following chronic conditions or diseases?'

Explanatory variables

The variables controlled for in the present study were taken into consideration after an extensive literature review. Overweight/obesity was categorised as no and

yes. Respondents with a body mass index of 25 and above were categorised as obese/overweight. High-risk waist circumference was categorised as no and yes.[36] Male and female respondents who have waist circumferences of more than 102 cm and 88 cm, respectively, were considered to have high-risk waist circumference.[37] High-risk waist to hip ratio was categorised as no and yes. Male and female respondents who have a waist to hip ratio of more than or equal to 0.90 and 0.85 cm, respectively, were considered to have a high-risk waist to hip ratio.[37] Physical activity status was categorised as frequent (every day), rare (more than once a week, once a week, one to three times in a month) and never. The question through which physical activity was assessed was 'How often do you take part in sports or vigorous activities, such as running or jogging, swimming, going to a health center or gym, cycling, or digging with a spade or shovel, heavy lifting, chopping, farm work, fast bicycling, cycling with loads?'

Age was categorised as young old (60–69 years), old-old (70–79 years) and oldest-old (80+ years). Education was categorised as no education/primary schooling not completed, primary completed, secondary completed, and higher and above. Marital status was categorised as currently married, widowed and others (separated/never married/divorced). Working status was categorised as working, retired and not working. Tobacco and alcohol consumption was coded as no and yes.

The monthly per capita consumption expenditure (MPCE) quintile was measured using household consumption data. Sets of 11 and 29 questions on the expenditures on food and non-food items, respectively, were used to canvas the sample households. Food expenditure was collected based on a reference period of 7 days, and non-food expenditure was collected based on reference periods of 30 days and 365 days. Food and non-food expenditures have been standardised to the 30-day reference period.[34] The monthly per capita consumption expenditure is computed and used as the summary measure of consumption. The variable was then divided into five quintiles, that is, from poorest to richest. Religion was categorised as Hindu, Muslim, Christian and Others. Caste was categorised as Scheduled Tribe, Scheduled Caste, Other Backward Class and others. The Scheduled Caste includes the 'untouchables', a group of population that is socially segregated and financially/economically by their low status as per Hindu caste hierarchy. The Scheduled Caste and Scheduled Tribe are among the most disadvantaged socioeconomic groups in India. The Other Backward Class is the group of people who were identified as 'educationally, economically and socially backward'. The Other Backward Class is considered low in the traditional caste hierarchy but is not considered untouchables. The 'other' caste category is identified as having higher social status. Place of residence was categorised as rural and urban. Region was categorised as North, Central, East, Northeast, West and South.

Statistical analysis

Descriptive statistics along with bivariate analysis are presented in the paper. χ^2 test was used to compare the intergroup differences and report the significance level.[38 39] Additionally, binary logistic regression analysis[40] was used to establish the association between outcome variable (multimorbidity) and other explanatory variables.

The binary logistic regression model is usually put into a more compact form as follows:

$$\text{Logit}\ \left[\mathrm{P}\left(\mathrm{Y}=1\right)\right]=\beta_0+\beta*X+\ \epsilon$$

The parameter β_0 estimates the log odds of the multimorbidity for the reference group, while β estimates the maximum likelihood, the differential log odds of the multimorbidity associated with a set of predictors X, as compared with the reference group, and ϵ represents the residual in the model.

The multivariate analysis had four models to explain the adjusted estimates. Model 1 provides the adjusted estimates for the control variables. Model 2, model 3 and model 4 provide the interaction effects[41 42] for obesity indicator and physical activity status with multimorbidity among older adults. An 'interaction variable' is a variable constructed from an original set of variables to try to represent either all of the interaction present or some part of it. In exploratory statistical analyses, it is common to use products of original variables as the basis of testing whether the interaction is present, with the possibility of substituting other more realistic interaction variables at a later stage. When there are more than two explanatory variables, several interaction variables are constructed, with pairwise products representing pairwise interactions and higher-order products representing higher-order interactions.[41–44]

Thus, for a response Y and two variables x_1 and x_2 an *additive* model would be:

$$\mathrm{Y}=\alpha+\beta_1 x_1+\beta_2 x_2+\varepsilon_0$$

In contrast to this,

$$\mathrm{Y}=\alpha+\beta_1 x_1+\beta_2 x_2+(\beta_3 x_s * x_a)\ \varepsilon_0$$

where Y is the dependent variable (multimorbidity) and α is intercept, x_1 is individual-level independent variable, x_2 is individual-level independent variable, x_a is obesity indicator, x_s is physical activity, $(\beta_3 x_s * x_a)$ is the interaction of obesity indicator and psychical activity, and ε_0 is error. Often, models are presented without the interaction term d $(x_1 * x_2)$, but this confounds the main effect and the interaction effect (ie, without specifying the interaction term, it is possible that any main effect found is actually due to interaction).[45]

Patient and public involvement

No patients were involved.

RESULTS

Table 1 presents the sociodemographic and economic profile of older adults in the LASI cohort. The table reveals that about one-fifth of the older adults were

Table 1 Sociodemographic and economic profile of older adults in the LASI cohort, India

Background characteristics	Sample	%
Obese/overweight*		
No	21 833	77.8
Yes	6217	22.2
High-risk waist circumference*		
No	21 399	76.3
Yes	6651	23.7
High-risk waist to hip ratio*		
No	6434	23
Yes	21 593	77
Physical activity status		
Frequent	5651	18
Rare	4023	12.8
Never	21 790	69.3
Age (in years)		
Young-old	18 410	58.5
Old-old	9501	30.2
Oldest-old	3553	11.3
Sex		
Male	14 931	47.5
Female	16 533	52.6
Education		
No education/primary not completed	21 380	68
Primary completed	3520	11.2
Secondary completed	4371	13.9
Higher and above	2191	7
Marital status		
Currently married	19 391	61.6
Widowed	11 389	36.2
Others	684	2.2
Working status		
Working	9680	30.8
Retired	13 470	42.8
Not working	8314	26.4
Tobacco consumption		
No	18 964	60.3
Yes	12 500	39.7
Alcohol consumption		
No	26 924	85.6
Yes	4540	14.4
MPCE quintile		
Poorest	6829	21.7
Poorer	6831	21.7
Middle	6590	21
Richer	6038	19.2
Richest	5175	16.5
Religion		
Hindu	25 871	82.2
Muslim	3548	11.3
Christian	900	2.9
Others	1145	3.6
Caste		
Scheduled Caste	5949	18.9
Scheduled Tribe	2556	8.1
Other Backward Class	14 231	45.2
Others	8729	27.7
Place of residence		
Rural	22 196	70.6
Urban	9268	29.5
Region		
North	3960	12.6
Central	6593	21
East	7439	23.6
Northeast	935	3
West	5401	17.2
South	7136	22.7
Total	31 464	100

*The sample may differ as all older adults did not give consent for measurements.
LASI, Longitudinal Aging Study in India; MPCE, monthly per capita consumption expenditure.

overweight/obese. Nearly, a quarter of the older adults had high-risk waist circumference, while about 8 in 10 older adults had high-risk waist to hip ratio. Around 69% of older adults never did physical activity, while only 18% did frequent physical activities. Around 62% of older adults were currently married and 36% were widowed. In the working status category, about 43% of older adults were retired, while around 31% were presently working. Older adults who consumed tobacco and alcohol were around 40% and 14%, respectively.

Table 2 shows the percentage of older adults suffering from multimorbidity in the LASI cohort. It was found that nearly 43% of older adults who were overweight/obese had multimorbidity. About 42% and 26% of older adults who had high-risk waist circumference and high-risk waist to hip ratio, respectively, were suffering from multimorbidity. About 27% of older adults who never did physical activities had multimorbidity. The status of multimorbidity among older adults showed an increasing trend with rising educational status. About 26% of older adults who were widowed were suffering from multimorbidity. The share of older adults suffering from multimorbidity was directly proportional to the MPCE quintile. Among the religious groups, the share of older adults suffering from multimorbidity was highest and lowest among Christians

Table 2 Percentage of older adults suffering from multimorbidity in the LASI cohort, India

Background characteristics	%	P value
Obese/overweight		0.001
No	18.4	
Yes	42.6	
High-risk waist circumference		0.001
No	18.1	
Yes	42.1	
High-risk waist to hip ratio		0.001
No	16.2	
Yes	26	
Physical activity status		0.001
Frequent	17	
Rare	15.8	
Never	27.2	
Age (in years)		0.001
Young-old	22.8	
Old-old	25.8	
Oldest-old	24.5	
Sex		0.001
Male	22.2	
Female	25.4	
Education		0.001
No education/primary not completed	19.7	
Primary completed	30.1	
Secondary completed	33.6	
Higher and above	35.2	
Marital status		0.044
Currently married	23.1	
Widowed	25.6	
Others	18.9	
Working status		0.001
Working	13.6	
Retired	26.9	
Not working	30.9	
Tobacco consumption		0.001
No	26.7	
Yes	19.6	
Alcohol consumption		0.001
No	24.6	
Yes	19.8	
MPCE quintile		0.001
Poorest	16.6	
Poorer	20.2	
Middle	22.2	
Richer	27.9	
Richest	35.9	
Religion		0.001
Hindu	23.2	
Muslim	26	
Christian	31.2	
Others	27.6	
Caste		0.001
Scheduled Caste	19.5	
Scheduled Tribe	11.1	
Other Backward Class	24.9	
Others	29	
Place of residence		0.001
Rural	19.1	
Urban	35.4	
Region		0.001
North	24.4	
Central	13.5	
East	22.9	
Northeast	16	
West	27.7	
South	32.4	
Total	24	

P value based on χ^2 test.
LASI, Longitudinal Aging Study in India; MPCE, monthly per capita consumption expenditure.

(31%) and Hindus (23%), respectively. Older adults from Scheduled Tribe (11.1%) suffered from the lowest share of multimorbidity among all the caste groups. Among the regions of India, South India (32%) recorded the highest share of older adults suffering from multimorbidity, while Central India (14%) recorded the lowest share. Overall about 24% of older adults in the LASI cohort suffered from multimorbidity.

Table 3 shows a representation of the logistic regression of older adults who were suffering from multimorbidity. It was found that older adults who were overweight/obese were 61% significantly more likely to have multimorbidity in comparison with those who were not overweight/obese (adjusted OR (AOR): 1.61, CI 1.48 to 1.74). Older adults with high-risk waist circumference and high-risk waist to hip ratio were 66% (AOR: 1.66, CI 1.52 to 1.80) and 45% (AOR: 1.45, CI 1.33 to 1.59) significantly more likely to suffer from multimorbidity, respectively, in reference to those who do not have high-risk waist circumference and high-risk waist to hip ratio, respectively. The odds of multimorbidity were significantly higher among older adults who were physically inactive in reference to older adults who were physically active (AOR: 1.33, CI 1.21 to 1.46). The likelihood of multimorbidity among women was significantly low in comparison with men (AOR: 0.86,

Table 3 Logistic regression estimates for multimorbidity among older adults in the LASI cohort, India

Background characteristics	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)	Model 4 AOR (95% CI)
Obese/overweight				
No	Ref		Ref	Ref
Yes	1.61* (1.48 to 1.74)		1.61* (1.48 to 1.74)	1.60* (1.48 to 1.74)
High-risk waist circumference				
No	Ref	Ref		Ref
Yes	1.66* (1.52 to 1.8)	1.66* (1.52 to 1.81)		1.66* (1.52 to 1.81)
High-risk waist to hip ratio				
No	Ref	Ref	Ref	
Yes	1.45* (1.33 to 1.59)	1.45* (1.33 to 1.59)	1.45* (1.33 to 1.59)	
Physical activity status				
Frequent	Ref			
Rare	1.03 (0.91 to 1.16)			
Never	1.33* (1.21 to 1.46)			
Age (in years)				
Young-old	Ref	Ref	Ref	Ref
Old-old	1.26* (1.17 to 1.34)	1.25* (1.17 to 1.34)	1.26* (1.17 to 1.34)	1.26* (1.17 to 1.34)
Oldest-old	1.10 (0.99 to 1.22)	1.09 (0.98 to 1.22)	1.10 (0.98 to 1.22)	1.10 (0.99 to 1.22)
Sex				
Male	Ref	Ref	Ref	Ref
Female	0.86* (0.79 to 0.94)	0.86* (0.79 to 0.94)	0.86* (0.79 to 0.94)	0.86* (0.79 to 0.94)
Education				
No education/primary not completed	Ref	Ref	Ref	Ref
Primary completed	1.27* (1.16 to 1.4)	1.27* (1.16 to 1.4)	1.28* (1.16 to 1.4)	1.28* (1.16 to 1.4)
Secondary completed	1.29* (1.18 to 1.41)	1.29* (1.18 to 1.41)	1.29* (1.18 to 1.41)	1.29* (1.18 to 1.41)
Higher and above	1.24* (1.1 to 1.39)	1.24* (1.1 to 1.39)	1.24* (1.1 to 1.39)	1.24* (1.1 to 1.39)
Marital status				
Currently married	Ref	Ref	Ref	Ref
Widowed	0.97 (0.9 to 1.04)	0.97 (0.9 to 1.04)	0.97 (0.9 to 1.04)	0.97 (0.9 to 1.04)
Others	0.81* (0.67 to 0.99)	0.81* (0.67 to 0.99)	0.81* (0.67 to 0.99)	0.81* (0.67 to 0.99)
Working status				
Working	Ref	Ref	Ref	Ref
Retired	1.79* (1.64 to 1.94)	1.78* (1.64 to 1.94)	1.78* (1.64 to 1.94)	1.79* (1.64 to 1.94)
Not working	1.77* (1.6 to 1.96)	1.76* (1.59 to 1.95)	1.77* (1.6 to 1.96)	1.77* (1.6 to 1.96)
Tobacco consumption				
No	Ref	Ref	Ref	Ref
Yes	1.01 (0.94 to 1.09)	1.01 (0.94 to 1.09)	1.01 (0.94 to 1.09)	1.01 (0.94 to 1.09)
Alcohol consumption				
No	Ref	Ref	Ref	Ref
Yes	1.04 (0.95 to 1.14)	1.04 (0.95 to 1.14)	1.04 (0.95 to 1.14)	1.04 (0.95 to 1.14)
MPCE quintile				
Poorest	Ref	Ref	Ref	Ref
Poorer	1.23* (1.11 to 1.36)	1.23* (1.11 to 1.36)	1.23* (1.11 to 1.36)	1.23* (1.11 to 1.36)
Middle	1.39* (1.26 to 1.53)	1.39* (1.26 to 1.53)	1.39* (1.26 to 1.53)	1.39* (1.26 to 1.53)
Richer	1.60* (1.45 to 1.77)	1.60* (1.45 to 1.77)	1.60* (1.45 to 1.77)	1.60* (1.45 to 1.77)
Richest	1.98* (1.79 to 2.19)	1.98* (1.79 to 2.19)	1.98* (1.79 to 2.19)	1.98* (1.79 to 2.19)
Religion				

Continued

Table 3 Continued

Background characteristics	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)	Model 4 AOR (95% CI)
Hindu	Ref	Ref	Ref	Ref
Muslim	1.32* (1.21 to 1.45)	1.32* (1.21 to 1.45)	1.33* (1.21 to 1.45)	1.32* (1.21 to 1.45)
Christian	1.20* (1.06 to 1.36)	1.20* (1.06 to 1.36)	1.20* (1.06 to 1.36)	1.20* (1.06 to 1.36)
Others	1.12 (0.97 to 1.29)	1.12 (0.98 to 1.29)	1.12 (0.97 to 1.29)	1.12 (0.97 to 1.29)
Caste				
Scheduled Caste	Ref	Ref	Ref	Ref
Scheduled Tribe	0.67* (0.59 to 0.77)	0.67* (0.59 to 0.77)	0.67* (0.59 to 0.77)	0.67* (0.59 to 0.77)
Other Backward Class	1.02 (0.93 to 1.12)	1.02 (0.93 to 1.12)	1.02 (0.93 to 1.12)	1.02 (0.93 to 1.12)
Others	1.10* (1.00 to 1.22)	1.10* (1.00 to 1.22)	1.10* (1.00 to 1.22)	1.10* (1.00 to 1.22)
Place of residence				
Rural	Ref	Ref	Ref	Ref
Urban	1.43* (1.34 to 1.53)	1.43* (1.34 to 1.53)	1.43* (1.34 to 1.53)	1.43* (1.34 to 1.53)
Region				
North	Ref	Ref	Ref	Ref
Central	0.71* (0.63 to 0.8)	0.71* (0.63 to 0.8)	0.71* (0.63 to 0.8)	0.71* (0.63 to 0.8)
East	1.21* (1.09 to 1.33)	1.2* (1.09 to 1.33)	1.21* (1.09 to 1.33)	1.21* (1.09 to 1.34)
Northeast	0.72* (0.63 to 0.83)	0.72* (0.63 to 0.83)	0.72* (0.63 to 0.83)	0.72* (0.63 to 0.83)
West	1.42* (1.28 to 1.58)	1.42* (1.28 to 1.58)	1.42* (1.28 to 1.58)	1.42* (1.28 to 1.58)
South	1.88* (1.71 to 2.07)	1.88* (1.71 to 2.07)	1.88* (1.71 to 2.07)	1.88* (1.71 to 2.07)
Obese/overweight × physical activity status				
Yes × frequent		Ref		
No × frequent		0.55* (0.46 to 0.66)		
No × rare		0.59* (0.49 to 0.7)		
No × never		0.77* (0.66 to 0.9)		
Yes × rare		0.97 (0.79 to 1.2)		
Yes × never		1.21* (1.04 to 1.4)		
High-risk waist circumference × physical activity status				
Yes × frequent			Ref	
No × frequent			0.59* (0.49 to 0.71)	
No × rare			0.59* (0.49 to 0.72)	
No × never			0.80* (0.68 to 0.94)	
Yes × rare			1.10 (0.88 to 1.38)	
Yes × never			1.30* (1.11 to 1.53)	
High-risk waist to hip ratio × physical activity status				
Yes × frequent				Ref
No × frequent				0.68* (0.54 to 0.84)
No × rare				0.61* (0.47 to 0.79)
No × never				0.94 (0.82 to 1.07)
Yes × rare				1.06 (0.93 to 1.20)
Yes × never				1.32* (1.20 to 1.46)

'×' means interaction.
*If p<0.05.
AOR, adjusted OR; LASI, Longitudinal Aging Study in India; MPCE, monthly per capita consumption expenditure; Ref, reference.

CI 0.79 to 0.94). The odds of multimorbidity were significantly higher among older adults who were not working in reference to older adults who were currently working (AOR: 1.77, CI 1.6 to 1.96).

Surprisingly, the odds of multimorbidity were 98% significantly more likely among older adults who were from the richest MPCE quintile in reference to older adults who belonged to the poorest MPCE quintile (AOR:

1.98, CI 1.79 to 2.19). Older adults who were from the Scheduled Tribe category were 33% significantly less likely to suffer from multimorbidity in comparison with older adults who were from the Scheduled Caste category (AOR: 0.67, CI 0.59 to 0.77). Older adults residing in urban areas were 43% significantly more likely to suffer from multimorbidity in reference to older adults residing in rural areas (AOR: 1.43, CI 1.34 to 1.53). The odds of multimorbidity were significantly higher among older adults of the southern region as compared with older adults of the northern region (AOR: 1.88, CI 1.71 to 2.07). Older adults who were obese and were physically inactive were 21% significantly more likely to suffer from multimorbidity in reference to older adults who were obese and were physically active (AOR: 1.21, CI 1.04 to 1.4). Older adults with high-risk waist circumference and physically inactive status had a 30% significantly higher likelihood of suffering from multimorbidity in comparison with older adults with high-risk waist circumference and physically active status (AOR: 1.30, CI 1.11 to 1.53). Older adults with a high-risk waist to hip ratio and physically inactive status had a 32% significantly higher likelihood of suffering from multimorbidity in comparison with older adults with a high-risk waist to hip ratio and physically active status (AOR: 1.32, CI 1.20 to 1.46).

DISCUSSION

Based on a large nationally representative sample of older Indian adults aged 60 and above, the present study has shown the associations between several anthropometric measures and multimorbidity in later years of life. It also examined the interactive effect of physical activity in those associations. The results were statistically significant even after adjusting for a wide range of variables in the study. The higher prevalence of multimorbidity among older men than women was contrary to earlier studies that found a female disadvantage in the co-occurrence of multiple diseases.[46 47] This differential can be explained by the survival bias that suggests that women who survive may have a better health condition than men who have a shorter life expectancy.[48]

In concordance with a growing body of research that is based on several cross-sectional as well as longitudinal data sets, in the present study, lack of physical activity was associated with a higher likelihood of multimorbidity.[49–51] There is also a likely reverse causal pathway by which chronic conditions contribute to physical inactivity, increasing the risk of sedentary lifestyles, which in turn could increase the risk of additional chronic conditions such as raised cholesterol and diabetes, producing a vicious cycle between multimorbidity and physical inactivity. On the other hand, results of the study on other unhealthy lifestyle factors such as smoking and alcohol consumption showing no association with multimorbidity are at variance with multiple studies that found smoking habit and drinking as risk factors for the simultaneous presence of two-plus chronic conditions.[52–54] The finding, however, concurs with a recent study that found an association of smoking and alcohol drinking only in combination with other lifestyle factors.[55]

Of the risk factors examined, obesity/overweight, high-risk waist circumference and high-risk waist to hip ratio were also associated with multimorbidity. Consistent with previous studies, multimorbidity was reported more often by older adults whose obesity-related anthropometric measures were found to be at risk.[56–58] Further, waist to hip ratio and waist circumference are shown to be more sensitive among several anthropometric indices of obesity while screening for multimorbidity.[59–61] The present study, in line with earlier studies, found a positive association between both measures and multimorbidity.[37] Thus, results confirm the association of obesity-related anthropometric measures with multimorbidity that has been repeatedly shown in previous studies.[49 62 63] Although we have adjusted for many of the sociodemographic and lifestyle variables to minimise reverse causality, it is possible to construct a reverse relationship of multimorbidity being the cause of overweight/obesity. Hence, future prospective longitudinal studies are required to identify causality.

Besides, studies have revealed the independent associations of obesity and other related high-risk body measures with physical inactivity.[64–67] Results of the statistical tests on interactions of obesity-related measures with physical activity in our study show that multimorbidity was more prevalent among older adults who were obese/overweight or at risk of waist to hip ratio and waist circumference with non-performance of any physical activity. The findings of the current analysis which apply to an older population of a developing country highlight the urgent need for further investigation of the effectiveness of physical activity in the management of chronic diseases in low-income and middle-income countries.

Further, the association between multimorbidity and age is well documented in the literature. Consistently, the current analysis shows that a higher age group is a risk factor for multimorbidity and supports the notion that the additional life years may constitute an increased chance of acquiring other chronic conditions.[23 46] With respect to socioeconomic patterning of multimorbidity, there are inconsistencies in developing countries regarding whether it is concomitant to the wealthy with a lesser impact on the poor or present among the population across all the socioeconomic spectrum.[30 68–70] However, the present study found that multimorbidity tends to be higher among individuals with higher levels of education, belonging to households with higher wealth quintiles and non-Scheduled Caste/Scheduled Tribe. The finding is consistent with previous studies that have shown statistically significant positive associations between socioeconomic variables such as education, household wealth and higher social groups and the prevalence of multimorbidity.[71]

The strengths of the present study include the large nationally representative sample of older population and objective obesity-related measures. There were also some

limitations. First, the cross-sectional design of the study makes it impossible to establish the observed directions of the relationships. Another limitation of the study is that it uses a relatively simple definition of counting diseases for measuring multimorbidity compared with previous studies.[72–74] Similarly, lifestyle factors were self-reported in the survey data and thus susceptible to measurement error. Also, overweight and obese are not split as separate categories due to relatively small sample size in the latter category and as also found in some other studies.[75] Finally, as a limitation for physical activity, the descriptors to assess activity in the present study do not include many female biased categories such as various aspects of housework, and the data for women may overestimate the never or rare category in the current analyses.

CONCLUSION

The high prevalence of multimorbidity implies the need for a holistic approach beyond the management of individual diseases. Given that multimorbidity results in substantial life years lost, for increased quality life years in the older ages it is necessary to understand how to manage co-occurring morbidities simultaneously. While developing health strategies for older adults, physical activity needs to be recognised as a way of minimising comorbidities. Further, the study highlights the importance of using multiple obesity-related measures to predict chronic conditions in the older population.

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