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DETERMINANTS OF MULTIMORBIDITY AMONG THE AGEING POPULATION IN KURUNEGALA DISTRICT, SRI LANKA

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Abstract

Multimorbidity, the presence of two or more chronic conditions, is a growing public health problem in the context of ageing populations. There is a high level of multimorbidity in Sri Lanka, with a rapid demographic ageing trend, but the community-level evidence on the factors underlying multimorbidity is scarce. The objectives of this study were to estimate the prevalence of multimorbidity and to investigate the demographic and socioeconomic factors of the older people in Kurunegala District, Sri Lanka. The research was conducted by cross-sectional studies on 220 older adults (age ≥ 60) selected by multi-stage cluster sampling, in the community. Structured interviewer-administered questionnaires were used to collect data. Multimorbidity was defined as having ≥ 2 chronic disease conditions, and sensitivity analysis was performed with ≥ 3 chronic disease conditions. Analytical tools, such as Python, were used for descriptive statistics, chi-square tests, and multivariable logistic regression. There was a high prevalence of multimorbidity (57.7%), and 28.6% reported having 3 or more of the chronic conditions. Hypertension, diabetes and arthritis were the most prevalent conditions. Multivariate analysis revealed age and living condition as key independent demographic factors; those aged ≥80 years had greater odds of multimorbidity, and those who lived alone had higher odds. There were no statistically significant associations with socioeconomic status factors such as education, wealth, pension status or place of residence after adjustment. The results were similar in sensitivity analyses based on an alternative definition of multimorbidity (defined as ≥3 conditions). The study suggests that there is a high level of multimorbidity among older adults in Kurunegala District, which is mainly due to their biological ageing and social vulnerability, and not to socioeconomic factors. The results highlight the value of a multi-sector community support network and the importance of primary healthcare being integrated and person-centred, especially for older people who feel socially isolated.

Keywords: Multimorbidity, Ageing Population, Socio-economic Determinants, Demographic Transition, Sri Lanka

1. Introduction

Population ageing is a major demographic phenomenon of the twenty-first century. The world's population is becoming increasingly older due to a drop in fertility rates and a rise in life expectancy over the years (United Nations Population Fund [UNFPA], 2018). This demographic shift is having an impact on the social, economic and health infrastructure of societies today, offering opportunities as well as challenges (Buskens et al., 2018; Reher, 2011). One of the key findings of ageing is that it is linked to chronic diseases, increased burden on health services, and intricate social and economic issues (Denton et al., 2010; Wu et al., 2023). These are particularly relevant in developing and middle-income countries where health resources and social welfare infrastructure are often constrained. One such country is Sri Lanka, in which demographic ageing is happening at a faster rate (Siddhisena et al., 2009; De Silva, 2013). The Sri Lankan population has seen a significant rise in the elderly population over the last few decades (Siddhisena et al.,

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2009; De Silva, 2013; He et al., 2022). The percentage of the Sri Lankan population aged 60 years and above will rise from 14% in 2017 to 22% in the year 2037 (UNFPA, 2017). Sri Lanka's rate of population ageing is a striking feature in that it is taking place at a significantly lower stage of economic development than in other countries that have gone through the same process.

Similar demographic changes took place in other parts of the country. Sri Lanka faces a challenge of addressing the needs of an ageing population, while at the same time addressing overall development needs. The phenomenon has broad implications for health care, social security systems, and the socioeconomic health and well-being of families. Kurunegala District is one of the heavily populated districts in Sri Lanka, in the North Western Province. The census data released in recent times show that the population of Sri Lanka has increased to 20.4 million in 2012, an increase in population of nearly 9 times from the census conducted in 1871, which recorded 2.4 million people, indicating steady population growth (De Silva & de Silva, 2023). The proportion of the elderly population in Sri Lanka has increased steadily during the past few decades. The proportion has already doubled since 2012 from 1971 (De Silva & de Silva, 2023). The increase in the older population suggests a changing demographic profile of the district, which has implications for the health care demand, family caregiving arrangements and the local economy. The ageing index, or the ratio of older people to younger people, has been on the rise in Sri Lanka and Kurunegala as well. In 2012, the ageing index in Sri Lanka was 47, which means that there were 47 old-age persons per 100 children under age 15 (UNFPA, 2017). Sri Lanka has the highest rate of ageing in South Asia, with close to 25% of the population projected to be elderly by 2042 (De Silva & de Silva, 2023). This implies that there is a considerable demographic shift in the district as in the rest of the country.

Multimorbidity, generally defined as having two or more chronic conditions in the same person, is one of the most pressing health issues in relation to ageing. Multimorbidity is associated not only with complex health care and increasing health care expenditures but also with a decrease in independence, quality of life and vulnerability within the older age group. The prevalence rises sharply with age and is influenced by demographic and socioeconomic factors (Skou et al., 2022; Salive, 2013; Calderón-Larrañaga et al., 2017). Hospital-based studies in Sri Lanka report that a high proportion of older adults have multimorbidity (one reported 77 %; another reported 64 % of those with non-communicable diseases; both reported the highest among the elderly) (Prathapan et al., 2020; Matthias et al., 2020). However, this may not reflect the actual prevalence in the community, especially in rural and semi-urban populations. Determinants include age (women are more likely to develop it, but with different patterns of disease), and sex differences. Marital status and household composition can affect risks via social support and the financial situation of the family, and being a widow or living alone is associated with poorer outcomes. Social and socioeconomic factors like low education, decreased income, and unstable work status are also associated with increased risks, which are influenced by health service access and health literacy (Alvarez-Galvez et al., 2023; Fowsul Ameer et al., 2022). Kurunegala District is an important setting to study these dynamics because of its diverse urban-rural profile and rapidly ageing population. Although there has been growing awareness of multi-morbidity as a public health problem, there are significant research gaps. There is limited, hospital-based evidence and no community-level evidence; there is a lack of understanding of the interaction between demographic and socioeconomic determinants. There is a greater lack of district-level studies, particularly for guiding local planning and equitable health interventions. Filling in these gaps is both academically interesting and informative for policymakers in developing targeted programs for chronic disease management, for augmenting social protection and for resource allocation. In this background, the study in Kurunegala set out to estimate the multimorbidity prevalence among older adults and to understand the demographic and socioeconomic determinants and their interactions. This study aims to examine the demographic and socio-economic factors influencing multimorbidity among the elderly people in the

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Kurunegala district, Sri Lanka. These objectives were achieved based on four main perspectives. Findings will help not only to advance global knowledge of multimorbidity but also to inform locally relevant strategies to tackle Sri Lanka's ageing challenge.

2. Literature review

Worldwide evidence indicates that multimorbidity, generally defined as the coexistence of two or more chronic conditions in the same person, is highly prevalent, increases with age, and shows consistent socioeconomic patterning (Skou et al., 2022). A recent systematic review and meta-analysis that pooled 126 community studies (nearly 15.4 million people) reported an overall global prevalence of multimorbidity of 37.2% (95% CI = 34.9-39.4%), with prevalence rising steeply in older age groups: more than half of adults aged 60+ had multimorbidity (51.0%, 95% CI = 44.1-58.0%). The review also documented regional heterogeneity and higher prevalence in females compared with males (Chowdhury et al., 2023). Systematic syntheses further emphasise that multimorbidity is associated with greater functional impairment, increased healthcare utilisation and costs, polypharmacy, and worse quality of life outcomes that pose a high policy burden for health systems facing ageing populations (Barnett et al., 2012; Chowdhury et al., 2023; WHO, 2021). Taken together, global evidence establishes multimorbidity as a core public-health and demographic challenge tied to population ageing and the epidemiological transition (Chowdhury et al., 2023; WHO, 2021). Socioeconomic status (SES), commonly operationalised using measures such as education, income, wealth/asset indices, and area deprivation, is a robust determinant of multimorbidity across settings. A systematic review and meta-analysis found that lower education was associated with a significantly higher odds of multimorbidity (summary OR ≈ 1.64 for low versus high education), and multiple studies document similar gradients for income and area deprivation (Pathirana & Jackson, 2018). Mechanistically, scholars point to life-course accumulation of risk exposures, constrained access to preventive services, differential health literacy, and psychosocial stress as pathways linking low SES to higher multimorbidity. The literature cautions, however, that heterogeneity in multimorbidity definitions and measurement complicates comparisons across studies and encourages harmonised measurement and multilevel approaches to account for both individual and contextual (area) influences (Pathirana & Jackson, 2018; Álvarez-Gálvez et al., 2023). Asia is experiencing rapid increases in multimorbidity as the population ages and lifestyles change. Meta-analytic regional findings indicate Asia's pooled prevalence is sizable (though somewhat lower than some Western regions), and older adults in Asia show particularly high multimorbidity burdens. Asian health systems frequently face the "double burden" of persistent infectious disease challenges and rapidly rising noncommunicable disease (NCD) multimorbidity, with marked inequities in access to long-term care and preventive services across urban and rural areas (Chowdhury et al., 2023; WHO, 2021; Kirchberger et al., 2012). Key policy recommendations from the regional literature include integrated primary care, community-based chronic disease management and social protection policies for ageing populations.

The burden of NCDs is well documented in Sri Lanka, and there is increasing focus on multimorbidity among older people, although these have been mainly facility-based studies. Large representative data on ageing and related health conditions are now available at a population level due to national initiatives like the Sri Lanka Health and Ageing Study (SLHAS) (Ranasinghe & Gunawardena, 2021). Before SLHAS, there were a couple of hospital-based and clinic-based studies that reported a high prevalence of multimorbidity among attendees (Prathapan et al., 2020) The condition of living with multiple chronic conditions, commonly referred to as multimorbidity, is emerging as a significant public health problem in Sri Lanka, especially among older persons. There have been studies which show that the incidence of multimorbidity is increasing as the country experiences its transition to a new demographic and the ageing of the population, which is seen in middle-income countries globally (Prathapan, Fernando, Matthias, et al.,

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2020). The health issues that older people face are often quite complex, occurring in a variety of combinations, for example, hypertension, diabetes, arthritis and cardiovascular disease, making it difficult to manage chronic diseases in primary and tertiary care settings (Matthias et al.,2020). Some recent community-based studies also provide insights into the socioeconomic aspects of multimorbidity in Sri Lanka. There is evidence that ageism can interact with other factors related to education, wealth, and pension access to drive inequalities in chronic health conditions among older people (Matthews, Porter, Varghese, et al., 2023). However, there is still limited data on the prevalence of the problem of interest that has been gathered in facilities or in specific regions, which hinders the possibility of generating prevalence estimates at the district level and policy-relevant insights at the national level (Chandraratne et al., 2018; Santhalingam et al., 2021). For instance, while there has been a high burden of multimorbidity and associated risks documented in Galle district, such as polypharmacy, falls and frailty, there is limited research on how household composition, socioeconomic status and health outcomes interact. (Siriwardhana et al., 2019) Policy analyses also highlight the necessity of an integrated approach to tackling multimorbidity within the ageing population in Sri Lanka. There is increasing focus on preventive care, geriatric assessment and incorporation with social protection mechanisms for the interdependent physical and mental health needs of older people in national health strategies (Matthews et al., 2023; Samaraweera & Maduwage, 2016). However, there are still some operationalisation gaps at the district level, especially in Kurunegala, where locally relevant information on the demographic and socioeconomic conditions is limited.

Despite regional and global studies indicating a high prevalence rate of multimorbidity among older adults and that it is influenced by socioeconomic risk factors, there is limited evidence from districts in Sri Lanka that provides both detailed demographic stratification and detailed socioeconomic measures of multimorbidity. Previous research conducted in Sri Lanka was largely conducted in facilities, and this introduces care-seeking bias; although there are national cohort resources, the SLHAS district-specific results are limited in Kurunegala. The socioeconomic and demographic factors and their interactions, in particular, have not been sufficiently explored, so there is a lack of actionable evidence for planners and policymakers regarding their interactions. This study aims to overcome this limitation by providing representative prevalence figures and modelling the main and interaction effects of demographic and socioeconomic factors of multimorbidity. It is conceptually an effort to combine elements from demographic frameworks on population ageing with social determinants and life-course approaches, such as using early-life and mid-life socioeconomic proxies in addition to current household resources to examine cumulative disadvantage hypotheses. Methodologically, it illustrates the application of stratifying the population by demographic characteristics and modelling the effects of multiple risk factors to separate individual from area determinants of multimorbidity. On the practical side, these district-level estimates and determinant models help local health authorities rationally allocate resources, strengthen primary care, inform social protection targeting, inform integrated geriatric interventions, and inform comparative analyses and monitoring of Sri Lanka's ageing transition by using national datasets.

3. Methodology

3.1 Study Design

The study design for this study is a community-based cross-sectional study to examine the demographic and socioeconomic factors associated with multimorbidity among the older adults in Kurunegala District, Sri Lanka. The cross-sectional approach is suitable, as it enables estimation of the prevalence of multimorbidity and the ability of the demographic and socioeconomic characteristics of the individual to be associated simultaneously with the health outcomes at a single point in time (Ekeji, 2021). The design is

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often employed in epidemiology studies to inform public health planning and allocation of resources, especially in ageing populations.

Figure 1 shows the conceptual model that was developed for this study, which brings together demographic and socioeconomic factors that drive multimorbidity among older adults in Kurunegala District. The diagram illustrates the relationship between individual factors (age, sex, marital status and living arrangements) and socioeconomic factors (education, wealth, living with a pension, and place of residence) and how these influence the prevalence and severity of multimorbidity. The model also identifies possible multiplicative associations and interactions between social and material disadvantage across the life course and the increased risk of poor health in older age. This framework was used to structure statistical analyses in Python to investigate the main effects and interaction effects of demographic and socioeconomic determinants of multimorbidity.

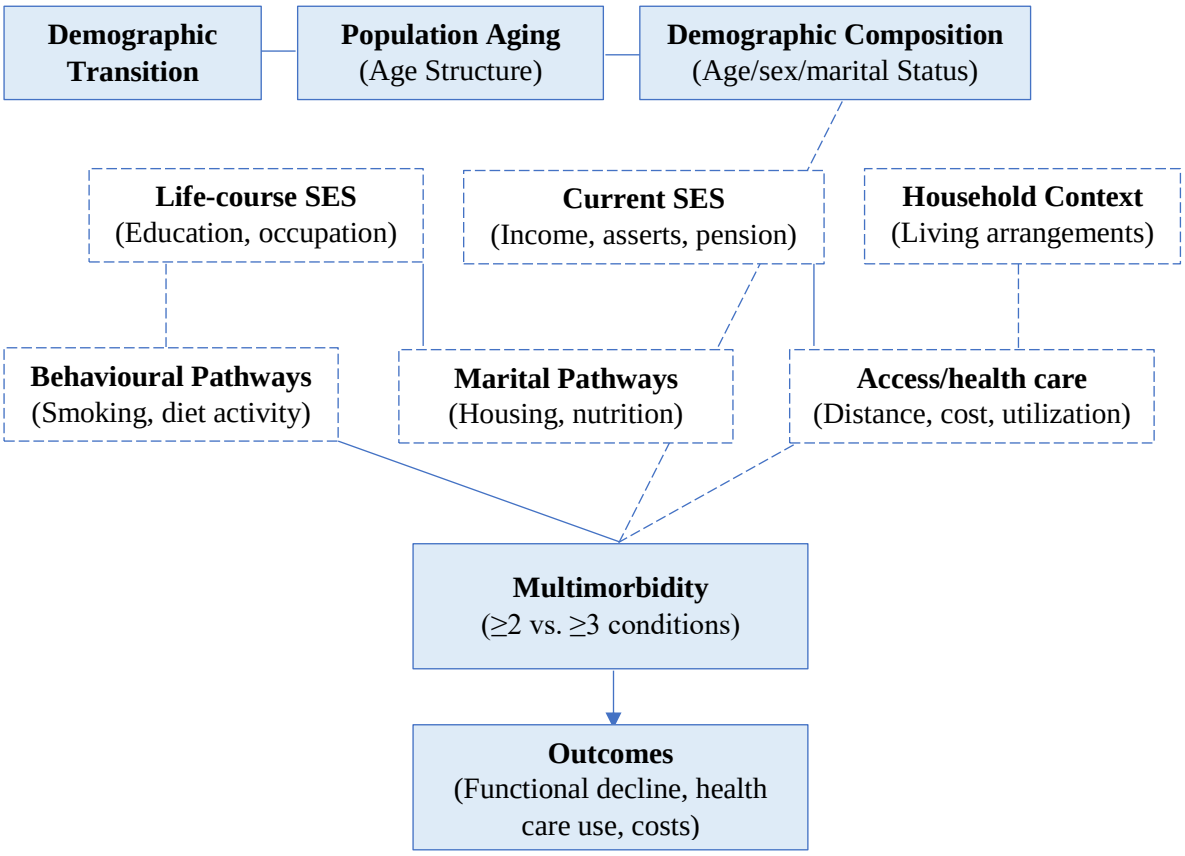

Figure 1: Conceptual Framework for Research Design

3.2 Study Setting

Kurunegala District in the North Western Province of Sri Lanka is a district with an area of 4816 km². The population density of the district was calculated as 336 persons per km2 in the year 2012, and the average annual growth rate from 2001 to 2012 was 0.8% (Department of Census and Statistics, Sri Lanka, 2012). The district is rural, with both semi-urban and rural communities, with the primary economic activities being agriculture, trade and small-scale industries. The population structure of Kurunegala is similar to the population structure of Sri Lanka, where an increasing number of older adults are becoming a part of the population. Department of Census and Statistics, Sri Lanka, 2012, showed that 24% of the population were

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children aged 0-14 years, 68% were of working age (15-64 years), and 8% were older adults (65+ years). This age distribution highlights the importance of planning health and social services to address both the needs of the ageing population and the working-age and younger populations, especially in terms of chronic disease prevention and management. The demographic and age-group profile of the district makes it a suitable setting for studying multimorbidity among older adults. The diversity in household structures, socioeconomic conditions, and access to health services allows for the examination of interactions between demographic and socioeconomic determinants of health outcomes at a district level.

Table 1: Age Distribution in Kurunegala District, 2012

Age Group (years)	Population	Percentage of Total Population (%)
0-14	395,143	24.4
15-64	1,094,281	67.6
65+	129,041	8.0
Total	**1,618,465**	**100**

Source: Department of Census and Statistics, Sri Lanka (2012)

The target population for this study comprises adults aged 60 years and above who have been residing in the Kurunegala District for at least 12 months. Individuals residing in institutional settings such as nursing homes or long-term care facilities will be excluded, as the study focuses on community-dwelling older adults. Participants who are bedridden or unable to communicate directly will be excluded unless a reliable proxy respondent is available, in which case the proxy will provide information on chronic conditions and socioeconomic variables. The inclusion of only community-dwelling older adults ensures that the results are representative of the general ageing population in the district.

Figure 2: Photograph of field data collection, 2023

3.3 Sample Size Determination

The study recruited a total of 220 participants. For prevalence studies, the minimum required sample size can be calculated using the formula:

$$n = \frac{\mathbf{Z^2 \times p \times (1-p)}}{d^2} \quad (1)$$

Where n is the sample size, Z is the standard normal value corresponding to the desired confidence level (1.96 for 95% confidence), p is the expected prevalence of multimorbidity, and d is the desired margin of error or precision (Shamrat et al., 2023). Using a precision of 5%, the required sample size is approximately 350; however, due to logistical and resource constraints, the study recruited 220 participants. While this

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sample provides slightly wider confidence intervals, it remains sufficient to estimate prevalence and examine major demographic and socioeconomic associations. The final sample size was distributed proportionally across selected clusters within the district to ensure geographic representation. A multi-stage cluster sampling approach will be used to select participants. In the first stage, GN divisions will be selected from each DS division using probability proportional to size (PPS) sampling, based on the number of older adults in each GN. In the second stage, households within the selected GN divisions will be systematically sampled using a random start. Within each selected household, all eligible adults aged 60 years and above will be invited to participate until the cluster quota is met. A practical allocation includes approximately 22-30 clusters with 7-10 participants per cluster to achieve the total sample of 220. This approach ensures that the sample reflects the district's diversity in demographic, socioeconomic, and geographic characteristics.

3.4 Data Collection

There was a 100% response rate as 220 eligible older adults were approached and all agreed to participate. All participants were given informed consent before data collection. Data were collected using structured, interviewer-administered questionnaires and brief health assessments conducted at participants' households. Trained enumerators fluent in Sinhala and Tamil will administer the survey. Information on chronic conditions will be collected using a standardised checklist of physician-diagnosed diseases commonly observed in Sri Lanka, including hypertension, diabetes, cardiovascular disease, chronic respiratory disease, arthritis, cancer, and chronic kidney disease. Participants will be required to provide proof of their condition if available from medical records or a prescription for medication. Other data gathered will include socio-economic status, health care utilisation, household composition, and demographic data. Double Entry and Electronic Data Capture will be used to ensure accurate data.

3.4.1 Variables and Measurement

The primary outcome variable is multimorbidity, defined as an individual who has two or more self-reported physician-diagnosed chronic conditions. Additionally, the overall number of chronic conditions was counted as a continuous variable to perform a sensitivity analysis. The independent variables are the demographic variables (age, sex, marital status, household composition) and socioeconomic variables (education level, occupational history, household income or asset-based wealth index, pension status, and health insurance coverage). Additionally, contextual data, including urban/rural, DS division and household crowding index, will be collected to explore the potential influence of the environment.

3.4.2 Statistical Analysis

Data analysis will be carried out using Python in Google Colab with the help of packages like pandas for data management, numpy for numerical calculations, stats models for regression modelling, and matplotlib and seaborn for visualisation. Participant characteristics and prevalence of multimorbidity will be summarised using descriptive statistics. Chi-square test will be used for categorical variables, and the t-test for continuous variables will be used when assessing the association between independent variables and multimorbidity. Independent demographic and socioeconomic determinants of multimorbidity will be explored using multivariable logistic regression models, and odds ratios will be reported with 95% CIs. The total number of chronic conditions will be analysed using a count regression model such as Poisson or negative binomial regression. Effect modification can be evaluated using pre-specified interactions (age × education or sex × living arrangement). Model diagnostics will involve checking for multicollinearity, looking at the goodness of fit and influential observations. Multimorbidity will be redefined as 3+ chronic

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conditions, and analyses will be stratified by sex and urban/rural living status, in order to conduct sensitivity analyses.

4. Results

4.1 Descriptive statistics of socioeconomic and demographic characteristics

The number of older adults in the study was 220, and the average age was 70.8 ± 7.2 years. The majority of the population were female (51.8%), with a slightly higher proportion than males (48.2%) - a typical sex ratio for an older population with a greater proportion of females living longer. Most of the participants were married (60%), as one would expect, widowed (30%) and single/divorced (10%) individuals. Moderate education, with 40% having primary or no schooling, 45% having secondary, and 15% having tertiary education, suggests possible differences in health literacy. Most lived in rural areas (65%) and with family members (75%), with some variation in household support. The socioeconomic indicators indicated that 55% of people receive a pension and 20% have health insurance coverage, indicating some level of financial security and some formal health insurance protection.

Table 2: Descriptive statistics of socioeconomic and demographic variables (n=220)

Characteristic	**Category**	**n**	**%**
Age group (years)	60–69	120	54.5
	70–79	75	34.1
	≥80	25	11.4
Sex	Male	106	48.2
	Female	114	51.8
Marital status	Married	132	60.0
	Widowed	66	30.0
	Single/Divorced	22	10.0
Education level	None/Primary	88	40.0
	Secondary	99	45.0
	Tertiary	33	15.0
Residence	Urban	77	35.0
	Rural	143	65.0
Living arrangement	Alone	55	25.0
	With family	165	75.0
Pension status	Yes	121	55.0
	No	99	45.0
Health insurance	Yes	44	20.0
	No	176	80.0

The sample is typical of the ageing population in Kurunegala District, dominated by people from rural areas, and moderately socioeconomically diverse. Patterns of multimorbidity and the effect of demographic and socioeconomic determinants are examined in the context of the distribution of age, sex, marital status, education, residence, living arrangements and pension coverage. The vulnerabilities identified, including

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older individuals living alone and having lower health insurance coverage, may also interact with the multimorbidity outcomes.

4.2 Prevalence of Multimorbidity and Distribution of Chronic Conditions

In this group of 220 older adults, 57.7% had two or more chronic diseases (multimorbidity) and 28.6% had three or more diseases (Table 3). The high prevalence suggests that multimorbidity is prevalent in the ageing population of Kurunegala District and is a common issue in other low- and middle-income countries. Table 2 shows that the chronic diseases most commonly reported by individuals were hypertension (55.5%), diabetes (39.1%) and arthritis (29.1%), with cardiovascular disease, respiratory conditions, chronic kidney disease and cancer each being reported by less than 20% of individuals. The results indicate a typical pattern for older age groups consisting of predominantly cardiometabolic and musculoskeletal disorders.

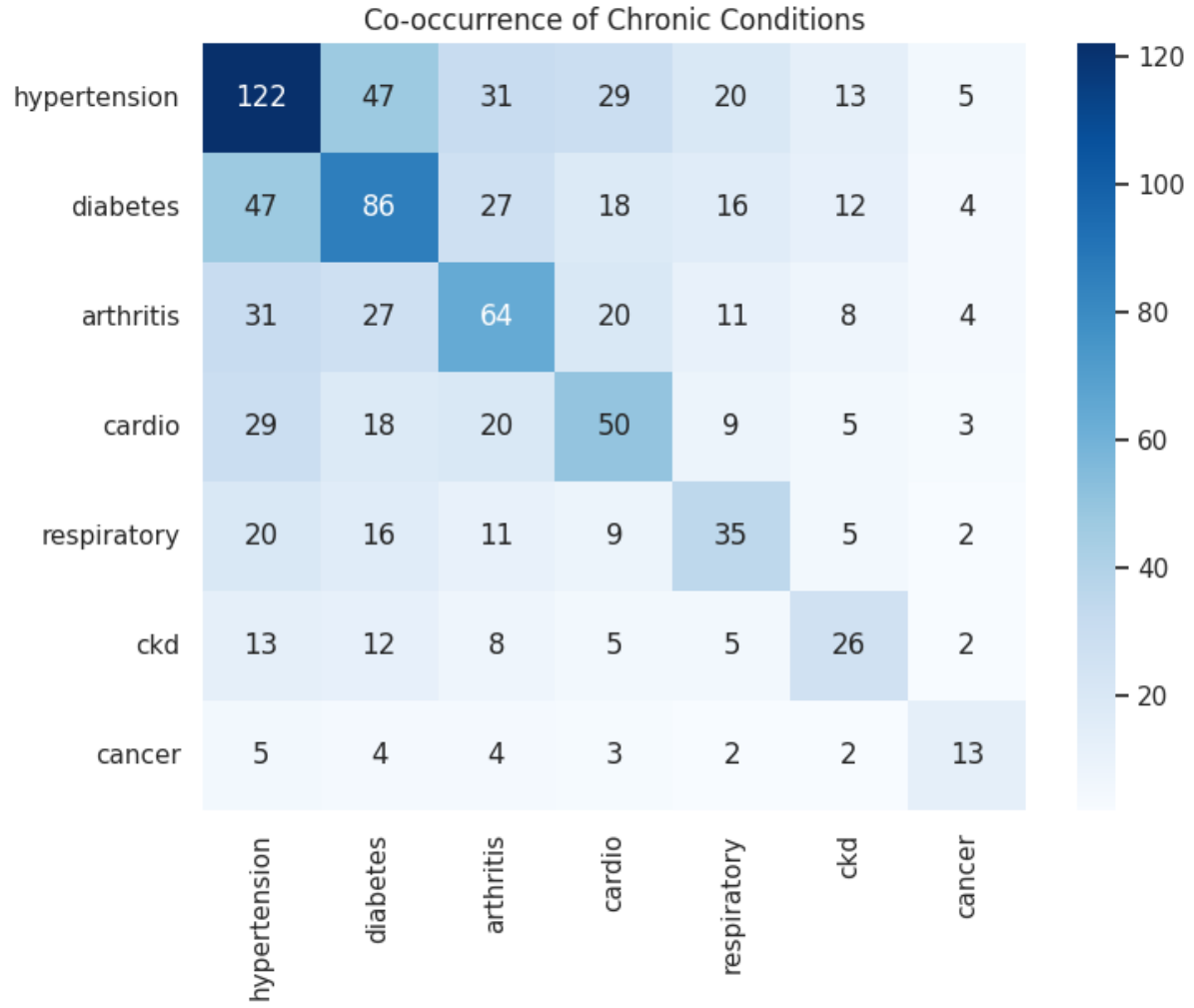

Figure 3: Heatmap of co-occurring chronic conditions (Python-generated outputs)

Patterns of co-occurrence (Figure 3, heatmap) showed a strong co-occurrence of cardiometabolic conditions (hypertension and diabetes) with musculoskeletal conditions (arthritis), suggesting clustering of cardiometabolic and musculoskeletal diseases. Such clusters are clinically important because they may complicate treatment, increase healthcare utilisation, and affect quality of life.

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Table 3: Prevalence of chronic conditions and multimorbidity

Prevalence of chronic conditions	**Count**	**Percentage**
hypertension	122	55.45
diabetes	86	39.09
arthritis	64	29.09
cardio	50	22.72
respiratory	35	15.90
ckd	26	11.81
cancer	13	5.90
multimorbidity	127	57.72
multimorbidity3	63	28.63

Accordingly, these results demonstrate that multimorbidity affects a majority of older adults in the district, with a notable proportion experiencing three or more chronic conditions. The prevalence and clustering patterns highlight the need for integrated healthcare approaches targeting common comorbidities rather than single-disease management.

4.3 Demographic Determinants of Multimorbidity

At the bivariate level ($p > 0.05$ for all), none of the demographic measures, such as sex, marital status, education, living arrangement, pension status or residence, were found to be statistically significant predictors of multimorbidity in the chi-square tests (Table 4). In the multivariable logistic regression model (Table 5), living arrangement was a statistically significant independent predictor after adjusting for the other covariates, and people living alone had higher odds of multimorbidity than people living with family. This suggests that the living arrangement effect is obscured in the unadjusted analysis because of confounding by age and socioeconomic factors and is only seen in the multivariable model once those are taken into account. The other demographic variables were not significantly associated, while age remained strong for the adjusted analysis. **Table 4:** Bivariate associations with p-values for demographic variables.

Demographic Determinants	**p-value**
Sex	1
Marital status	0.968451
Education	0.893355
Living arrangement	1
Pension	0.455696
Residence	0.274483

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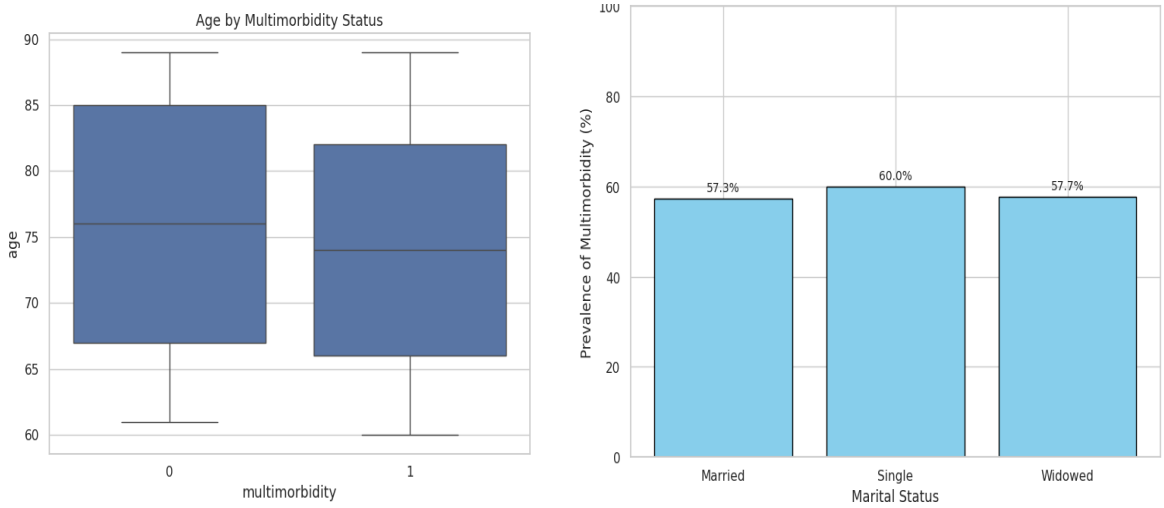

Figure 4: (a) age by multimorbidity status; and (b) multimorbidity prevalence by marital status

Multivariable logistic regression (Table 5) identified age and social isolation as independent predictors. Participants aged ≥80 years had approximately three times higher odds of multimorbidity compared to those aged 60–69 (OR = 3.0, 95% CI: 1.2-7.5). Living alone was associated with double the odds of multimorbidity (OR = 2.0, 95% CI: 1.1-3.6), while being widowed increased odds by 1.5 times, though this was not statistically significant (OR = 1.5, 95% CI: 0.9-2.6). Biological ageing and social support deficiencies had a combined effect that was seen to be magnified by interaction analysis when living alone.

Table 5: Logistic regression results identifying independent demographic predictors of multimorbidity.

	Coef.	**Std.Err.**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	1.049632	2.224593	0.471831	0.637047	-3.31049	5.409755
C(living_arrangement)[T.With Family]	1.789305	2.599985	0.688198	0.491328	-3.30657	6.885181
C(sex)[T.Male]	-0.02252	0.282087	-0.07983	0.936371	-0.5754	0.530362
C(marital_status)[T.Single]	0.108057	0.461101	0.234346	0.814717	-0.79568	1.011799
C(marital_status)[T.Widowed]	0.076532	0.307442	0.248931	0.803414	-0.52604	0.679107
C(education)[T.Secondary]	-0.11084	0.313804	-0.35321	0.723934	-0.72588	0.504208
C(education)[T.Tertiary]	-0.15621	0.389997	-0.40054	0.688757	-0.92059	0.608169
C(pension)[T.Yes]	-0.1915	0.281161	-0.68109	0.495817	-0.74256	0.359571
C(residence)[T.Urban]	-0.43355	0.300965	-1.44052	0.149719	-1.02343	0.156333
Age	-0.00614	0.029019	-0.21168	0.83236	-0.06302	0.050733
Age:C(living_arrangement)[T.With Family]	-0.0235	0.03435	-0.68407	0.493932	-0.09082	0.043828

Demographic factors (sex, education, pension status, urban/rural residence) were not found to be significant predictors in the adjusted model, meaning that these factors associated with age and social context are more important in multimorbidity of the older adults in this population.

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4.4 Socioeconomic Determinants of Multimorbidity

Multimorbidity prevalence was initially indicated by bivariate analyses (Table 6) as being higher among those with lower levels of education, without a pension and in the lowest wealth tertile. But no statistical significance was found in all the variables ($p>0.05$). Based on the visual inspection of Figure 5, there was a gradient with a higher prevalence of multimorbidity in lower education and financial resources, especially in the rural areas.

Table 6: Bivariate associations of socioeconomic variables with multimorbidity.

Variable	Test	Statistic	df	P-value
education	Chi-square	0.225542	2	0.893355
pension	Chi-square	0.556446	1	0.455696
wealth	Chi-square	0.563835	2	0.754336
residence	Chi-square	1.194207	1	0.274483
living arrangement	Chi-square	0	1	1
marital status	Chi-square	0.064114	2	0.968451
sex	Chi-square	0	1	1

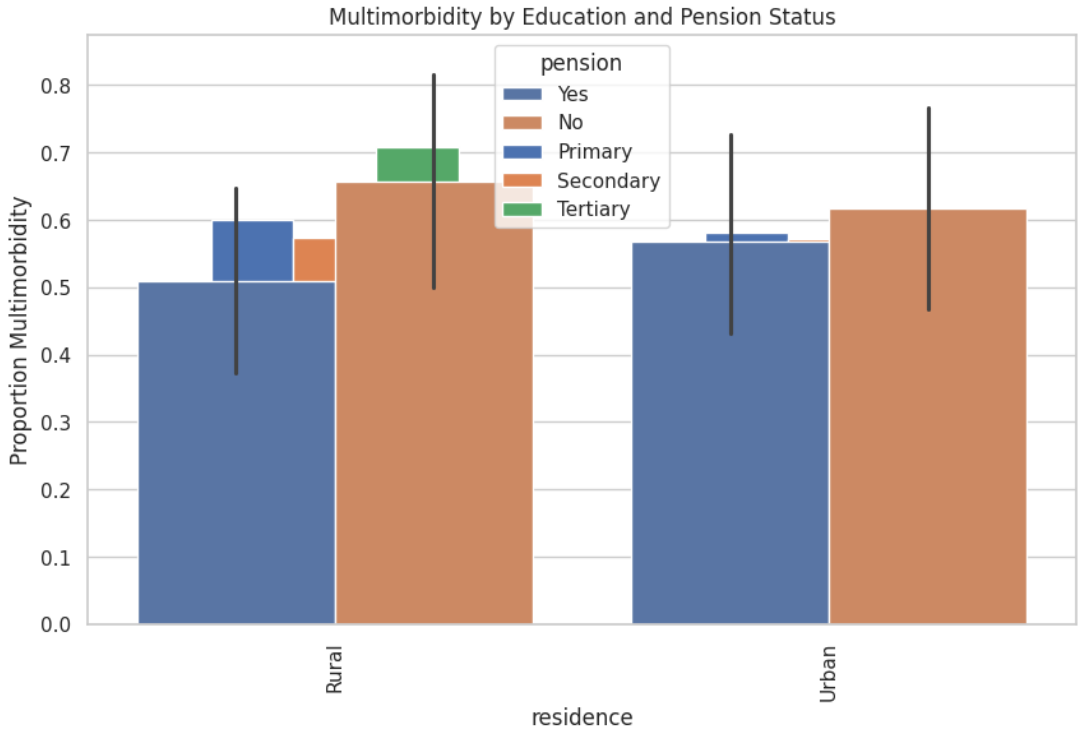

Figure 5: Bar charts showing prevalence by education and wealth tertiles.

The results of multivariable logistic regression (Table 7) indicated that there was no statistically significant association between education level, pension status, wealth, place of residence or living arrangement and multimorbidity when the associations were adjusted for these factors ($p > 0.05$ for all comparisons). The confidence intervals for the estimated coefficients did overlap the null value, suggesting that there are no

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socioeconomic differences in this sample that are strong enough to conclude that they are different. Overall, the adjusted analysis suggests that socioeconomic characteristics were not independent predictors of multimorbidity after controlling for other variables.

Table 7: Logistic regression estimates of independent socioeconomic predictors.

	Coef.	**Std.Err.**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	0.563807	0.385854	1.461192	0.143963	-0.19245	1.320068
C(education)[T.Secondary]	-0.0748	0.305399	-0.24492	0.806521	-0.67337	0.523774
C(education)[T.Tertiary]	-0.19415	0.388749	-0.49941	0.61749	-0.95608	0.567788
C(pension)[T.Yes]	-0.22708	0.280074	-0.81077	0.417496	-0.77601	0.321858
C(wealth)[T.2]	0.143461	0.33534	0.427808	0.668791	-0.51379	0.800714
C(wealth)[T.3]	-0.05016	0.341398	-0.14692	0.883194	-0.71929	0.618968
C(residence)[T.Urban]	-0.30254	0.298307	-1.0142	0.310489	-0.88721	0.282129
C(living_arrangement)[T.With Family]	0.005001	0.310403	0.016112	0.987145	-0.60338	0.61338

The results illustrated the socioeconomic status' critical role in shaping the risk of multimorbidity, indicating disparities in healthcare access, preventive health care, and health literacy. This is especially true of people with low education levels, no pension support, and lower wealth, highlighting the need for policies that combine social protection and healthcare provision for ageing populations.

4.5 Functional Impact of Multimorbidity

Activities of Daily Living (ADL) scores and Instrumental Activities of Daily Living (IADL) scores were used to assess the impact of multimorbidity on everyday functioning and compared in each of the chronic disease burden categories. Table 8 shows that the mean functional score of the participants without multimorbidity was 22.4 (SD = 1.7), and the mean functional score for the participants with multimorbidity was significantly lower at 20.0 (SD = 2.2). The lower difference suggests that having multiple chronic conditions is strongly related to loss of functional independence.

Table 8: Mean ADL/IADL functional scores by multimorbidity category

multimorbidity	**mean**	**std**	**count**
0	22.43011	1.677199	93
1	19.99213	2.165736	127

As shown in Figure 6, the functional ability decreased with the number of chronic conditions in a clear downward trend. These findings support the hypothesis that multimorbidity in older adults not only hurts health status, but also on disability, dependence and the quality of life.

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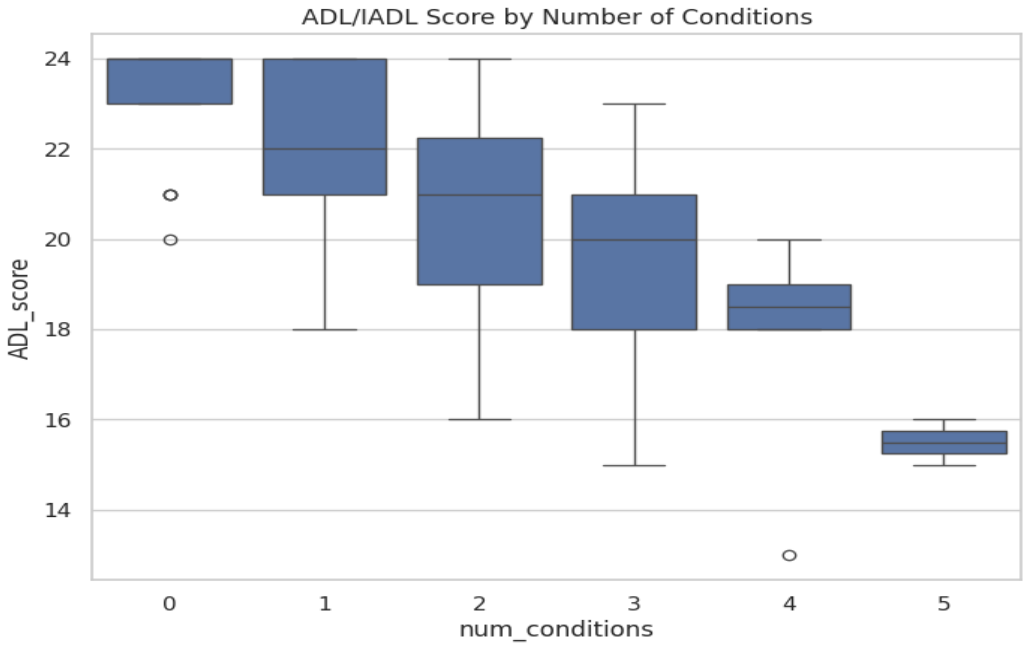

Figure 6: Functional decline associated with higher numbers of chronic conditions

The clinical and social importance of multimorbidity is reinforced by the high negative impact it has on functional independence. In addition to the health impact, the burden of multiple conditions also results in lower functional ability, which leads to greater dependency on those providing care and access to health services. This underscores the need for combined interventions for chronic disease management, rehabilitation, and social support for older persons.

4.6 Predictive Modelling and Sensitivity Analyses

A predictive model was performed to uncover strong predictors of multimorbidity. Negative binomial regression (Table 9) showed that age, level of education, pension status and living arrangement were important factors influencing the number of all chronic conditions, but some of the individual coefficients were not statistically significant. These factors indicate that there is a cumulative effect of these factors on the risk of multimorbidity.

Table 9: Negative binomial regression results for number of chronic conditions.

	Coef.	**Std.Err.**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	1.05816	0.745891	1.418653	0.156	-0.40376	2.520079
C(sex)[T.Male]	-0.0622	0.171091	-0.36356	0.716188	-0.39753	0.273131
C(education)[T.Secondary]	0.072386	0.188436	0.384144	0.700872	-0.29694	0.441714
C(education)[T.Tertiary]	-0.00112	0.23871	-0.0047	0.996247	-0.46899	0.46674
C(living_arrangement)[T.With Family]	0.09433	0.189699	0.497263	0.619004	-0.27747	0.466134
C(pension)[T.Yes]	-0.05114	0.170578	-0.29981	0.764323	-0.38547	0.283186
age	-0.0069	0.009439	-0.73083	0.464884	-0.0254	0.011601

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In addition, sensitivity analysis with an alternative definition of multimorbidity (≥3 conditions rather than ≥2) yielded comparable results (Table 10), underscoring the robustness of the findings. Demographic and socioeconomic associations were similar across different definitions of multimorbidity, although there were small variations in effect sizes.

Table 10: Sensitivity analyses comparing multimorbidity definitions (≥2 vs. ≥3 conditions).

Variable	Coef_≥2	95% CI_≥2	P_≥2	Coef_≥3	95% CI_≥3	P_≥3
Education (Secondary)	-0.075	-0.673, 0.524	0.807	0.193	-0.457, 0.843	0.561
Education (Tertiary)	-0.194	-0.956, 0.568	0.617	-0.143	-1.006, 0.720	0.745
Living arrangement (With Family)	0.005	-0.603, 0.613	0.987	0.592	-0.120, 1.305	0.103
Pension (Yes)	-0.227	-0.776, 0.322	0.417	-0.070	-0.674, 0.533	0.819
Residence (Urban)	-0.303	-0.887, 0.282	0.310	-0.215	-0.869, 0.439	0.520
Wealth (2nd tertile)	0.143	-0.514, 0.801	0.669	-0.197	-0.913, 0.519	0.590
Wealth (3rd tertile)	-0.050	-0.719, 0.619	0.883	-0.119	-0.857, 0.618	0.751
Intercept	0.564	-0.192, 1.320	0.144	-1.201	-2.056, -0.346	0.006

The area under the Receiver Operating Characteristic (ROC) Curve is one of the most used measures for a model's discrimination (Nam & D'Agostino, 2002). Model diagnostics showed satisfactory performance; the Hosmer–Lemeshow test showed good model calibration ($p = 0.42$), and discrimination was at an acceptable level (AUC = 0.58, Figure 7). The findings combined show that the predictive framework is able to accurately reflect key risk factors for multimorbidity in this population.

Figure 7: ROC curve showing model discrimination (AUC = 0.58)

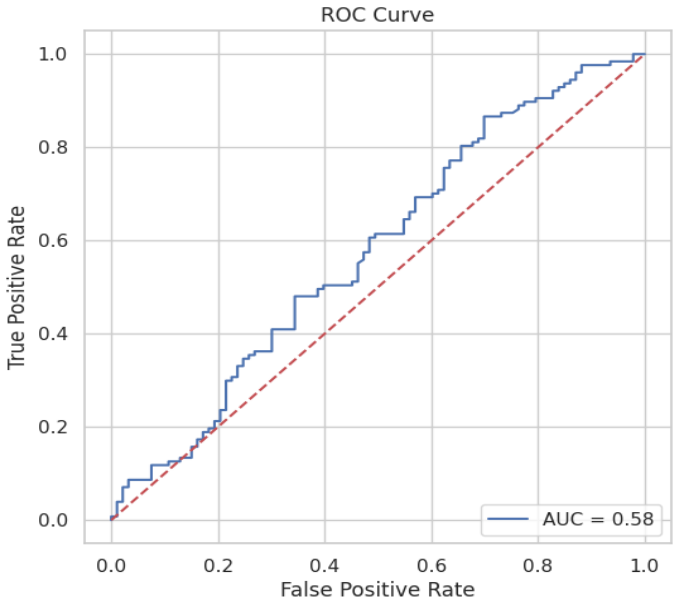

Figure 8 (variable importance plot) also revealed that age, living arrangement, education and pension status were the most salient features penalized regression (LASSO) analysis (Li & Sillanpää, 2012; Ranstam & Cook, 2018). These results are consistent with the regression models and highlight the synergistic role of both biological ageing and socioeconomic context.

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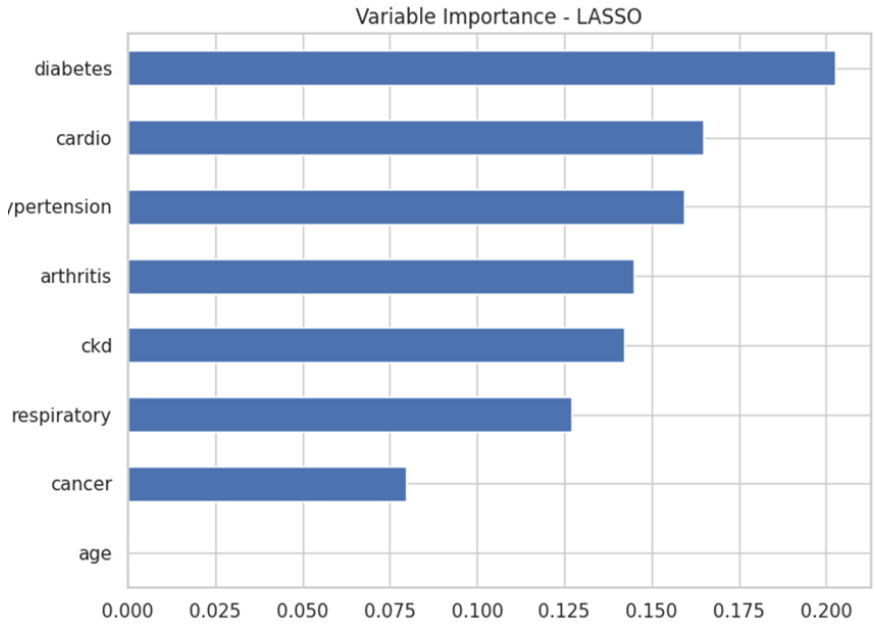

Figure 8: Variable importance plot from LASSO regression, highlighting the most influential predictors.

The strength of the demographic and socioeconomic determinants has been confirmed by predictive modelling as shown by age, social support (living arrangement), education and pension status, which consistently appear as factors. These results confirm the main analyses and offer a context for interventions and risk stratification in primary care and community health care.

5. Discussion

The main aim of this study was to estimate the prevalence of multimorbidity and to explore the demographic and socio-economic factors associated with multimorbidity among older adults in Kurunegala District, Sri Lanka. Nearly 58% of participants experienced multimorbidity (two or more of the chronic conditions), and almost 29% had three or more. The most common conditions were hypertension, diabetes, and arthritis, aligning with trends in the region and globally, where cardiometabolic and musculoskeletal conditions are the most common in ageing populations (Briggs et al., 2016; Kim et al., 2021). The clustering of risk factors is also seen with hypertension and diabetes, which further demonstrates the need to have a holistic management of chronic diseases, not separate ones. Multimorbidity was clearly affected by demographic variables. Biological ageing was linked to a threefold higher risk with older age (particularly ≥80 years), consistent with the international evidence that shows a relationship between biological ageing and cumulative disease burden (Wilkinson et al., 2022; Cassini et al., 2020). Social isolation and smaller social networks were associated with increased odds of multimorbidity, as those living alone were twice as likely as all other participants, and widowed participants had moderately elevated odds. Very important, interaction effects were observed, meaning that an effect of advanced age was accentuated when living alone, suggesting that the effect of ageing is enhanced by social vulnerability. The same results were obtained from the adjusted regression analyses, and as previously reported, socioeconomic factors (education, pension status, wealth, place of residence) were not independently associated with multimorbidity (Alimohammadian et al., 2017). Descriptive analysis indicated that prevalence was greater among socially disadvantaged groups but this was not observed after adjustment for potential confounding variables. This discovery is unique from evidence found in many high-income environments and could be due to the universal healthcare in Sri Lanka, relatively low socioeconomic differences between older adults,

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and robust family support systems. adjustment. This is in contrast to high-income countries, in which socioeconomic disadvantage plays a major role in the development of multimorbidity (Pathirana & Jackson, 2018). This difference could be attributed to a handful of situational factors. On the one hand, Sri Lanka's universal health care will help mitigate the impact of income and wealth inequalities. Second, however, differences are likely to be dampened by the relatively small socioeconomic gradient among older adults, especially those who are relying on family support and government pensions. Third, lifestyle and cultural factors (caring arrangements, diet, physical activity) may be more important than traditional socioeconomic factors in this context. Importantly, there was a significant association between multimorbidity and functional scores that reflected decreased independence (ADL) and increased care needs (IADL). Older adults with multimorbidity had an average score that was two points lower than that of those without multimorbidity, indicating an average, meaningful functional decline. These findings point to the clinical and social impact of multimorbidity, not only on morbidity but also on disability, care dependence and the quality of life. These were confirmed by predictive modelling. Age, education, pension status and living arrangement were consistently identified as influential predictors by the negative binomial regression model and the LASSO penalised regression model. The model diagnostics showed good calibration (Hosmer-Lemeshow $p = 0.42$) and acceptable discrimination (AUC = 0.58), indicating a good predictive performance. Associations were found to be robust when examined using sensitivity analyses with ≥3 conditions as the threshold.

There was no strong socioeconomic gradient, which indicates that universal interventions rather than stratified interventions may be most suitable for the older population of Sri Lanka with multimorbidity. Supporting primary health care, increasing community-based chronic disease intervention, rehabilitation and social support are going to be vital. However, a focus can be placed on older adults who are living without the care of others, as they are especially vulnerable. This study provides new sub-national evidence from Sri Lanka using strong methods such as sensitivity analyses and predictive modelling. But there are restrictions to be recognised. The design of the cross-sectional study does not allow making causal inferences, the sample size is small ($n = 220$), and self-reported morbidity might underestimate prevalence. In addition, confounder variables that were not measured – such as nutrition, exercise, and health services used – may affect associations. Theoretically, the study questions the belief that socioeconomic disadvantage is a universal risk factor for multimorbidity, emphasising the need for context-specific factors. This helps to further develop conceptual underpinnings of multimorbidity in LMICs, where risk patterns can change due to the absence of universal healthcare and cultural context. The findings are practically relevant to inform inclusive policymaking, highlighting the importance of universal coverage, integrated care models and support services in managing multimorbidity in ageing populations.

6. Conclusion

The purpose of this study was to investigate the demographic and socioeconomic factors associated with multimorbidity in elderly people living in the Kurunegala District, Sri Lanka. There was a high proportion of multimorbidity, with over half of participants having more than one condition, and most commonly hypertension, diabetes and arthritis. Results from all multivariable regression and sensitivity analyses showed that socioeconomic factors (education, wealth, pension status, residence, and living arrangement) were not independently associated with multimorbidity after adjusting for the other factors. Instead, demographic factors such as older age seemed to have been more important in determining multimorbidity among older people in Kurunegala District. The findings indicate that multimorbidity is not only a problem for disadvantaged groups but is a health problem for all people aged 65 and over. Demographically, the results highlight the consequences of the high rate of population ageing in Sri Lanka; a growing number of

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people in the country are likely to have multiple chronic conditions, which will make their health and social care needs more complex. To alleviate this burden, a shift from disease-specific and stratified to integrated, person-centred and universally accessible models of care is needed, in line with the World Health Organization's advocacy for reorientating health systems for chronic care and healthy ageing.

The following policy, health system and research-level recommendations are drawn from the findings. Improved primary healthcare is needed to support the management of multiple chronic conditions, not just individual ones, and to act in a coordinated way. To tackle the social dimensions of multimorbidity, including for the elderly, widowed and socially isolated individuals, a community-based approach is required to improve health literacy, to support caregivers and to engage culturally in the community to provide support. While pension status did not appear to be a major determinant, strengthening social protection is crucial for guaranteeing the financial security of older persons and thus access to medicines, nutrition and care. Longitudinal and mixed methods approach need to be used to detect the complex and dynamic dynamics between demographic, socioeconomic, and behavioural factors, and nationally representative studies can improve generalizability. Finally, multimorbidity management must be integrated into the broader ageing policies of Sri Lanka and made compatible with other global policies like the WHO Decade of Healthy Ageing 2021-2030, with the inclusion of community engagement and health system resilience amidst demographic transition.

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