STATISTICAL MODELLING FOR PREDICTING MULTI-MORBIDITY AMONG ELDERLY POPULATION IN KERALA

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Abstract

Context/Background: General improvement in healthcare facilities over the years is one of the main reasons for the continuing increase in the proportion of elders. Increased life expectancy will lead to multi-morbidity that affects most of the individuals in the productive age group as well as those who are aged.
Aims/Objectives: To determine the prevalence and predictors of multi-morbidity among elderly population in Kerala with its variation among socio-demographic spectrum and health behaviours.
Methodology: Elderly Population aged > 60 years was used to examine multi-morbidity and its associated risk factors. Statistical Analysis: Chi-square test and Binary logistic regression analysis were employed to find the association and also to identify the risk factors of developing multi-morbidity. Receiver Operating Characteristic (ROC) Curve Analysis was carried out to detect the cut-off probability giving an equalized classification of multi-morbidity and non-multi-morbidity for the Logistic Regression Model.
Results: The prevalence of multi-morbidity in Kerala was found to be 51%. The major risk factors causing multi-morbidity among elderly in Kerala were gender, religion, caste etc.
Conclusions: Prediction percentages in Kerala revealed a greater risk of multi-morbidity which was more among the vulnerable groups of the population. Later Years of life should be protected, promoted and prolonged.

Keywords: Prevalence, Aged population, Comorbidities, Geriatrics

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1. INTRODUCTION

General improvement in healthcare facilities over the years is one of the main reasons for the continuing increase in the proportion of the elders. Increasing longevity is accompanied by multiple morbidities (defined as co-existence of two or more chronic conditions) and has become progressively common for the older and elderly population. Multi-morbidity is a major public health problem that affects most of the individuals in the productive age group as well as those who are aged. Reduced physical activity, poor health status and quality of life, disabilities, problems associated with long-term illness such as chronic diseases, psychological problems, economic and social problems, increased hospital visits and mortality are the adverse outcomes due to the ageing process. A major challenge in taking care of the elders is to ensure that they do not merely live longer, but lead a secure, dignified and productive life. Giving careful attention to lifestyle factors can influence individual risk of developing many of the diseases of later life and thus promoting healthy ageing. The situation of Kerala, as far as population ageing is concerned, seems to be a catastrophic one. Kerala has the highest percentage of elderly population in India according to the Kerala Economic Review-2021.[1] In the context of population ageing in Kerala by Economic Review 2021 Volume 1 Govt. of Kerala, the percentage of population in the age group 60 years and above to the total population was 12.6 percent for Kerala against the national average of 8 percent, as per Census 2011.[1]This issue needs to be looked into for the Indian state of Kerala, which is undergoing a demographic transition towards an ageing population and also a special focus on multi-morbidity is necessary to be given to understand the health status of the elderly population. Thus, the present study was undertaken to determine the prevalence and predictors of multi-morbidity among elderly population in Kerala with its variation among socio-demographic spectrum and health behaviours.

2. MATERIALS AND METHODS

The data for the present study has been taken from the Longitudinal Ageing Study in India (LASI) wave 1 2017-18, which is the World's largest and India's first longitudinal ageing study. The sampling approach/design of the LASI study is a multistage stratified area probability cluster sampling approach.[2] For the proposed research, the request has been made and permission has been granted by the Director/ Principal Investigator (LASI Project), International Institute for Population Sciences (IIPS), Deonar, Mumbai for the use of LASI data.

Statistical Methods:

There was data of 1209 elderly population (aged 60 and above) in Kerala. From these data of 588 elders was extracted by eliminating subjects with missing data of pre-decided study parameters. Descriptive Study Design was used for the analysis. Univariate and Bivariate analyses such as frequency tables and cross-tabulations for all study variables were generated to identify the prevalence of multi-morbidity. Chi-square test was employed to find the association of independent variables with multi-morbidity. Logistic regression was performed to identify the risk factors of developing multi-morbidity and to identify modifiable factors, if any. Unadjusted and Adjusted Odds Ratios along with its 95% Confidence Interval for variables significantly contributing to the prediction of multi-morbidity determined to understand the risk of multi-morbidity in subjects with the presence of exposure to the event in comparison to subjects with absence of exposure to the event. Significance level of 5% ($P<0.05$) was used to find the statistically significant variables and these variables were used as predictor variables of multi-morbidity. Receiver Operating Characteristic (ROC) Curve Analysis was carried out to detect the cut-off probability giving an equalized classification of multi-morbidity and non-multi-morbidity for the Logistic Regression Model. The data was analysed by using the licensed copy of SPSS version 28.

Independent variables and Outcome variable:

The demographic parameters of the study population included Age, Gender, Religion, Caste, Place of Residence, Marital Status, Education, Living Arrangement, Socio-economic Parameters: Work Status and Monthly Per capita Consumption Expenditure (MPCE) Quintile, Health Behaviours: Tobacco consumption, Alcohol consumption, and Chronic Health Conditions: Chronic Heart Diseases, Diabetes mellitus, High Cholesterol, Hypertension, Stroke, Chronic Lung Diseases, Cancer, Bone or Joint diseases, Neurological or Psychiatric problems were extracted from LASI data sheet for the study purpose.[2] Multi-morbidity i.e. simultaneous presence of two or more chronic health conditions in an individual, was further identified. The parameter 'Multi-morbidity' was the Dependent Variable while other study variables were Independent Variables.

3. RESULTS AND DISCUSSION

Results:

Amongst 588 elders from Kerala, the prevalence of multi-morbidity was 51% i.e. more than half of the elderly population was found to be multi-morbid (Fig 1).

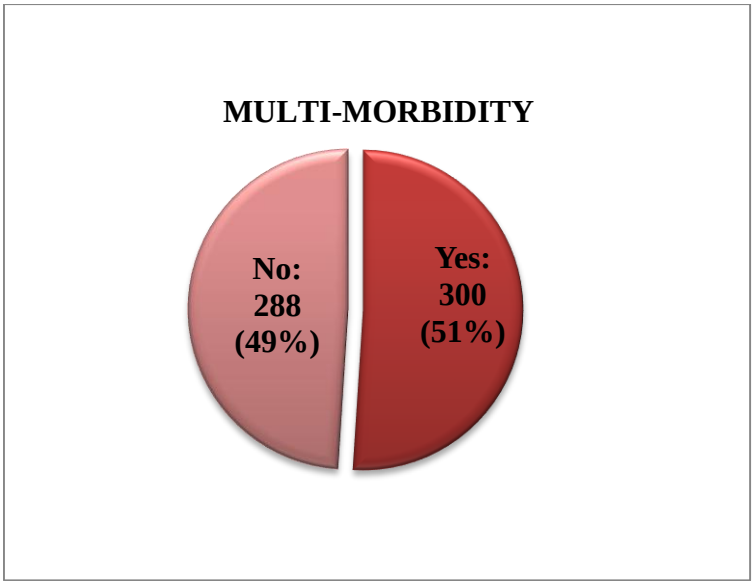

Fig 1: Prevalence of multi-morbidity in Elderly population of Kerala

Table 1 depicts the association of multi-morbidity with socio-demographic characteristics and health behaviours. Amongst 11 independent variables, Residence, Religion, Caste, Education, Alcohol and Tobacco consumption have no significant association with multi-morbidity. Whereas Gender, Living Arrangement, MPCE Quintile, Marital and Work status were found significantly associated with multi-morbidity. Unadjusted odds ratios and respective 95% Confidence Interval (CI) of these significantly associated independent variables revealed that: Females in comparison to males have a 1.47 times chance of getting multi-morbidity with 95% CI (1.015 – 2.130), those who stayed alone or with only spouse/children/others in comparison to those who were living with spouse and children, have 1.43 times chance of developing multi-morbidity with 95% CI (1.031 – 1.973). The chance of getting multi-morbidity among those who belong to the wealthiest MPCE Quintile was 1.56 times with 95% CI (1.124 – 2.156) when compared to those who belong to poor/middle MPCE Quintile. Marital status of the elderly population resulted that, those who are Never married/ Widowed/ Divorced had 1.53 times chance of developing multi-morbidity with 95% CI (1.023 – 2.291) in comparison to currently married while those who were not working have 3.39 times chance of getting multi-morbidity with 95% CI (2.272 – 5.054) when compared with those who were working.

Table 1: Multi-morbidity with socio-demographic characteristics and health behaviours among elderly

Characteristic	**Categories**	**Multi-morbidity**			**χ^2**	**P-value**
		Yes (300) n (%)	**No (288) n**	**Total (588)**		
Residence	Rural	158(50.5)	155	313	0.078	0.7794
	Urban	142(51.6)	133	275		
Religion	Hindu	171(48.2)	184	355	2.915	0.0878
	Muslim/Christian	129 (55.4)	104	233		
Caste	SC/ST/OBC	187 (51.5)	176	363	0.093	0.7605
	Open	113 (50.2)	112	225		
Gender	Male (Ref)	210 (48.5)	223	433	4.179	0.0409
	Female	90 (58.1)	65	155		

Living Arrangement	Living Alone or with Spouse/Children/Others	163(55.4)	131	294	4.601	0.0320
	Living with Spouse and Children (Ref)	137 (46.6)	157	294		
MPCE Quintile	Poor/Middle (Ref)	141 (45.8)	167	308	7.110	0.008
	Rich	159 (56.8)	121	280		
Marital Status	Never Married/Widow/ Divorced etc	73 (59.3)	50	123	4.318	0.0377
	Currently Married (Ref)	227(48.8)	238	465		
Education	Secondary/ Higher Education	114(52.1)	105	219	0.149	0.6991
	Secondary Education	186 (50.4)	183	369		
Work Status	Working (Ref)	44(29.3)	106	150	37.9	<0.001
	Not Working	256(58.4)	182	438		
Alcohol Consumption	Yes	111(55)	91	202	1.902	0.168
	No	189(49)	197	386		
Tobacco Consumption	Yes	127(52.5)	115	242	0.3503	0.5539
	No	173(50)	173	346		

MPCE, Monthly Per Capita Consumption Expenditure; Ref, Reference Category.

Backward logistic regression analysis (Table 2) was performed to find the predictors of multi-morbidity using 11 independent variables. Out of these 11 variables, Gender, MPCE Quintile, Alcohol, Work status, Religion and Caste were found significantly contributing to the prediction of multi-morbidity. Female elders had 2 times higher probability of getting multi-morbidity with 95 % CI (1.291 – 3.097) while elders who were in the wealthiest group have 1.76 times high chance of developing multi-morbidity with a 95 % CI (1.232 – 2.513). Those who were consuming alcohol have 1.71 times chance of getting multi-morbid with 95 % CI (1.145 – 2.547). Considering work status, elders who were not working found with 3.8 times higher chance of multi-morbidity with 95 % CI (2.495 – 5.775). Elders belonging to Muslim/Christian religion showed 1.51 times higher probability of having multi-morbidity with 95 % CI (1.05 – 2.186) while those who were ST/SC/OBC have 1.6 times chance of developing multi-morbidity with 95 % CI (1.079 – 2.294).

Table 2: Backward Logistic Regression model predicting Multi-morbidity

Independent Variable	**B**	**S.E.**	**Wald**	**Df**	**Sig.**	**Adjusted OR**	**95.0% C.I. for OR**	
							Lower	**Upper**
Gender (Female)	0.693	0.223	9.624	1	0.002	1.999	1.291	3.097
MPCE Quintile (Rich)	0.565	0.82	9.644	1	0.002	1.759	1.232	2.513
Alcohol (Yes)	0.535	0.204	6.873	1	0.009	1.707	1.145	2.547
Work status (Not Working)	1.334	0.214	38.826	1	0.00	3.796	2.495	5.775
Religion (Muslim/Christian)	0.415	0.187	4.936	1	0.026	1.515	1.05	2.186
Caste (ST/SC/OBC)	0.453	0.192	5.553	1	0.018	1.573	1.079	2.294
Constant	-2.046	0.319	41.042	1	0.00	0.129		

Sig., Significance; S.E., Standard Error; Df, Degrees of Freedom; OR, Odds Ratio; C.I, Confidence Interval; MPCE, Monthly Per Capita Consumption Expenditure.

The logistic regression model derived to determine the probability of multi-morbidity using these 6 significant independent variables is as follows:
1

$$P(\text{Multi-morbidity}) = \frac{1}{1 + e^{-(\beta o + \beta xi)}}$$

Where

β_0 = Constant = -2.046

β_{xi} = 0.693Gender + 0.565MPCEQ + 0.535Alcohol + 1.334Work status + 0.415Religion + 0.453Caste

The values for categories of independent variables in this model should be introduced as per given in table 3.

Table 3: Values of Categories of Independent Variables

Categorical Variables	Category	Coding Value
Gender	Male	0
	Female	1
MPCE Quintile	Poor/Middle	0
	Rich	1
Alcohol	No	0
	Yes	1
Work Status	Working	0
	Not Working	1
Religion	Hindu	0
	Muslim/Christian	1
Caste	SC/ST/OBC	1
	Open	0

MPCE, Monthly Per Capita Consumption Expenditure.

Table 4 shows the prediction or classification ability of the model based on 6 significant variables (Gender, MPCE Quintile, Alcohol consumption, work status, Religion and caste). It revealed that 71% of total multi-morbid participants correctly predicted that they had multi-morbidity while 55.6% of non-multi-morbid population was correctly predicted that they had no multi-morbidity. Thus, overall correct prediction percentage of model with these variables was 63.4% with cut-off probability 0.5; i.e.; if P≥0.5 Multi-morbidity was existing; Otherwise (P<0.5) Multi-morbidity was not existing.

Table 4: Model classification based on 6 significant Variables

Observed		Predicted		
		Multi-morbidity		% Correct
		Yes	No	
Multi-morbidity	Yes	213	87	71
	No	128	160	55.6
Overall Percentage				63.4

The cut value is 0.500

Table 5 shows the prediction ability of the model based on all 11 study variables. The model revealed that 72.7% of multi-morbid participants were correctly predicted that they had multi-morbidity while 53.5% of non-multi-morbid population correctly predicted that they do not have multi-morbidity. Thus, overall correct prediction percentage of model with 11 variables was 63.3% with cut-off probability 0.5.

Table 5: Model Classification Based on all 11 study Variables

Observed	Predicted		
	Multi-morbidity		% Correct
	Yes	No	

Multi-morbidity	**Yes**	218	82	72.7
	No	134	154	53.5
Overall Percentage				63.3

The cut value is 0.500

The prediction percentage of Logistic Regression model with 6 significant variables and model with all 11 study variables showed similar predictive ability. However correct prediction percentage of multi-morbidity was very high as compared to correct prediction percentage of non- multi-morbidity with cut-off probability 0.5.

For balancing these prediction percentages Receiver Operating Characteristic (ROC) curve analysis was performed.

The Receiver Operating Characteristic (ROC) Curve Analysis revealed that cut-off probability 0.45 could determine similar correct prediction percentages of multi-morbidity and non-multi-morbidity.

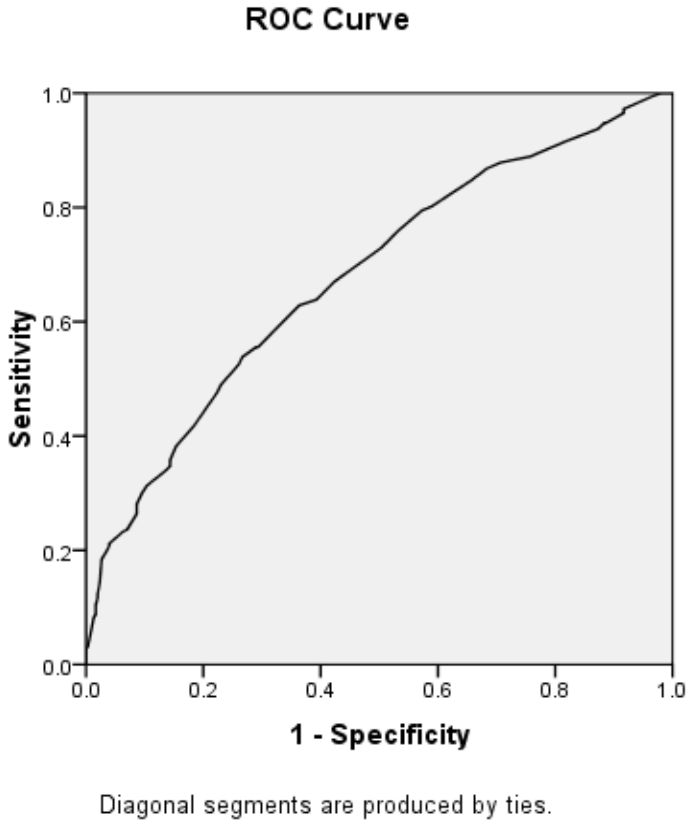

Fig 2: Receiver Operating Characteristic (ROC) Curve

Area Under the Curve was found to be 68%. The optimal cut-off for determining equalised proportion of presence and absence of multi-morbidity 0.45 pointed 63.7% sensitivity and 62.8% specificity.

Table 6: Model Classification Based on 6 significant Variables using modified cut-off

Observed		**Predicted**		
		Multi-morbidity		
		Yes	**No**	**% Correct**
Multi-morbidity	**Yes**	191	109	63.7
	No	107	181	62.8
Overall Percentage				63.3

The cut value is 0.45

Finally, the prediction model based on 6 significant variables also resulted 63.7% of total multi-morbid population correctly predicted that they had multi-morbidity while 62.8% of non multi-morbid population correctly predicted that they had no multi-morbidity (Table 6). Thus, overall prediction percentage of model with these variables was 63.3% with a cut-off probability 0.45; that is if P≥0.45 Multi-morbidity was existing; Otherwise (P<0.45) Multi-morbidity was not existing.

4. DISCUSSION

The present study illustrated the socio-demographic predictors of Multi-morbidity among elderly population in Kerala by utilizing nationally representative data (LASI). Further, we documented the risk factors among health behaviours that influenced the high prevalence of multi-morbidity. Our study estimated a 51% overall prevalence of multi-morbidity among elderly aged 60 years and above which is higher than studies done in various parts of Kerala with observed prevalence ranging from 16.2% - 45.4%.[3-6] Similar results were observed in a study conducted by Khanam et al., 2011., the overall prevalence of multi-morbidity among the elderly people was 53.8%.[7] And also in a study conducted by Picco et al.,2016., among Singapore elderly the prevalence of multi-morbidity was found to be 51.5 %.[8] In nations like Brazil, South Africa, US and Sweden, the prevalence was found to be much higher than the present study.[9-12] Various studies have reported different prevalence, depending on the age group of the study population, number of morbid conditions observed, differences in definition of multi-morbidity and method of data collection.

In bivariate analysis, different variables including socio-demographic characteristics and health behaviours were used to find the association with multi-morbidity and found that Gender, Living Arrangement, MPCE Quintile, Marital and Work status found significantly associated with multi-morbidity. In our study, unadjusted odds ratios and respective 95% Confidence Interval (CI) of these significantly associated independent variables were performed and revealed that comparing to males, females have 1.47 times chance of getting multi-morbidity with 95% CI (1.015 – 2.130). Similar results were obtained among studies such as Khanam et al., 2011; Marengoni, Winblad, Karp, & Fratiglioni, 2008; Ninh et al., 2015; Phaswana-Mafuya et al., 2013.[13] Females usually neglect their own health in taking care of their family members and are more likely to be unemployed, widowed, less engaged in physical activity in old age and have relatively higher tendency to share their conditions in self-reports than older men.[14] The findings of the present study suggested the urgent need of elderly persons especially women, for health care services in Kerala. In a study by Khan et al., 2022., risk of multi-morbidity was highest among the better affluent groups (Richest) as compared to those belonged to poorer households who are having the lower odds of having any multi-morbidity.[15] Similarly, the results of present study exhibited the chance of getting multi-morbidity increased with increasing wealth conditions which was 1.56 times with 95% CI (1.124 – 2.156) when compared to those who belong to poor/middle MPCE Quintile. The possible explanation for this could be that they are more likely to see doctor, resulting in diagnosing of chronic diseases and they have better healthcare accessibility. In contrast, the findings of the study by Khanam et al., 2011., Hoang et al., 2008; and Jerliu et al., 2012 showed that those who were in rich category were less likely to have multi-morbidity than those who were in poor category.[13] This may be due to the fact that wealthier individuals could spend their financial resources to afford healthcare services and a better and healthier diet, resulting in reduction in sickness and poor and unhealthy nutrition which may cause multi-morbidity. Elders who stayed alone or with only spouse/children/others have 1.43 times chance of exhibiting multi-morbidity with 95% CI (1.031 – 1.973) when compared with those who were living with spouse and children. Dung Duc Le et al., 2016., also supports the finding of our study that those living alone were more likely to have multi-morbidity than those living with other categories.[13] The reason could be living alone may reflect an individual's vulnerable status in terms of financial insecurity, which in turn may influence the health conditions of older persons (United Nations Population Fund & HelpAge International, 2012).[16] Extended family structure is an important healthcare for elderly population (Le et al., 2011).[17] Thus, lack of such support may leads to increase in the risk of having chronic diseases among those living alone. In our study those who are Never married/ Widowed/ Divorced had higher probability of developing multi-morbidity when compared with married elders. In contrast to this finding, Dung Duc Le et al., 2016., Khanam et al., 2011., and Phaswana-Mafuya et al., 2013 found that those who were in other group (that was, single/separated/ divorced/widowed) had a lower probability of having multi-morbidity than those who were married in both genders.[7,13,18] In our study not working elders had a greater chance of acquiring multi-morbidity when compared to working elders which was similar to the study by Dung Duc Le et al., 2016.[13] Elders with no occupation may reflect sedentary status which was associated with risk factors for health. Another possible explanation is that healthier individuals are more likely to continue working, while those in

poorer health or in illness are more likely to withdraw from the workforce.

Multi-morbidity was significantly predicted by Backward logistic regression analysis and it revealed that out of 11 study variables Gender, MPCE Quintile, Alcohol, Work status, Religion and Caste were significant predictors of multi-morbidity and in those female elders, those who were in wealthiest groups, those who were consuming alcohol, not working elders, those who belonged to Muslim/Christian and those who were in ST/SC/OBC categories were at high risk of being multimorbid. In 2022, Study by Khan et al.,2022., reported similar findings of our study which showed that Muslim have higher likelihood of having multi-morbidity when compared to Hindu as reference category.[19] In a study by G K Mini et al., 2017., found that alcohol users were more likely to suffer from multi-morbidity.[19] Contrasting result was observed from the study conducted by Khan et al.,2022., and Boro B et al., 2022., that the older adults from lower caste categories SC, ST and OBC were less likely of having multi-morbidity compared with the people in other category and Hindus had the lowest among religions.[15,20] This could be explained due to the adoption of unhealthy life-styles among the higher socioeconomic groups which are also major risk factors of morbidity conditions.

Prediction models based on logistic regression analysis were executed in our study which showed the classification ability based on 6 significant variables such as gender, MPCE Quintile, alcohol consumption, work status, religion and caste. The model was able to correctly discriminate between elderly population who were multimorbid with prediction percentage of having multi-morbidity (71%) and those non multimorbid participants with prediction percentage of not having multi-morbidity as 55.6%. Overall prediction percentage of the model was 63.4% with cut-off probability 0.5. All 11 study variables were used to find the prediction ability of the model which revealed that 72.7% of multimorbid participants correctly predicted that they had multi-morbidity while 53.5% of non-multimorbid population correctly predicted that they do not have multi-morbidity. Overall prediction percentage of model with 11 variables was 63.3% with cut-off probability 0.5. Multi-morbidity was existing if $P \geq 0.5$; Otherwise ($P<0.5$) Multi-morbidity was not existing. Predictive ability of the two models with 6 significant variables and 11 study variables showed similar prediction percentages. However, prediction percentage of multi-morbidity was very high as compared to prediction percentage of non- multi-morbidity.

The Receiver Operating Characteristic (ROC) Curve Analysis were performed for balancing these prediction percentages and also to find the optimal cut-off for determining equalised proportion of presence and absence of multi-morbidity which revealed that cut-off probability 0.45 could determine similar prediction percentages of multi-morbidity and non-multi-morbidity. Area Under the Curve was found to be 68%. About 63.7% of the sensitivity, i.e population are having multi-morbidity and 62.8% of specificity elderly population do not have multi-morbidity (Table 6). Balanced prediction model based on 6 significant variables with cut-off probability 0.45; correctly predicted that 63.7% of total multimorbid population had multi-morbidity while 62.8% of non-multimorbid participants had no multi-morbidity with overall prediction percentage 63.3%.

5. CONCLUSION

Our study put forward a greater risk of multi-morbidity among the elderly population in Kerala. The findings suggest it is necessary that health services should be equipped to detect and manage a wide range of chronic conditions among vulnerable groups in the elderly population. Factors that determine multi-morbidity should be identified and more efforts from policymakers and government should be given focusing and investing more on chronic disease management and treatment as well as health conditions of older persons by improving healthcare facilities and the quality of healthcare services. Knowledge about geriatric issues especially non-communicable diseases and geriatric care should be provided for healthcare providers. More geriatric care centers and elderly clubs should be established in Kerala so that older persons can communicate, share information, open their social network, and help each other which encourages them to participate in cultural and social activities, especially for those who are living alone. A major challenge in taking care of the elders is to ensure that they do not merely live longer, but lead a secure, dignified and productive life.

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