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Associations of sedentary time, sleep duration and physical exercise with multimorbidity among older adults in Shanghai, China: a cross-sectional study based on national physical fitness surveillance data

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Abstract

Background Multimorbidity has emerged as a significant challenge for healthcare systems globally. This study aims to examine the associations between key determinants of lifestyle behavior and various multimorbidity patterns.

Methods In a cross-sectional sample of older adults (aged 60–79) from the Fifth National Physical Fitness Surveillance in Shanghai, latent class analysis (LCA) was used to identify multimorbidity patterns among 9 chronic diseases. Multinomial logistic regression was performed to analyze the associations between sedentary time, sleep duration, physical exercise, and the different multimorbidity patterns. Weighted analysis was performed to appropriately account for complex sampling designs and provide more robust results.

Results Among 13,465 study participants (unweighted mean age 69.3 years; weighted mean age 67.4 years, 50.7% female), the overall prevalence of multimorbidity was 40.9%–42.3%. Four latent classes among the older adults were identified, with the relatively healthy class (63.6%–64.6%) had an average of less than 1 chronic disease. The other 3 classes, namely the metabolic-cardiovascular-joint-digestive-respiratory disease class (2.9%–3.0%), the metabolic-cardiovascular disease class (14.5%–15.5%), and the joint-digestive-respiratory disease class (17.9%–18.0%), each had an average of more than 2 chronic diseases, representing different multimorbidity patterns. Prolonged sedentary time (> 3 h/day) increased the odds of belonging to the metabolic-cardiovascular-joint-digestive-respiratory disease class by 56%–57% (unweighted odds ratio [OR] 1.57, 95% confidence interval [CI] 1.27–1.94; weighted OR 1.56, 95%

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CI 1.36–1.80), the metabolic-cardiovascular disease class by 38% (unweighted OR 1.38, 95% CI 1.25–1.53; weighted OR 1.38, 95% CI 1.29–1.48), and the joint-digestive-respiratory disease class by 30%–32% (unweighted OR 1.32, 95% CI 1.19–1.45; weighted OR 1.30, 95% CI 1.22–1.38). Shorter sleep duration (< 7 h/day) also increased the odds of membership in the metabolic-cardiovascular disease class by 48%–49% (unweighted OR 1.49, 95% CI 1.35–1.65; weighted OR 1.48, 95% CI 1.38–1.58), the metabolic-cardiovascular-joint-digestive-respiratory disease class by 37%–47% (unweighted OR 1.47, 95% CI 1.19–1.80; weighted OR 1.37, 95% CI 1.19–1.58), and the joint-digestive-respiratory disease class by 41%–42% (unweighted OR 1.42, 95% CI 1.29–1.56; weighted OR 1.41, 95% CI 1.32–1.50). Each additional daily hour of low-intensity physical exercise (LIPE) reduced the odds of membership in the metabolic-cardiovascular-joint-digestive-respiratory disease class by 24%–25% (unweighted OR 0.76, 95% CI 0.64–0.90; weighted OR 0.75, 95% CI 0.66–0.84), the joint-digestive-respiratory disease class by 20%–21% (unweighted OR 0.79, 95% CI 0.73–0.86; weighted OR 0.80, 95% CI 0.76–0.85), and the metabolic-cardiovascular disease class by 11%–12% (unweighted OR 0.88, 95% CI 0.81–0.95; weighted OR 0.89, 95% CI 0.85–0.94). Compared to LIPE, high-intensity physical exercise (HIPE) showed a significant advantage only in reducing the odds of the metabolic-cardiovascular disease class by 18%–23% (unweighted OR 0.77, 95% CI 0.62–0.97; weighted OR 0.82, 95% CI 0.71–0.95).

Conclusions Over 40% of older adults in Shanghai, China, suffer from multimorbidity. Prolonged sedentary behavior and shorter sleep duration were associated with membership in the metabolic-cardiovascular-joint-digestive-respiratory disease class, the metabolic-cardiovascular disease class, and the joint-digestive-respiratory disease class. Physical exercise showed varying degrees of protection against these 3 multimorbidity patterns, with special attention warranted for LIPE. Identifying the relationship between determinants of lifestyle behavior and patterns of multimorbidity can help develop more targeted prevention and management strategies.

Keywords Multimorbidity, Sedentary, Sleep, Physical exercise, Shanghai, China

Background

Multimorbidity is typically defined as the simultaneous presence of at least 2 chronic diseases in an individual [1]. With lifestyle changes and an aging population, multimorbidity is becoming increasingly common, with evidence suggesting that over 1/3 of the global population may be affected [2]. Compared to patients with a single chronic disease, those with multimorbidity face more complex health challenges, often leading to increased healthcare resource consumption, reduced quality of life, and even premature death [3]. As a result, multimorbidity is recognized as a major challenge to global health systems [4].

China currently has the largest older adult population in the world and is experiencing the fastest rate of aging [5]. By 2040, the population aged 60 and above is projected to exceed 400 million, accounting for approximately 28% of the total population [6]. Multimorbidity impose a significant disease burden on Chinese society. Previous studies have shown that 35.7% to 66.3% of Chinese older adults suffer from multimorbidity [7–10], with prevalence rates varying depending on the age of the study population and the types of chronic diseases considered. Shanghai is one of the first cities in China to enter an aging society and has a relatively higher degree of aging [11]. Previous studies have shown that the prevalence of multimorbidity among older adults in Shanghai may be as high as 49.2% to 74.3% [12–14].

The causes of multimorbidity are highly complex, but among the associated risk factors, determinants of lifestyle behavior undoubtedly play a crucial role [15, 16]. Adopting a healthier lifestyle is considered a key strategy in the prevention and management of multimorbidity [17]. Sedentary behavior is defined as any waking activity with an energy cost of ≤ 1.5 metabolic equivalents (METs) while sitting, reclining, or lying down [18]. Previous studies have shown that prolonged sedentary behavior (≥ 8 h/day) is a significant risk factor for chronic diseases and multimorbidity in older adults [19]. More recent research indicates that even a lower cutoff value (3 h/day) is associated with the prevalence of multimorbidity, with exceeding this threshold increasing the odds by 11% to 39% [20]. Additionally, evidence shows that older adults with sleep problems are more likely to suffer from multimorbidity [21]. Poor sleep quality and shorter sleep duration (< 7 h/day) are both positively associated with the prevalence of multimorbidity [22–24]. Moreover, a lack of physical activity also increases the risk of multimorbidity [25, 26], making increased physical activity (both in intensity and duration) a protective factor against multimorbidity. Evidence shows that increasing physical activity can effectively reduce the risk of multimorbidity in the general population and the risk of all-cause mortality in individuals with multimorbidity [27–30]. As a form of physical activity, exercise, also known as leisure-time physical activity (LTPA), offers similar protective effects against multimorbidity as other forms of physical activity

[31, 32]. Individuals with multimorbidity may benefit even more from increased physical activity than the general population [33]. However, previous studies in China on the association between determinants of lifestyle behavior and multimorbidity have rarely considered and discussed the combined effects of sedentary behavior, sleep, and physical activity on multimorbidity. A broader definition of physical activity should also encompass sedentary behavior and sleep [34]. Moreover, existing studies on the determinants of lifestyle behavior and multimorbidity often focus on a binary classification—Whether there is multimorbidity or not—while exploration of the heterogeneity of different multimorbidity patterns is relatively limited. This limitation hinders the development of detailed lifestyle behavior intervention policies targeting multimorbidity among older adults in China.

Therefore, based on data from the Fifth National Physical Fitness Surveillance of older adults aged 60–79 in Shanghai, our study aims to (a) examine the prevalence and patterns of multimorbidity among older adults in Shanghai; and (b) identify the associations between sedentary time, sleep duration, physical exercise, and different multimorbidity patterns.

Methods

Data sources and sampling procedures

The National Physical Fitness Surveillance is a repeated cross-sectional design nationally representative sampling survey conducted every five years, aimed at systematically assessing the physical fitness and exercise health of the population. The survey covers children aged 3–6, adults aged 20–59, and older adults aged 60–79. Since baseline at 2000, five rounds of this survey have been completed, with details of the fifth survey available in the "Fifth National Physical Fitness Surveillance Implementation Plan" [35].

The 2020 survey in Shanghai was conducted by the Shanghai Research Institute of Sports Science (SHRISS), following the stratified random cluster sampling procedure of China's National Physical Fitness Surveillance, which has been described in detail elsewhere [36]. The sampling procedure for Shanghai included the following steps: (1) selecting all districts from both urban and rural areas, (2) randomly choosing streets from districts and towns in counties, (3) randomly selecting residential communities or villages from the chosen streets and towns, (4) systematically sampling (to ensure equal numbers per gender-age group) eligible participants from selected communities and villages, who were permanent residents of Shanghai, and (5) each sampling point (selected community or village) may slightly increase the sample size, but in principle, the proportion should not exceed 5%. Our study was approved by the ethics committee of Shanghai Research Institute of Sports Science (SHRISS). All participants provided informed consent.

Study design and population

This study was conducted as a cross-sectional analysis on the data of the Fifth National Physical Fitness Surveillance in Shanghai, 2020. The final effective sample size for older adults was 14,026. A total of 488 participants were excluded due to missing clear chronic disease diagnoses or necessary diagnostic information, 34 were excluded for missing data on physical exercise, and another 39 were excluded due to missing key covariate information. Ultimately, 13,465 participants were included in the study. The detailed participant selection process is shown in Fig. 1.

Chronic diseases and multimorbidity

Nine chronic diseases were included in the study based on the availability of data, as the common chronic diseases in China are included in the national physical fitness surveillance, 8 of which—namely hypertension, joint disease, dyslipidemia, diabetes, heart disease, osteoporosis, digestive disease, and respiratory disease—were identified based on responses to the question, "Have you been diagnosed with any of the following conditions by a hospital?". Additionally, the prevalence of obesity was determined using waist circumference data (measured by interviewers at the midpoint between the lower margin of the last rib and the iliac crest to the nearest 0.1 cm, with participants standing and their feet 25–30 cm apart) according to the diagnostic criteria for central obesity in China [37, 38] (waist circumference $\geq$ 90.0 cm for males and $\geq$ 85.0 cm for females). Multimorbidity was defined as the co-occurrence of at least 2 chronic diseases in the same individual.

Sedentary time, sleep duration, and physical exercise

Sedentary time was defined as the self-reported total time spent each day on desk-bound work and sedentary leisure activities (e.g., reading, watching TV, playing chess). Based on the evidence from previous study [20], we used 3 h per day as the cutoff value. Sleep duration was based on participants' self-reported average daily sleep time. Participants were asked, "How many hours and minutes do you usually sleep each day, including naps?" This was converted to hours, with 7 h per day used as the cutoff value based on the results of previous research [24]. Physical exercise was measured as the self-reported total minutes of exercise per week at various intensities, which we converted into daily

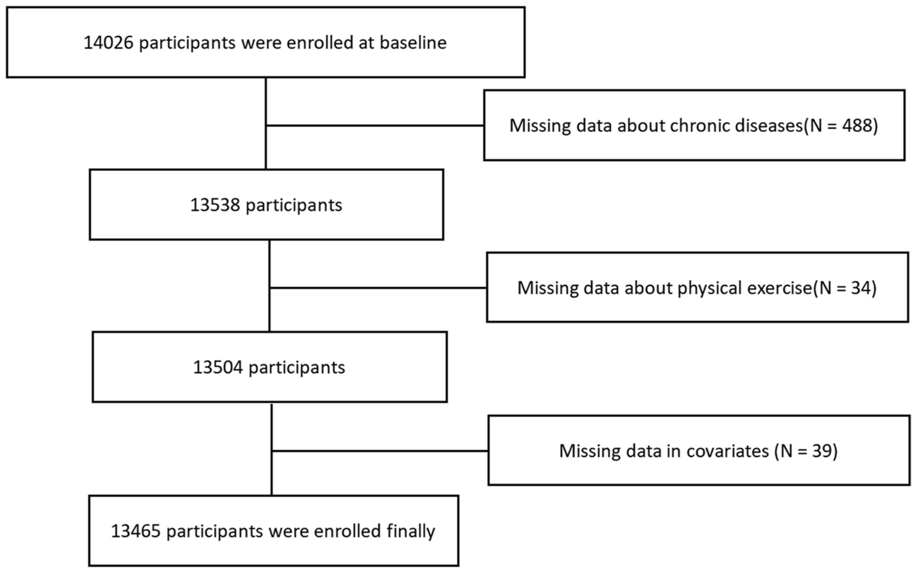

Fig. 1 Flowchart of participant selection for present study

exercise hours. Low-intensity physical exercise (LIPE) was defined as activities where breathing and heart rate remain stable, with no significant exertion (e.g., walking). Moderate-intensity physical exercise (MIPE) involved increased breathing and heart rate but was not strenuous, with light sweating (e.g., cycling). High-intensity physical exercise (HIPE) was characterized by rapid breathing, a noticeable increase in heart rate, and significant sweating (e.g., running).

Covariates
Sociodemographic variables and health-related factors previously shown to be associated with multimorbidity or physical exercise were included in the analysis. The sociodemographic variables included place of residence (urban, rural, suburban), age (years), gender (male, female), education level (never attended school, primary school, middle school, high school or above), marital status (married, widowed/divorced/unmarried), living situation (living with others, living alone), and whether there were sports facilities in the residential community. These variables were obtained through a questionnaire survey. Similarly, the variables of smoking status (never, current, former) and alcohol consumption (never, less than 1 time per month, 1 time per month or more) were also based on participants' self-reported results. The BMI and grip strength variables are obtained through standardized physical measurements with calibrated digital scale, calibrated stadiometer and hand grip strength test. Most covariates have already been determined at the baseline of the survey in 2000.

Risk of bias
In this study, we took the following measures to reduce potential bias. First, we hired trained interviewers and used rigorous, validated questionnaires to collect data. Secondly, we used a cluster random sampling frame covering all administrative districts in the city. Moreover, older adults with exercise contraindications were not included in the study, therefore some acute respiratory diseases such as COVID-19 can be excluded. Furthermore, we have weighted the analyses to appropriately consider complex sampling designs. Finally, we used cross-validation of some items in the questionnaire to check the reliability of the data.

Statistical analysis
We weighted the analyses to appropriately consider complex sampling designs. Based on previous research practice [36], the weights were derived for the 2020 older adult population statistics released by the Shanghai Civil Affairs Department [39]. Since the sampling points already account for the distribution of the older adult population, the weighting primarily considers gender and age groups.

The study population was described as follows: categorical variables were presented as numbers (percentages), continuous variables as means ± standard deviations (SD), and non-normally distributed continuous variables were additionally described using medians with interquartile ranges (IQR). Chi-square tests and T-tests were used to assess differences in these characteristics between males and females.

Latent class analysis (LCA) was used to analyze multimorbidity patterns. LCA is a model-based, person-centered statistical method that identifies latent subgroups based on participants' response patterns to categorical variables [40], allowing for the identification of distinct multimorbidity patterns from the presence of nine chronic diseases without requiring prior assumptions about these patterns. The optimal number of latent classes was determined by considering both clinical interpretability and model fit indices, including Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and entropy [41], as these indices varied with the number of latent classes. Each latent class was named based on the chronic disease with the highest prevalence within that class [42]. After conducting latent class analysis, multinomial logistic regression was performed to assess the associations between sedentary time, sleep duration, physical exercise and the odds of belonging to different multimorbidity patterns. Sociodemographic variables as well as covariates such as smoking and alcohol consumption were included in the regression model to control for possible confounders.

Statistical analyses were performed using R version 4.3.2. In all analyses, a p-value of less than 0.05 was considered statistically significant.

Results

The 13,465 participants had a mean unweighted age of 69.3 ± 5.5 years and weighted age of 67.4 ± 4.9, with a slightly higher proportion of female (50.7%). A total of 41.7% had an education level of high school or above, and most were married (89.6%). 34.6% of participants reported an average sedentary time of > 3 h per day, with a higher proportion in males than in females (36.2% vs. 33.0%, $p < 0.001$). 36.4% of participants had an average sleep duration of < 7 h per day, with a significantly higher proportion in females than in males (40.5% vs. 32.2%, $p < 0.001$). The results of the weighted analysis demonstrated only slight changes in these proportions. In terms of physical exercise, participants had an average low-intensity physical exercise (LIPE) time of 0.6 ± 0.6 h per day, with no significant gender difference. Participants had an average moderate-intensity physical exercise (MIPE) time of 0.2 ± 0.5 h per day, with IQR indicating that females may engage more in MIPE than males (IQR: 0.0–0.1 h/day vs. 0.0–0.0, $p = 0.002$). The average high-intensity physical exercise (HIPE) time was 0.1 ± 0.3 h per day, with males having a higher average HIPE time than females (0.1 ± 0.3 h/day vs. 0.0 ± 0.2, $p < 0.001$). The weighted analysis results showed only minor changes in gender differences. Regarding chronic diseases, the 3 most prevalent conditions were obesity (38.9%), hypertension (38.2%), and joint disease (19.6%). The overall prevalence of multimorbidity (≥ 2 chronic diseases) was 42.3% ($n = 5701$), with a higher prevalence in females than in males (44.9% vs. 39.7%, $p < 0.001$). The weighted prevalence of multimorbidity was 40.9%, prevalence in females is still higher than male (43.2% vs. 38.6%, $p < 0.001$). The details are shown in Table 1.

Latent class analysis (LCA) results

Based on clinical interpretability and model fit, the final LCA model identified 4 latent classes. The parameters used to determine the optimal number of latent classes are shown in Table 2, and the response probabilities for different chronic diseases within each latent class are illustrated in Fig. 2.

The names of the latent classes were determined based on the distribution of chronic disease prevalence within each class. Class 1 had a low probability of obesity and hypertension, with a lower likelihood of developing chronic diseases compared to other latent classes, and was therefore labeled the relatively healthy class. Class 2 had a higher probability of developing various chronic diseases compared to the other latent classes and was thus labeled the metabolic-cardiovascular-joint-digestive-respiratory disease class. Class 3 had a higher probability of developing metabolic and cardiovascular diseases such as obesity, hypertension, heart disease, and diabetes, and was therefore labeled the metabolic-cardiovascular disease class. Class 4 had a higher probability of developing joint, digestive and respiratory disease and was labeled the joint-digestive-respiratory disease class.

Table 3 presents the sample size, mean age, average number of chronic diseases, gender distribution, sedentary time, sleep duration, and physical exercise levels for each latent class. Among the four latent classes, the relatively healthy class had the highest proportion (unweighted: 63.6%; weighted: 64.6%), while the metabolic-cardiovascular-joint-digestive-respiratory disease class had the lowest (unweighted: 3.0%; weighted: 2.9%). The joint-digestive-respiratory disease class (unweighted: 17.9%; weighted: 18.0%) and the metabolic-cardiovascular disease class (unweighted: 15.5%; weighted: 14.5%) fell in between. The metabolic-cardiovascular-joint-digestive-respiratory disease class had the highest mean age (unweighted: 70.5 ± 5.0 years; weighted: 68.8 ± 4.8 years), while the relatively healthy class was the youngest (unweighted: 69.0 ± 5.5 years; weighted: 67.2 ± 4.9 years). The weighted and unweighted age differences are both statistically significant ($p < 0.001$). The metabolic-cardiovascular-joint-digestive-respiratory disease class also had the highest proportion of females

Table 1 Unweighted and weighted study characteristics, stratified by gender

Characteristic	Total (N = 13465)	Gender		p-value
		Male (N = 6641)	Female (N = 6824)	
Residence				0.667
Rural	3170 (23.5)	1579 (23.8)	1591 (23.3)	
Urban	6213 (46.1)	3039 (45.8)	3174 (46.5)	
Suburban	4082 (30.3)	2023 (30.5)	2059 (30.2)	
Age (years)				
Unweighted	69.3 ± 5.5	69.3 ± 5.5	69.2 ± 5.5	0.103
Weighted	67.4 ± 4.9	67.5 ± 4.9	67.4 ± 4.9	<0.001
Education Level				<0.001
Never attended	544 (4.0)	115 (1.7)	429 (6.3)	
Primary school	2537 (18.8)	1065 (16.0)	1472 (21.6)	
Junior high school	4767 (35.4)	2346 (35.3)	2421 (35.5)	
High school or above	5617 (41.7)	3115 (46.9)	2502 (36.7)	
Marital Status				<0.001
Married	12061 (89.6)	6239 (93.9)	5822 (85.3)	
Widowed/divorced/unmarried	1404 (10.4)	402 (6.1)	1002 (14.7)	
Living Situation				<0.001
Living with others	12491 (92.8)	6324 (95.2)	6167 (90.4)	
Living alone	974 (7.2)	317 (4.8)	657 (9.6)	
Community Sports Facilities	12834 (95.3)	6334 (95.4)	6500 (95.3)	0.762
BMI (kg/m^2)	24.3 ± 3.0	24.5 ± 2.9	24.1 ± 3.1	<0.001
Grip Strength (kg)	29.5 ± 8.7	35.8 ± 7.4	23.4 ± 4.6	<0.001
Smoking Status				<0.001
Never	10019 (74.4)	3384 (51.0)	6635 (97.2)	
Current	2565 (19.0)	2393 (36.0)	172 (2.5)	
Former	881 (6.5)	864 (13.0)	17 (0.2)	
Alcohol Consumption				<0.001
Never	9924 (73.7)	3557 (53.6)	6367 (93.3)	
Less than 1 time per month	854 (6.3)	675 (10.2)	179 (2.6)	
1 time per month or more	2687 (20.0)	2409 (36.3)	278 (4.1)	
Sedentary Time				
Unweighted				<0.001
> 3h/day	4657 (34.6)	2403 (36.2)	2254 (33.0)	
≤ 3h/day	8808 (65.4)	4238 (63.8)	4570 (67.0)	
Weighted				0.016
> 3h/day	4791 (35.6)	2456 (37.0)	2335 (34.2)	
≤ 3h/day	8674 (64.4)	4182 (63.0)	4492 (65.8)	
Sleep Duration				
Unweighted				
≥ 7h/day	8558 (63.6)	4501 (67.8)	4057 (59.5)	<0.001
< 7h/day	4907 (36.4)	2140 (32.2)	2767 (40.5)	
Weighted				<0.001
≥ 7h/day	8644 (64.2)	4534 (68.3)	4110 (60.2)	
< 7h/day	4821 (35.8)	2104 (31.7)	2717 (39.8)	
LIPE (h/day)				
Unweighted	0.6 ± 0.6	0.6 ± 0.6	0.6 ± 0.6	0.664
	0.4 (0.0–1.0)	0.4 (0.0–1.0)	0.4 (0.0–1.0)	
Weighted	0.6 ± 0.6	0.6 ± 0.6	0.6 ± 0.6	0.872
	0.4 (0.0–1.0)	0.4 (0.0–1.0)	0.5 (0.0–1.0)	

Table 1 (continued)

Characteristic	Total (*N* = 13465)	Gender		*p*-value
		Male (*N* = 6641)	Female (*N* = 6824)	
MIPE (h/day)				
Unweighted	0.2 ± 0.5	0.2 ± 0.5	0.2 ± 0.5	0.002
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.1)	
Weighted	0.2 ± 0.5	0.2 ± 0.5	0.2 ± 0.6	0.003
	0.0 (0.0–0.1)	0.0 (0.0–0.0)	0.0 (0.0–0.1)	
HIPE (h/day)				
Unweighted	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.2	<0.001
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	
Weighted	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.3	0.026
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	
Obesity	5236 (38.9)	2564 (38.6)	2672 (39.2)	0.526
Hypertension	5149 (38.2)	2625 (39.5)	2524 (37.0)	0.003
Joint Disease	2634 (19.6)	1030 (15.5)	1604 (23.5)	<0.001
Dyslipidemia	2157 (16.0)	874 (13.2)	1283 (18.8)	<0.001
Diabetes	1363 (10.1)	709 (10.7)	654 (9.6)	0.038
Heart Disease	1100 (8.2)	471 (7.1)	629 (9.2)	<0.001
Osteoporosis	1099 (8.2)	299 (4.5)	800 (11.7)	<0.001
Digestive Disease	909 (6.8)	424 (6.4)	485 (7.1)	0.102
Respiratory Disease	541 (4.0)	271 (4.1)	270 (4.0)	0.747
Multimorbidity				
Unweighted	5701 (42.3)	2638 (39.7)	3063 (44.9)	<0.001
Weighted	5511 (40.9)	2562 (38.6)	2949 (43.2)	<0.001
Number of Chronic Diseases				
Unweighted	1.5 ± 1.4	1.4 ± 1.3	1.6 ± 1.4	<0.001
Weighted	1.5 ± 1.4	1.4 ± 1.3	1.5 ± 1.4	<0.001

All categorical variables: n (%). All continuous variables: Mean ± SD. LIPE, MIPE, HIPE: Mean ± SD & Median (IQR). All unweighted categorical variables: Pearson's Chi-squared test. All unweighted continuous variables: Welch Two Sample t-test. All weighted categorical variables: chi-squared test with Rao & Scott's second-order correction. All weighted continuous variables: t-test adapted to complex survey samples

Table 2 Key parameters for determining the optimal number of latent classes

Number of latent class	Number of parameters	G2	df	AIC	BIC	X2	Entropy	Maximum log-likelihood
2	19	1642.5	492	93271.7	93414.4	2137.9	3.5	-46616.9
3	29	876.7	482	92525.9	92743.7	1286.5	3.4	-46234.0
4	39	588.1	472	92257.3	92550.1	657.5	3.4	-46089.7
5	49	534.5	462	92223.7	92591.6	614.6	3.4	-46062.8
6	59	470.6	452	92179.8	92622.8	524.5	3.4	-46030.9
7	69	445.9	442	92175.1	92693.1	501.8	3.4	-46018.5
8	79	425.8	432	92175.0	92768.2	486.1	3.4	-46008.5
9	89	439.4	422	92208.7	92876.9	473.8	3.4	-46015.3
10	99	401.0	412	92190.2	92933.4	424.7	3.4	-45996.1

(unweighted: 68.8%; weighted: 69.6%), whereas the relatively healthy class had the highest proportion of males (unweighted: 52.5%; weighted: 52.4%). The differences are also significant ($p < 0.001$). In terms of chronic disease prevalence, the metabolic-cardiovascular-joint-digestive-respiratory disease class had the highest unweighted average number of chronic diseases, while the relatively healthy class had the lowest (5.4 ± 1.0 vs.

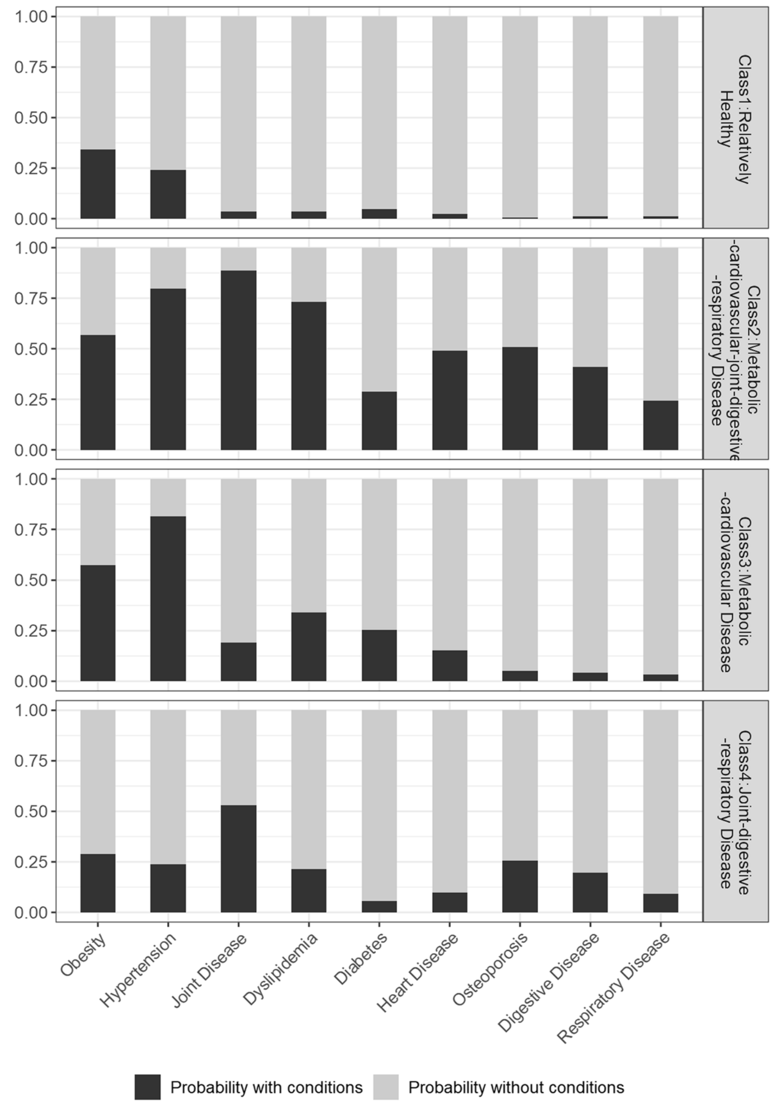

Fig. 2 Comparison of response probabilities of 4 latent classes to 9 chronic diseases

0.8 ± 0.7, $p < 0.001$). The weighted analysis results showed only minor changes in average number of chronic diseases (5.4 ± 1.0 vs. 0.7 ± 0.7, $p < 0.001$). The metabolic-cardiovascular-joint-digestive-respiratory disease class, metabolic-cardiovascular disease class, and joint-digestive-respiratory disease class each had an average of 2 chronic diseases and above. Therefore, they represented typical multimorbidity patterns. In contrast, the relatively healthy class had an average of less than 1 chronic disease and was used as the reference group.

In terms of lifestyle behaviors, the metabolic-cardiovascular-joint-digestive-respiratory disease class had the highest unweighted proportion of participants with an average sedentary time of > 3 h/day, while the relatively healthy class had the lowest (42.0% vs. 32.2%, $p < 0.001$). The weighted analysis results showed slight growth in the proportion, while the difference remains significant (42.7% vs. 33.3%, $p < 0.001$). Similarly, the metabolic-cardiovascular-joint-digestive-respiratory disease class had the highest unweighted proportion of participants with an average sleep duration of < 7 h/day, while the relatively healthy class had the lowest (44.7% vs. 32.7%, $p < 0.001$). The weighted analysis results showed slight decline in the proportion, while the difference remains significant (42.6% vs. 32.4%, $p < 0.001$). In terms of physical exercise, the average unweighted LIPE time in the metabolic-cardiovascular-joint-digestive-respiratory disease class, metabolic-cardiovascular disease class, and joint-digestive-respiratory disease class was lower than in the relatively healthy class (0.5 ± 0.6 h/day vs. 0.6 ± 0.6, $p < 0.001$).

Table 3 Unweighted and weighted main characteristics of study participants, stratified by latent classes

Characteristic	Latent Classes				p-value
	Class1: Relatively Healthy (N = 8561)	**Class2: Metabolic-cardiovascular-joint-digestive-respiratory Disease (N = 407)**	**Class3: Metabolic-cardiovascular Disease (N = 2089)**	**Class4: Joint-digestive-respiratory Disease (N = 2408)**	
Age					
Unweighted	69.0 ± 5.5	70.5 ± 5.0	70.4 ± 5.4	69.2 ± 5.4	<0.001
Weighted	67.2 ± 4.9	68.8 ± 4.8	68.4 ± 5.0	67.4 ± 4.8	<0.001
Number of Chronic Diseases					
Unweighted	0.8 ± 0.7	5.4 ± 1.0	3.0 ± 0.8	2.2 ± 0.9	<0.001
Weighted	0.7 ± 0.7	5.4 ± 1.0	3.0 ± 0.8	2.1 ± 0.9	<0.001
Gender					
Unweighted					<0.001
Male	4498 (52.5)	127 (31.2)	1047 (50.1)	969 (40.2)	
Female	4063 (47.5)	280 (68.8)	1042 (49.9)	1439 (59.8)	
Weighted					<0.001
Male	4558 (52.4)	119 (30.4)	1005 (51.5)	950 (39.2)	
Female	4140 (47.6)	272 (69.6)	947 (48.5)	1474 (60.8)	
Sedentary Time					
Unweighted					<0.001
> 3h/day	2755 (32.2)	171 (42.0)	808 (38.7)	923 (38.3)	
≤ 3h/day	5806 (67.8)	236 (58.0)	1281 (61.3)	1485 (61.7)	
Weighted					<0.001
> 3h/day	2896 (33.3)	167 (42.7)	781 (40.0)	953 (39.3)	
≤ 3h/day	5802 (66.7)	224 (57.3)	1171 (60.0)	1471 (60.7)	
Sleep Duration					
Unweighted					<0.001
≥ 7h/day	5764 (67.3)	225 (55.3)	1190 (57.0)	1379 (57.3)	
< 7h/day	2797 (32.7)	182 (44.7)	899 (43.0)	1029 (42.7)	
Weighted					<0.001
≥ 7h/day	5880 (67.6)	224 (57.4)	1132 (58.0)	1406 (58.0)	
< 7h/day	2818 (32.4)	167 (42.6)	820 (42.0)	1018 (42.0)	
LIPE (h/day)					
Unweighted	0.6 ± 0.6	0.5 ± 0.6	0.5 ± 0.6	0.5 ± 0.6	<0.001
	0.5 (0.0–1.0)	0.4 (0.0–1.0)	0.4 (0.0–1.0)	0.4 (0.0–1.0)	
Weighted	0.6 ± 0.7	0.5 ± 0.6	0.5 ± 0.6	0.5 ± 0.6	0.153
	0.5 (0.0–1.0)	0.4 (0.0–1.0)	0.4 (0.0–1.0)	0.4 (0.0–1.0)	
MIPE (h/day)					
Unweighted	0.2 ± 0.5	0.2 ± 0.4	0.2 ± 0.5	0.2 ± 0.5	0.004
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.1)	
Weighted	0.2 ± 0.5	0.2 ± 0.4	0.2 ± 0.5	0.2 ± 0.5	0.003
	0.0 (0.0–0.1)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.1)	
HIPE (h/day)					
Unweighted	0.1 ± 0.3	0.0 ± 0.2	0.0 ± 0.2	0.1 ± 0.3	0.002
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	
Weighted	0.1 ± 0.3	0.0 ± 0.2	0.0 ± 0.2	0.1 ± 0.3	0.070
	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	

All categorical variables: n (%). All continuous variables: Mean ± SD. LIPE, MIPE, HIPE: Mean ± SD & Median (IQR). All unweighted categorical variables: Kruskal-Wallis rank sum test. All unweighted continuous variables: One-way ANOVA. All weighted variables: Kruskal-Wallis rank-sum test for complex survey samples

The weighted analysis results demonstrated only minor changes in average LIPE time in relatively healthy class (0.6 ± 0.7 h/day). A relatively significant difference in unweighted MIPE time was observed only between the metabolic-cardiovascular-joint-digestive-respiratory disease class and the relatively healthy class (0.2 ± 0.4 h/day vs. 0.2 ± 0.5, $p = 0.004$). The weighted analysis results showed only slight changes in average MIPE time. The average unweighted HIPE time in the metabolic-cardiovascular-joint-digestive-respiratory disease class and metabolic-cardiovascular disease class was significantly lower than that in the relatively healthy class (0.0 ± 0.2 h/day vs. 0.1 ± 0.3, $p = 0.002$). The weighted analysis results also demonstrated only slight changes in average HIPE time. The details are shown in Table 3.

Multinomial logistic regression results

Multinomial logistic regression was performed to examine the associations between sedentary time, sleep duration, physical exercise, and multimorbidity patterns, while controlling for sociodemographic and health-related covariates. The results of the multinomial logistic regression showed that, compared to the relatively healthy class, an average sedentary time of > 3 h/day increased the odds of belonging to the metabolic-cardiovascular-joint-digestive-respiratory disease class by 56%–57% (unweighted odds ratio [OR] 1.57, 95% confidence interval [CI] 1.27–1.94; weighted OR 1.56, 95% CI 1.36–1.80). It also increased the odds of membership in the metabolic-cardiovascular disease class by 38% (unweighted OR 1.38, 95% CI 1.25–1.53; weighted OR 1.38, 95% CI 1.29–1.48) and the joint-digestive-respiratory disease class by 30%–32% (unweighted OR 1.32, 95% CI 1.19–1.45; weighted OR 1.30, 95% CI 1.22–1.38). Similarly, an average sleep duration of < 7 h/day increased the odds of membership in the metabolic-cardiovascular disease class by 48%–49% (unweighted OR 1.49, 95% CI 1.35–1.65; weighted OR 1.48, 95% CI 1.38–1.58), metabolic-cardiovascular-joint-digestive-respiratory disease class by 37%–47% (unweighted OR 1.47, 95% CI 1.19–1.80; weighted OR 1.37, 95% CI 1.19–1.58), and the joint-digestive-respiratory disease class by 41%–42% (unweighted OR 1.42, 95% CI 1.29–1.56; weighted OR 1.41, 95% CI 1.32–1.50).

In terms of physical exercise, for each additional hour per day of LIPE, the odds of belonging to the metabolic-cardiovascular-joint-digestive-respiratory disease class, the joint-digestive-respiratory disease class, and the metabolic-cardiovascular disease class decreased by 24%–25% (unweighted OR 0.76, 95% CI 0.64–0.90; weighted OR 0.75, 95% CI 0.66–0.84), 20%–21% (unweighted OR 0.79, 95% CI 0.73–0.86; weighted OR 0.80, 95% CI 0.76–0.85), and 11%–12% (unweighted OR 0.88, 95% CI 0.81–0.95; weighted OR 0.89, 95% CI 0.85–0.94), respectively. For each additional hour per day of MIPE, the odds of membership in the metabolic-cardiovascular-joint-digestive-respiratory disease class and joint-digestive-respiratory disease class decreased by 26%–30% (unweighted OR 0.74, 95% CI 0.58–0.94; weighted OR 0.70, 95% CI 0.59–0.82) and 15%–17% (unweighted OR 0.85, 95% CI 0.77–0.94; weighted OR 0.83, 95% CI 0.78–0.88), respectively. The weighted analysis results indicated that MIPE was negatively associated with membership in the metabolic-cardiovascular disease class, although the association was very weak (weighted OR 0.92, 95% CI 0.86–0.98). Moreover, each additional hour per day of HIPE reduced the odds of belonging to the metabolic-cardiovascular disease class by 18%–23% (unweighted OR 0.77, 95% CI 0.62–0.97; weighted OR 0.82, 95% CI 0.71–0.95). The weighted analysis results indicated that HIPE was also negatively associated with membership in the joint-digestive-respiratory disease class, although the association was very weak (weighted OR 0.89, 95% CI 0.80–0.99). The details are shown in Fig. 3.

Discussion

Although China's healthcare system is facing the challenges of multimorbidity due to an accelerating aging population, there are relatively few epidemiological studies on the determinants of lifestyle behavior related to multimorbidity in this context. This study, based on data from the Fifth National Physical Fitness Surveillance, examined the prevalence and patterns of multimorbidity among older adults in Shanghai, China, and their associations with key determinants of lifestyle behavior (sedentary time, sleep duration, and physical exercise).

Our results showed that 40.9%–42.3% of older adults aged 60–79 in Shanghai, China, had multimorbidity. This prevalence is relatively lower than previous studies conducted on older adults in Shanghai (49.2%–74.3% [12–14]) and also below the estimate from a meta-analysis of 126 global multimorbidity studies, which reported a prevalence of 51.0% (95% CI 44.1%–58.0%) [2] among individuals aged 60 and above.

This discrepancy is likely due to differences in the types of chronic diseases studied and the characteristics of the study populations. On one hand, this study only included 9 physical chronic diseases, while cognitive and psychological disorders were not included in the study. On the other hand, older adults (≥ 80 years) and those with exercise contraindications were not included. However, the overall multimorbidity prevalence of over 40% underscores the seriousness of the multimorbidity among older adults. The 3 most common chronic diseases were obesity, hypertension, and joint disease. Previous studies

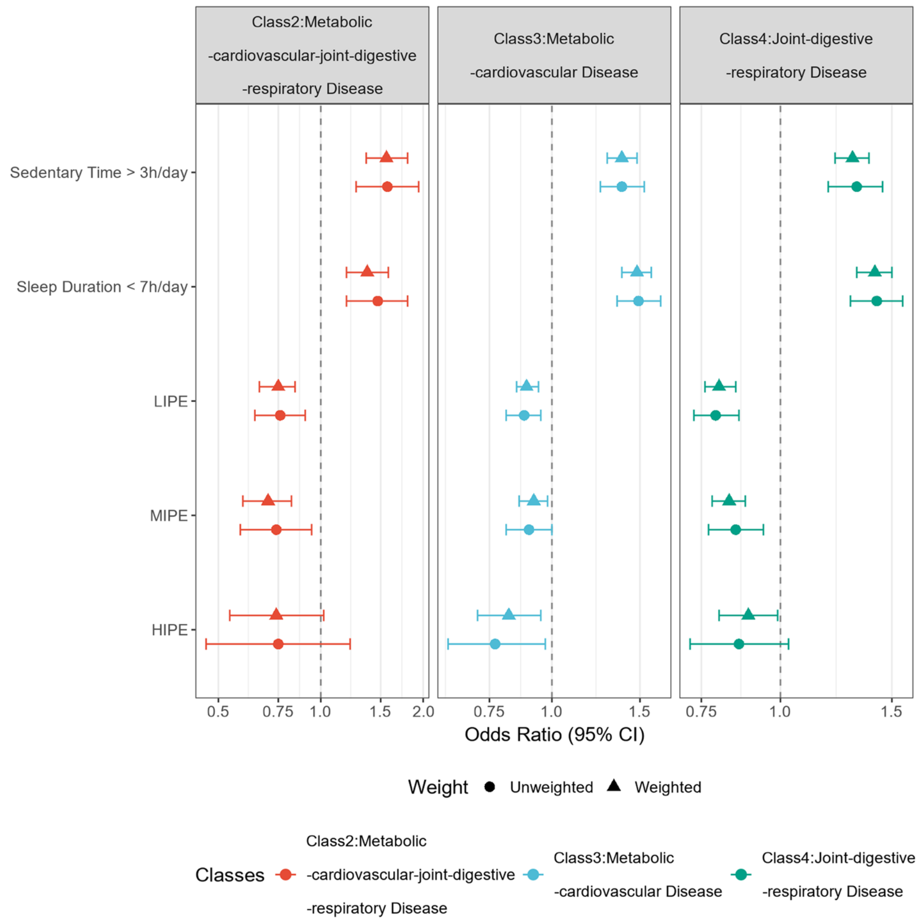

Fig. 3 Unweighted and weighted associations between sedentary time, sleep duration, physical exercise, and multimorbidity patterns

have shown a correlation between obesity, cardiovascular disease, and joint disease due to underlying metabolic-inflammatory pathways [43].

Based on LCA, we identified 4 latent classes among the older adults in Shanghai. The relatively healthy class had an average of less than 1 chronic disease, which served as the reference group. The other 3 classes, namely the metabolic-cardiovascular-joint-digestive-respiratory disease class, the metabolic-cardiovascular disease class, and the joint-digestive-respiratory disease class, each had an average of more than 2 chronic diseases, representing different multimorbidity patterns. Latent classes with similar chronic disease profiles, such as the relatively healthy class, the metabolic-cardiovascular disease class, and the metabolic-cardiovascular-joint-digestive-respiratory disease class, have also been identified in previous studies [41, 44], while we have named these classes more specifically. The naming of latent classes was based on the chronic disease with the highest prevalence within each class, a relatively straightforward method for describing and defining LCA model outcomes. Identifying these multimorbidity patterns with distinct chronic disease profiles will help in developing targeted multimorbidity intervention strategies.

The multimorbidity patterns were generally older than the relatively healthy class ($p < 0.001$), indicating that aging is a major factor contributing to multimorbidity, consistent with previous research findings [1]. The proportion of females was higher in all multimorbidity patterns compared to the relatively healthy class, and females had a higher prevalence of multimorbidity ($p < 0.001$), which aligns with previous research findings [45]. Previous evidence suggests that the higher prevalence of multimorbidity in females compared to males may be attributed to postmenopausal metabolic changes and underlying sociodemographic inequalities, such as educational attainment [46]. In our study, the proportion of females with an education level above high school was significantly lower than that of males (unweighted: 36.7% vs. 46.9%, $p < 0.001$; weighted: 38.1% vs. 47.6%, $p < 0.001$). Given the age and gender differences in multimorbidity prevalence, health intervention policies should place greater focus on older adult women. Health interventions should be developed from multiple perspectives, including sociodemographic and medical factors, to address gender health inequalities.

After controlling for other covariates, we further identified the associations between sedentary time, sleep duration, different intensities of physical exercise, and multimorbidity patterns. The results showed that sedentary time of more than 3 h per day increased the odds of membership in various multimorbidity patterns, with the highest increase in the metabolic-cardiovascular-joint-digestive-respiratory disease class (56%–57%) and the lowest in the joint-digestive-respiratory disease class (30%–32%). Previous study has also shown that sedentary time exceeding 3 h per day increases the risk of developing cardiovascular-metabolic multimorbidity by 39% (95% CI 29%–50%), and sedentary time exceeding 6 h per day raises this risk to 49% (95% CI 35%–64%) [20]. We found that sedentary time exceeding 3 h per day significantly increased the risk of developing the metabolic-cardiovascular-joint-digestive-respiratory disease class, suggesting that the health risks associated with prolonged sedentary behavior extend beyond the cardiovascular system. Additionally, evidence shows that sedentary behavior is an independent risk factor for multimorbidity, and the increased risk it poses is not mitigated by levels of physical activity [19]. Therefore, health intervention strategies should focus on reducing sedentary time by replacing it with more active behaviors [47].

A sleep duration of less than 7 h per day similarly increased the odds of membership in various multimorbidity patterns, with a 48%–49% increase for the metabolic-cardiovascular disease class, a 37%–47% increase for the metabolic-cardiovascular-joint-digestive-respiratory disease class and a 41%–42% increase for the joint-digestive-respiratory disease class. A previous study showed that shorter sleep duration (< 7 h/day) increased the odds of multimorbidity by 38%, which is similar to our findings, although that study did not further explore multimorbidity patterns. It also emphasized that moderate and poor sleep quality were positively associated with an increased risk of multimorbidity [23]. Another study indicated that shorter sleep duration is an independent risk factor for multimorbidity, regardless of socioeconomic and behavioral characteristics [24]. Therefore, sleep hygiene, like sedentary behavior, diet, and physical activity, should be a key component of health intervention policies.

Physical exercise in this study demonstrated a protective effect against multimorbidity. On average, each additional hour per day of low-intensity physical exercise (LIPE) reduced the odds of belonging to various multimorbidity patterns, ranging from a 24%–25% reduction in the metabolic-cardiovascular-joint-digestive-respiratory disease class to a 11%–12% reduction in the metabolic-cardiovascular disease class. Moderate-intensity physical exercise (MIPE) showed a slight advantage over LIPE in reducing the odds of belonging to metabolic-cardiovascular-joint-digestive-respiratory disease class (26%–30% vs. 24%–25%). High-intensity physical exercise (HIPE) demonstrated a significant advantage over LIPE in reducing the odds of membership in metabolic-cardiovascular disease class (18%–23% vs. 11%–12%). Earlier studies have primarily focused on the protective effects of moderate-to-vigorous physical activity (MVPA) on cardiovascular-metabolic risks [48]. However, in our results, neither MIPE nor HIPE showed significantly greater advantages over LIPE in multimorbidity patterns other than the metabolic-cardiovascular disease class. In fact, due to aging and other factors, adherence to MVPA guidelines among individuals over 60 is relatively low [49]. In the unweighted sample of our study, we observed that only 24.6% and 9.3% of older adults engaged in MIPE and HIPE, respectively. As an alternative to MVPA, low-intensity physical activity (LIPA) has also shown protective effects against cardiovascular-metabolic risks [50]. Evidence suggests that each additional hour of LIPA per day can reduce the odds of developing multimorbidity by 13% [51]. Therefore, balancing adherence and health benefits, promoting LIPE in addition to MIPE and HIPE is a prudent strategy for preventing and managing multimorbidity.

Our study shows that the LCA model is useful for identifying health disparities within the multimorbidity population. Combined with multinomial logistic regression, it can further determine the strength of associations between various multimorbidity patterns and different risk or protective factors. This approach can aid in developing targeted intervention strategies for different multimorbidity groups. Additionally, this method of identifying heterogeneity within the multimorbidity population can be applied to a wider range of healthcare settings in the future.

Strengths and limitations

To our knowledge, this is the first study based on data from the National Physical Fitness Surveillance to investigate associations between determinants of lifestyle behavior and multimorbidity patterns, utilizing appropriate and reliable statistical models for multimorbidity analysis. However, this study also has some potential limitations. First, due to limited data availability, it included only 9 chronic diseases, restricting the identification of multimorbidity patterns beyond this scope. Future surveys could cover more chronic diseases. Second, information on chronic disease diagnoses and lifestyle determinants was primarily self-reported. Although some quality control measures were in place (such as reminding participants that chronic diseases should be diagnosed by a hospital), some inaccuracies may still exist. Furthermore, since this study did not include people aged 80 and above and those with contraindications to exercise, caution should be exercised when extrapolating the results of this study to other groups. Lastly, as a cross-sectional study, it can identify associations between variables but cannot establish causality. Future longitudinal studies with a broader scope are needed to confirm the multimorbidity patterns among older adults in China and to explore their relationship with determinants of lifestyle behavior, including their impact on long-term health outcomes. Weighted analysis was performed to appropriately consider complex sampling designs. Compared to the unweighted analysis results, the weighted analysis showed only slight changes, indirectly indicating the robustness of our findings.

Conclusions

Over 40% of older adults in Shanghai, China, suffer from multimorbidity, with most common chronic diseases including obesity, hypertension, and joint disease. Using latent class analysis (LCA), we identified 3 multimorbidity patterns among older adults: the metabolic-cardiovascular-joint-digestive-respiratory disease class, the metabolic-cardiovascular disease class, and the joint-digestive-respiratory disease class, along with the relatively healthy class as a reference group. Multivariable regression results showed that an average sedentary time of > 3 h/day and a sleep duration of < 7 h/day increased the odds of membership in various multimorbidity patterns, while physical exercise reduced this risk to varying degrees. As a more accessible protective factor against multimorbidity, LIPE (low-intensity physical exercise) should receive greater attention. Future longitudinal studies are needed to evaluate the relationships between multimorbidity patterns, determinants of lifestyle behavior, and long-term health outcomes. Lastly, we hope future policies for multimorbidity prevention and management will consider the differences between multimorbidity patterns and implement more targeted intervention strategies to curb the rise of multimorbidity.

Abbreviations

MET	Metabolic Equivalent
LTPA	Leisure-Time Physical Activity
LIPE	Low-Intensity Physical Exercise
MIPE	Moderate-Intensity Physical Exercise
HIPE	High-Intensity Physical Exercise
SD	Standard Deviation
IQR	Interquartile Range
LCA	Latent Class Analysis
BIC	Bayesian Information Criterion
AIC	Akaike Information Criterion
OR	Odds Ratio
CI	Confidence Interval
MVPA	Moderate to Vigorous Physical Activity
LIPA	Low-Intensity Physical Activity

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Authors' contributions
D.W., C.W. and B.L. designed the study and contributed to the data analysis, data interpretation, reviewing and editing. K.L. contributed to the literature search, data analysis, data interpretation, and writing. J.W. interpreted the findings, reviewed and revised the manuscript. Y.R., F.Z., Y.C. and B.Z. contributed to the study design and interpretation of the findings. J.H. contributed to the data preprocessing and interpretation. All authors read and approved the final manuscript.

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Data availability
Upon a reasonable request, the datasets used during the current study are available from the corresponding authors.

Declarations

Ethics approval and consent to participate
This study was conducted in full accordance with the Declaration of Helsinki. Ethical approval for this study was granted by the Ethics Committee of Shanghai Institute of Sports Science (LLSC20230017). All study participants provided informed consent to participate in this study, after learning about the procedures involved. Participation was entirely voluntary; any participant was able to withdraw their consent at any time, without consequence.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Skou ST, Mair FS, Fortin M, Guthrie B, Nunes BP, Miranda JJ, et al. Multimorbidity Nat Rev Dis Primers. 2022;8:48.
2. Chowdhury SR, Das DC, Sunna TC, Beyene J, Hossain A. Global and regional prevalence of multimorbidity in the adult population in community settings: a systematic review and meta-analysis. eClinicalMedicine. 2023;57:101860.
3. Tran PB, Kazibwe J, Nikolaidis GF, Linnosmaa I, Rijken M, van Olmen J. Costs of multimorbidity: a systematic review and meta-analyses. BMC Med. 2022;20:234.

4. Pearson-Stuttard J, Ezzati M, Gregg EW. Multimorbidity—a defining challenge for health systems. The Lancet Public Health. 2019;4:e599-600.
5. Lancet T. Population ageing in China: crisis or opportunity? The Lancet. 2022;400:1821.
6. World Health Organization. Ageing and health - China. https://www.who.int/china/health-topics/ageing. Accessed 27 Jul 2024.
7. Hu Y, Wang Z, He H, Pan L, Tu J, Shan G. Prevalence and patterns of multimorbidity in China during 2002–2022: A systematic review and meta-analysis. Ageing Res Rev. 2024;93:102165.
8. Xiong F, Wang Y, Zhu J, Li S, Guan Q, Jing Z. Association of multimorbidity patterns with motoric cognitive risk syndrome among older adults: Evidence from a China longitudinal study. Int J Geriatr Psychiatry. 2023;38:e6021.
9. Li C, Zhou R, Yao N, Cornwell T, Wang S. Health Care Utilization and Unmet Needs in Chinese Older Adults With Multimorbidity and Functional Impairment. J Am Med Dir Assoc. 2020;21:806–10.
10. Chen Y, Ji H, Shen Y, Liu D. Chronic disease and multimorbidity in the Chinese older adults' population and their impact on daily living ability: a cross-sectional study of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). Arch Public Health. 2024;82:17.
11. Yu Z-Q, Chen L-P, Qu J-Q, Wu W-Z, Zeng Y. A study on the sustainability assessment of China's basic medical insurance fund under the background of population aging–evidence from Shanghai. Front Public Health. 2023;11:1170782.
12. Su P, Ding H, Zhang W, Duan G, Yang Y, Chen R, et al. The association of multimorbidity and disability in a community-based sample of elderly aged 80 or older in Shanghai. China BMC Geriatr. 2016;16:178.
13. Li C, Peng W, Li M, Li X, Yang T, Yan H, et al. Exploring the relationship between depression and different multimorbidity patterns among older people covered by long-term care insurance in Shanghai. China Psychogeriatrics. 2022;22:99–107.
14. Wang Z, Peng W, Li M, Li X, Yang T, Li C, et al. Association between multimorbidity patterns and disability among older people covered by long-term care insurance in Shanghai. China BMC Public Health. 2021;21:418.
15. Guo C, Liu Z, Fan H, Wang H, Zhang X, Fan C, et al. Associations of healthy lifestyle and three latent socioeconomic status patterns with physical multimorbidity among middle-aged and older adults in China. Prev Med. 2023;175:107693.
16. Craig A, Mtintsilana A, Mapanga W, Dlamini SN, Norris SA. Socioeconomic position, perceived weight, lifestyle risk, and multimorbidity in young adults aged 18 to 35 years: a Multi-country Study. BMC Public Health. 2023;23:1360.
17. Lai C, Fu R, Huang C, Wang L, Ren H, Zhu Y, et al. Healthy lifestyle decreases the risk of the first incidence of non-communicable chronic disease and its progression to multimorbidity and its mediating roles of metabolic components: a prospective cohort study in China. J Nutr Health Aging. 2024;28:100164.
18. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;14:75.
19. Vancampfort D, Stubbs B, Koyanagi A. Physical chronic conditions, multimorbidity and sedentary behavior amongst middle-aged and older adults in six low- and middle-income countries. Int J Behav Nutr Phys Act. 2017;14:147.
20. Cândido LM, Wagner KJP, da Costa ME, Pavesi E, de Avelar NCP, Danielewicz AL. Sedentary behavior and association with multimorbidity and patterns of multimorbidity in elderly Brazilians: data from the Brazilian National Health Survey, 2019. Cad Saude Publica. 2022;38:e00128221.
21. Idalino SCC, Canever JB, Cândido LM, Wagner KJP, de Souza MB, Danielewicz AL, et al. Association between sleep problems and multimorbidity patterns in older adults. BMC Public Health. 2023;23:978.
22. Xue B, Xue Y, Dong F, Zheng X, Shi L, Xiao S, et al. The impact of socioeconomic status and sleep quality on the prevalence of multimorbidity in older adults. Front Public Health. 2022;10:959700.
23. Lin Y, Hu Y, Guo J, Chen M, Xu X, Wen Y, et al. Association between sleep and multimorbidity in Chinese elderly: Results from the Chinese Longitudinal Healthy Longevity Survey (CLHLS). Sleep Med. 2022;98:1–8.
24. Ruiz-Castell M, Makovski TT, Bocquet V, Stranges S. Sleep duration and multimorbidity in Luxembourg: results from the European Health Examination Survey in Luxembourg, 2013–2015. BMJ Open. 2019;9:e026942.
25. Keats MR, Cui Y, DeClercq V, Dummer TJB, Forbes C, Grandy SA, et al. Multimorbidity in Atlantic Canada and association with low levels of physical activity. Prev Med. 2017;105:326–31.
26. He L, Biddle SJH, Lee JT, Duolikun N, Zhang L, Wang Z, et al. The prevalence of multimorbidity and its association with physical activity and sleep duration in middle aged and elderly adults: a longitudinal analysis from China. Int J Behav Nutr Phys Act. 2021;18:77.
27. Balogun SA, Aitken D, Wu F, Scott D, Jones G, Winzenberg T. Linear and Nonlinear Associations Between Physical Activity, Body Composition, and Multimorbidity Over 10 Years Among Community-Dwelling Older Adults. The Journals of Gerontology: Series A. 2021;76:2015–20.
28. Boro B, Saikia N. Association of multimorbidity and physical activity among older adults in India: an analysis from the Longitudinal Ageing Survey of India (2017–2018). BMJ Open. 2022;12:e053989.
29. Liu B-P, Zhu J-H, Wan L-P, Zhao Z-Y, Wang X, Jia C-X. The impact of physical activity intensity on the dynamic progression of cardiometabolic multimorbidity: prospective cohort study using UK biobank data. JMIR Public Health Surveill. 2023;9:e46991.
30. Chudasama YV, Khunti KK, Zaccardi F, Rowlands AV, Yates T, Gillies CL, et al. Physical activity, multimorbidity, and life expectancy: a UK Biobank longitudinal study. BMC Med. 2019;17:108.
31. Feter N, Leite JS, Umpierre D, Caputo EL, Rombaldi AJ. Multimorbidity and leisure-time physical activity over the life course: a population-based birth cohort study. BMC Public Health. 2021;21:700.
32. Chudasama YV, Zaccardi F, Gillies CL, Dhalwani NN, Yates T, Rowlands AV, et al. Leisure-time physical activity and life expectancy in people with cardiometabolic multimorbidity and depression. J Intern Med. 2020;287:87–99.
33. Fessler L, Maltagliati S, Sieber S, Cullati S, Tessitore E, Craviari C, et al. Physical activity matters for everyone's health, but individuals with multimorbidity benefit more. Prev Med Rep. 2023;34:102265.
34. Cristi-Montero C. An integrative methodology for classifying physical activity level in apparently healthy populations for use in public health. Rev Panam Salud Publica. 2017;41:e161.
35. State Sports General Administration. Notice of the General Administration of Sports on carrying out the Fifth National Physical Fitness Surveillance. https://www.gov.cn/xinwen/2019-02/02/content_5363384.htm. Accessed 23 Jul 2024.
36. Tian Y, Jiang C, Wang M, Cai R, Zhang Y, He Z, et al. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000–14. Lancet Diabetes Endocrinol. 2016;4:487–97.
37. Bao Y, Lu J, Wang C, Yang M, Li H, Zhang X, et al. Optimal waist circumference cutoffs for abdominal obesity in Chinese. Atherosclerosis. 2008;201:378–84.
38. Obesity Prevention and Control Branch of Chinese Nutrition Society. Expert consensus on obesity prevention and control among Chinese residents. Chin J Epidemiol. 2022;43:609–26.
39. Shanghai Civil Affairs. 2020 Shanghai elderly population and aging undertaking monitoring statistical information released. https://mp.weixin.qq.com/s/TzBdZzZHwkiIOyt8MQQCSA. Accessed 10 Dec 2024.
40. Weller BE, Bowen NK, Faubert SJ. Latent class analysis: a guide to best practice. Journal of Black Psychology. 2020;46(4):287–311.
41. Zhou X, Qin J-J, Li H, Chen J, Zhang Q, Ye X. The effect of multimorbidity patterns on physical and cognitive function in diabetes patients: a longitudinal cohort of middle-aged and older adults in China. Front Aging Neurosci. 2024;16:1388656.
42. Bayes-Marin I, Sanchez-Niubo A, Egea-Cortés L, Nguyen H, Prina M, Fernández D, et al. Multimorbidity patterns in low-middle and high income regions: a multiregion latent class analysis using ATHLOS harmonised cohorts. BMJ Open. 2020;10:e034441.
43. Bektas A, Schurman SH, Sen R, Ferrucci L. Aging, Inflammation and the Environment. Exp Gerontol. 2018;105:10–8.
44. Marzban M, Jamshidi A, Khorrami Z, Hall M, Batty JA, Farhadi A, et al. Determinants of multimorbidity in older adults in Iran: a cross-sectional study using latent class analysis on the Bushehr Elderly Health (BEH) program. BMC Geriatr. 2024;24:247.
45. Lay AAR, Nascimento CF, Burgos FC, Huerta ADCL, Zeballos RER, Silva VP, et al. Gender differences between multimorbidity and all-cause mortality among older adults. Curr Gerontol Geriatr Res. 2020;2020:7816785.

46. Sembiah S, Dasgupta A, Taklikar CS, Paul B, Bandyopadhyay L, Burman J, et al. Gender inequalities in prevalence, pattern and predictors of multimorbidity among geriatric population in rural West Bengal. J Family Med Prim Care. 2022;11:4555–61.
47. Shi H, Hu FB, Huang T, Schernhammer ES, Willett WC, Sun Q, et al. Sedentary behaviors, light-intensity physical activity, and healthy aging. JAMA Netw Open. 2024;7:e2416300.
48. Knaeps S, Lefevre J, Wijtzes A, Charlier R, Mertens E, Bourgois JG. Independent associations between sedentary time, moderate-to-vigorous physical activity, cardiorespiratory fitness and cardio-metabolic health: a cross-sectional study. PLoS ONE. 2016;11:e0160166.
49. Strain T, Flaxman S, Guthold R, Semenova E, Cowan M, Riley LM, et al. National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5·7 million participants. Lancet Glob Health. 2024;12:e1232–43.
50. Li Y, White K, O'Shields KR, McLain AC, Merchant AT. Light-Intensity Physical Activity and Cardiometabolic Risk Among Older Adults With Multiple Chronic Conditions. Am J Health Promot. 2019;33:507–15.
51. Loprinzi PD. Light-Intensity Physical Activity and Medical Multimorbidity. South Med J. 2016;109:174–7.

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