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Gender differences in depressive symptoms among Chinese older adults based on fairlie decomposition analysis

Lei Yuan [a,*,1], Boyang Yu [b,1], Yan Bing [a,1], Maolin Du [c,1], Zhe Zhao [a], Jinhai Sun [a,**]

[a] Department of Health Management, Faculty of Military Health Service, Naval Medical University, Shanghai, China
[b] Department of Medical Health Service, General Hospital of Northern Theater Command of PLA, Shenyang, China
[c] Department of Office, Naval Medical University, Shanghai, China

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ABSTRACT

This study aimed to investigate the factors influencing depressive symptoms among Chinese older adults based on gender differences. Data from the eighth wave of Chinese Longitudinal Health Longevity Survey were used. We analyzed the influencing factors of depressive symptoms reported by older adults using the chi-squared test and logistic model. Fairlie decomposition analysis was performed to quantify the contribution level of each influencing factor. We found that 11.71 % of older adults met the CES-D-10 criteria for depressive symptoms. Females (13.89 %) reported a significantly higher level of depressive symptoms than males (9.24 %). Age, residence, sleeping time, exercise, activities of daily living functional disability, instrumental activity of daily living functional disability, and living status influenced depressive symptoms in older adults. Higher education and lower body mass index were only significant in male, whereas middle annual income and exercising were significant only in female. The Fairlie decomposition model explained the reasons for 75.64 % of the gender differences in depressive symptoms, with instrumental activity of daily living functional disability (33.60 %), age (−17.79 %), and education level (17.41 %) being major factors affecting gender differences in depressive symptoms. This is the first nationwide study to examine gender differences in depressive symptoms among older adults. These results provide a basis for relevant Chinese government departments to formulate policies to prevent and control depressive symptoms.

1. Introduction

The global population is entering the aging phase of the demographic cycle. The number of adults aged 60 or older will increase from 900 million (12.0 %) to 2 billion (22.0 %), between 2015 and 2050, of the total global population. In addition, population aging appears to be more rapid than in the past. In the next 20 years, the number of people >60 in China is projected to reach 28.0 % of the population due to longer life expectancy and declining fertility rates, making it one of the most rapidly aging populations worldwide [1]. According to the Seventh National Population Census in China, the number of adults aged 60 or older was 264 million (18.7 % of the total population), and older adult aged 65 or over was 191 million (13.5 %), an increase of 4.6 % compared to the 2010 sixth

* Corresponding author. Department of Health Management, Naval Medical University, No. 800 Xiangyin Road, Shanghai, 200433, China.
** Corresponding author.
E-mail addresses: yuanleigz@163.com (L. Yuan), sunjinhai2003@sina.cn (J. Sun).
[1] These authors contributed equally as co-first authors.

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national census [2].

Older adults face unique physical and mental health challenges as their numbers grow. Above 20.00 % of older adults suffer from a mental or neurological disorder. According to the World Health Organization (2017) [3], depressive symptoms (DS) are among the most common mental and neurological disorders affecting adults aged 60 and over in the world [4]. According to a meta-analysis research, the global median prevalence of depression in older individuals was 10.3 %, with quartile values ranging from 4.7 % to 16.0 % [5]. East Asian nations are also experiencing this crisis; a study reveals that Japan, the nation with the most acute global ageing issue, has older adults who experience chronic psychological or mental disorders [6]. A survey conducted by the Ministry of Health, Labor and Welfare of Japan found that the number of individuals suffering from mood disorders, including depression and bipolar disorder, was 1.3 million in 2017, which represents an increase of 38 % from 2005 [7]. China is also facing this reality. Owing to variations in study sample sizes, related studies conducted in China have revealed that the prevalence of DS among Chinese older adults varies between 13 % and 41 % [8,9]. A recent article published in the Lancet Psychiatry showed that DS is a major factor in China's global burden of diseases [10]. Depression has been predicted to become the second leading cause of disability by 2020 [11]. Furthermore, several studies have shown that depressive symptoms are associated with multiple chronic diseases in Chinese older adults [12,13]. These two thus form a vicious circle: Multiple chronic diseases interact to limit compensatory mechanisms, resulting in physical and cognitive decline, which in turn affects the severity and burden of multiple chronic diseases.

Depression results from a complex interaction of social, psychological, and biological factors; relevant research shows an interrelationship between depression and physical health, and how they affect and promote each other [14]. Related literature shows that the DS risk factors in older adults include demographic characteristics such as education [15] and income levels [16], health behavior indicators such as sleeping time [17,18] and smoking [19], health status indicators such as activities of daily living (ADL) functional disabilities [20], family social support indicators such as marital status [21,22], and social activities [23]. Further studies are required to assess the impact of gender differences on DS. Many studies have found gender differences in the prevalence of DS [16,24–27]. However, these studies have found inconsistencies in the prevalence of depressive symptoms between male and female due to gender differences, and most studies remain at the level of screening and analysis of influencing factors, but no studies have further analyzed the causes of this inequality in prevalence. There are limited quantitative studies on the degree of contribution of each influencing factor. Fairlie decomposition analysis (FDA) can better quantify the contribution and significance level of various influencing factors and has been used in public health [28–30]. However, it is uncommon to see the application of FDA on the mental health of older adults.

Therefore, our study identifies and analyzes the factors that influence DS among older adults in China based on gender. Moreover, FDA was used to quantify the contribution of each influencing factor. This study provides evidence for Chinese health authorities to

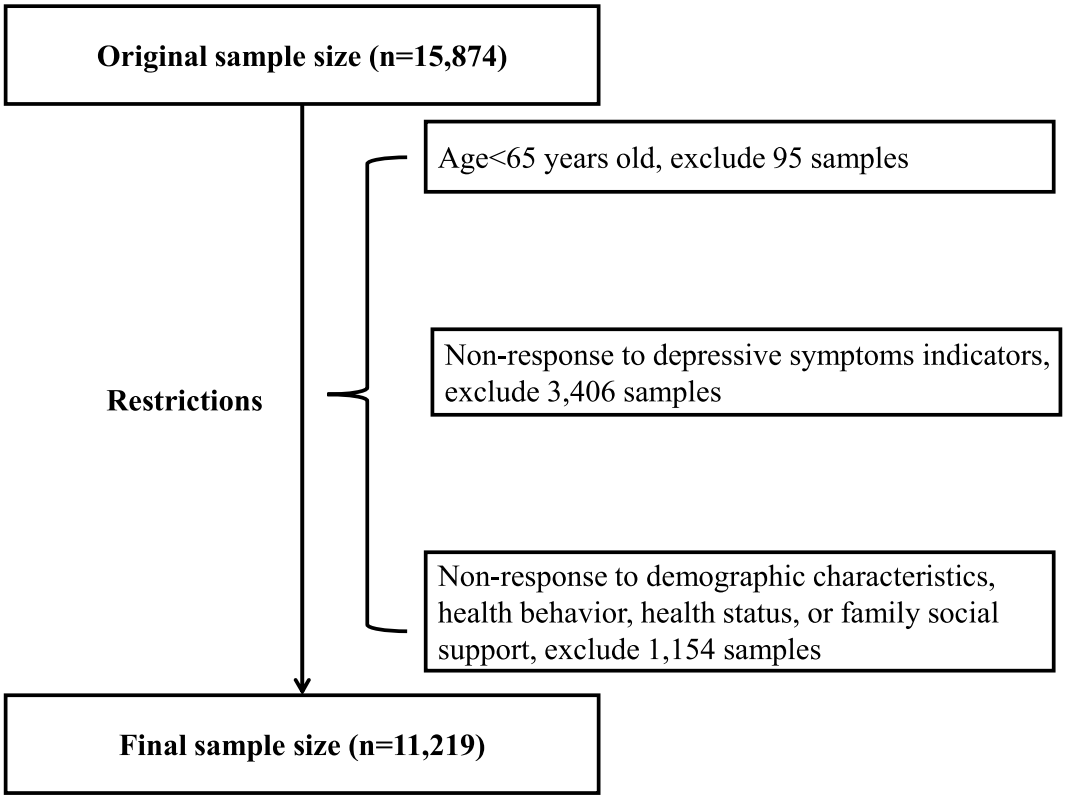

Fig. 1. Flowchart of study participants.

formulate policies for early prevention, detection, and management of DS, thus improving older adults' physical and mental health.

2. Materials and methods

2.1. Data sources

This study used data from the eighth wave of the Chinese Longitudinal Health Longevity Survey (CLHLS), Center for Healthy Aging and Development Studies at Peking University in 2020 [31]. Until now, CLHLS is China's most extensive cohort study on the older adult population and the world's largest study on older adults of advanced age (80 years or above) [32]. CLHLS provides high-quality microdata, including 113,000 people in 23 provinces, municipalities, and autonomous regions from 1998 to 2018; older adults of advanced age account for 67.40 % of the total sample. The eighth wave of CLHLS was conducted between 2017 and 2018 and included 15,874 people. According to the CLHLS survey project team, the study was approved by the Research Ethics Committees of Peking university (No. IRB00001052-13074) and Duke University (Pro1052-13074). The survey respondents provided informed consent before participating [33]. Based on our research needs, we selected 15,874 samples. After excluding missing and unanswered values, we included 11,219 respondents' data in this study. These respondents included 5260 (46.88 %) males, 5959 (53.12 %) females, and 6692 (59.65 %) older adults of advanced age (80 years or above). The data processing flow is shown in Fig. 1.

2.2. Dependent variable

The Chinese version of the ten-item abbreviated form of the Center for Epidemiological Studies Depression Scale (CES-D-10) exhibited good consistent internal reliability and construct (Cronbach's alpha coefficients = 0.813) [34,35]. Related research indicated that CES-D-10 is more accurate in predicting DS than CES-D [36]. The specific items are as follows: ① I was bothered by some small things; ② I had trouble keeping my mind on what I was doing; ③ I felt depressed; ④ I feel increasingly old and useless, and everything I do feels very difficult. ⑤ I felt hopeful about the future; ⑥ I felt scared; ⑦I feel as happy as I did when I was young; ⑧I felt lonely; ⑨ I felt unable to continue my life; ⑩ My sleep was restless. The options under each item are divided into four levels: "Rarely or None of the Time," "Some days," "Occasionally," and "Most of the Time" [34]. The responses for the items of negative feelings were assigned to an index value of 0, 1, 2, and 3. Items of positive feelings (items 5 and 7) were assigned 3, 2, 1, and 0. The total score ranged from 0 to 30; a score greater than or equal to 10 was rated as a possible DS [37–39].

2.3. Independent variable

Based on relevant studies on factors influencing DS [14,15,17,18,20–23], we selected variables that might impact DS in older adults from the CLHLS datasets. The variables were divided into four categories: demographic characteristics (gender, age, education level, residence, and annual income), health behavior (smoking, drinking, sleeping times, and exercise), health status (body mass index, activities of daily living (ADL) functional disability, and instrumental activities of daily living (IADL) functional disability), and family social support (marital status, living status, social activity, annual physical examination). The specific variable definitions and

Table 1
Variable definitions and values assigned to different variables.

Type	Name	Assignment
Dependent variable	DS[a]	Non-DS = 0, DS = 1
Independent variable	**Demographic characteristics**	
	Gender	Female = 0, Male = 1
	Age (years)	<80 = 0, ≥80 = 1
	Education level (years)	0 = 0, 1–6 = 1, ≥7 = 2
	Residence	Rural = 0, Town = 1, City = 2
	Annual income	Very poor = 0, Poor = 1, Middle = 2, Rich = 3
	Health behavior	
	Smoking	No = 0, Yes = 1
	Drinking	No = 0, Yes = 1
	Sleeping times (h)	6.0–7.9 = 0, <4.0 = 1, 4.0–5.9 = 2, 8.0–9.9 = 3, ≥10 = 4
	Exercise	No = 0, Yes = 1
	Health status	
	BMI[b] (kg/m^2)	18.5–23.9 = 0, <18.5 = 1, 24.0–27.9 = 2, ≥28.0 = 3
	ADL[c] functional disability	No = 0, Yes = 1
	IADL[d] functional disability	No = 0, Yes = 1
	Family social support	
	Marital status	Married and living with spouse = 0, Widower = 1, Other[e] = 2
	Living status	Living with household members = 0, Alone = 1, Nursing home = 2
	Social activity	No = 0, Yes = 1
	Annual physical examination	No = 0, Yes = 1

[a]DS: depressive symptoms; [b]BMI: body mass index; [c]ADL: activities of daily living; [d]IADL: instrumental activities of daily living; [e]Other: includes married but not living with a spouse, divorced, and never married.

Table 2
Distribution of the variables in female and male respondents.

Variable	Female (n/%)	Male (n/%)	Total	χ^2	p
CES-D-10				58.56	<0.001
<10	5131 (86.11)	4774 (90.76)	9905 (88.29)		
≥10	828 (13.89)	486 (9.24)	1314 (11.71)		
Age				56.27	<0.001
<80	2210 (37.09)	2317 (44.05)	4527 (40.35)		
≥80	3749 (62.91)	2943 (55.95)	6692 (59.65)		
Education level				1402.83	<0.001
0	3194 (53.60)	1017 (19.33)	4211 (37.53)		
1–6	1367 (22.94)	1995 (37.93)	3362 (29.97)		
≥7	1398 (23.46)	2248 (42.74)	3646 (32.50)		
Residence				2.67	0.263
Rural	2626 (44.07)	2239 (42.57)	4865 (43.36)		
Town	1932 (32.42)	1739 (33.06)	3671 (32.72)		
City	1401 (23.51)	1282 (24.37)	2683 (23.92)		
Annual income				17.34	0.001
Very poor	1578 (26.48)	1304 (24.79)	2882 (25.69)		
Poor	1125 (18.88)	905 (17.21)	2030 (18.09)		
Middle	824 (13.83)	704 (13.38)	1528 (13.62)		
Rich	2432 (40.81)	2347 (44.62)	4779 (42.60)		
Smoking				1323.18	<0.001
No	5697 (95.60)	3691 (70.17)	9388 (83.68)		
Yes	262 (4.40)	1569 (29.83)	1831 (16.32)		
Drinking				896.68	<0.001
No	5601 (93.99)	3861 (73.40)	9462 (84.34)		
Yes	358 (6.01)	1399 (26.60)	1757 (15.66)		
Sleeping times				101.14	<0.001
6.0–7.9	2058 (34.54)	1793 (34.09)	3851 (34.31)		
<4.0	240 (4.03)	121 (2.30)	361 (3.22)		
4.0–5.9	1050 (17.62)	689 (13.10)	1739 (15.49)		
8.0–9.9	1547 (25.96)	1695 (32.22)	3242 (28.88)		
≥10	1064 (17.86)	962 (18.29)	2026 (18.05)		
Exercise				130.43	<0.001
No	4176 (70.08)	3145 (59.79)	7321 (65.26)		
Yes	1783 (29.92)	2115 (40.21)	3898 (34.74)		
BMI[a]				104.77	<0.001
18.5–23.9	2842 (47.69)	2718 (51.67)	5560 (49.56)		
<18.5	1167 (19.58)	702 (13.35)	1869 (16.66)		
24.0–27.9	1329 (22.30)	1392 (26.46)	2721 (24.25)		
≥28.0	621 (10.42)	448 (8.52)	1069 (9.53)		
ADL[b] functional disability				80.01	<0.001
No	4501 (75.53)	4337 (82.45)	8838 (78.78)		
Yes	1458 (24.47)	923 (17.55)	2381 (21.22)		
IADL[c] functional disability				413.08	<0.001
No	2047 (34.35)	2809 (53.40)	4856 (43.28)		
Yes	3912 (65.65)	2451 (46.60)	6363(56.72)		
Marital status				1139.02	<0.001
Married and living with spouse	1900 (31.88)	3181 (60.48)	5081 (45.29)		
Widower	3966 (66.55)	1832 (34.83)	5798 (51.68)		
Other[d]	93 (1.57)	247 (4.69)	340 (3.03)		
Living status				65.07	<0.001
Living with household members	4614 (77.43)	4390 (83.46)	9004 (80.26)		
Alone	1133 (19.01)	719 (13.67)	1852 (16.51)		
Nursing home	212 (3.56)	151 (2.87)	363 (3.24)		
Social activity				95.81	<0.001
No	1828 (30.68)	1182 (22.47)	3010 (26.83)		
Yes	4131 (69.32)	4078 (77.53)	8209 (73.17)		
Annual physical examination				43.54	<0.001
No	1867 (31.33)	1351 (25.68)	3218 (28.68)		
Yes	4092 (68.67)	3909 (74.32)	8001 (71.32)		

[a] BMI: body mass index.
[b] ADL: activities of daily living.
[c] IADL: instrumental activities of daily living.
[d] Other: includes married but not living with a spouse, divorced, and never married.

assignment of values are shown in Table 1.

2.4. Statistical analysis

The data were analyzed using descriptive statistical methods. Enumerated data were expressed as n (%), and the chi-square test was

Table 3
Distribution of DS variables based on gender.

Variable	Female			Male		
	Non-DS (N/%)	DS (N/%)	P	Non-DS (N/%)	DS (N/%)	P
Age			0.275			0.027
<80	1917 (37.36)	293 (35.39)		2126 (44.53)	191 (39.30)	
≥80	3214 (62.64)	535 (64.61)		2648 (55.47)	295 (60.70)	
Education level			0.003			<0.001
0	2707 (52.76)	487 (58.82)		884 (18.52)	133 (27.37)	
1–6	1189 (23.17)	17 (21.49)		1809 (37.89)	186 (38.27)	
≥7	1235 (24.07)	163 (19.69)		2081 (43.59)	167 (34.36)	
Residence			<0.001			0.768
Rural	2246 (43.77)	380 (45.89)		2039 (42.71)	200 (41.15)	
Town	1625 (31.67)	307 (37.08)		1572 (32.93)	167 (34.36)	
City	1260 (24.56)	141 (17.03)		1163 (24.36)	119 (24.49)	
Annual income			<0.001			<0.001
Very poor	1293 (25.20)	1145 (34.42)		1145 (23.99)	159 (32.72)	
Poor	959 (18.69)	166 (20.05)		828 (17.34)	77 (15.84)	
Middle	740 (14.42)	84 (10.14)		648 (13.57)	56 (11.52)	
Rich	2139 (41.69)	293 (35.39)		2153 (45.10)	194 (39.92)	
Smoking			0.242			0.407
No	4899 (95.48)	798 (96.38)		3342 (70.00)	349 (71.81)	
Yes	232 (4.52)	30 (3.62)		1432 (30.00)	137 (28.19)	
Drinking			0.222			0.002
No	4815 (93.84)	786 (94.93)		3476 (72.81)	385 (79.22)	
Yes	316 (6.16)	42 (5.07)		1298 (27.19)	101 (20.78)	
Sleeping times			<0.001			<0.001
6.0–7.9	1828 (35.63)	230 (27.78)		1655 (34.67)	138 (28.40)	
<4.0	147 (2.86)	93 (11.23)		85 (1.78)	36 (7.41)	
4.0–5.9	782 (15.24)	268 (32.37)		555 (11.63)	134 (27.57)	
8.0–9.9	1416 (27.60)	131 (15.82)		1591 (33.33)	104 (21.39)	
≥10	958 (18.67)	106 (12.80)		888 (18.60)	74 (15.23)	
Exercise			<0.001			<0.001
No	3534 (68.88)	642 (77.54)		2789 (58.42)	356 (73.25)	
Yes	1597 (31.12)	186 (22.46)		1985 (41.58)	130 (26.75)	
BMI[a]			0.002			<0.001
18.5–23.9	2463 48.00)	379 (45.77)		2474 (51.82)	244 (50.20)	
<18.5	968 (18.87)	199 (24.03)		590 (12.36)	112 (23.05)	
24.0–27.9	1170 (22.80)	159 (19.20)		1297 (27.17)	95 (19.55)	
≥28.0	530 (10.33)	91 (11.00)		413 (8.65)	35 (7.20)	
ADL[b] functional disability			<0.001			<0.001
No	3921 (76.42)	580 (70.05)		3994 (83.66)	343 (70.58)	
Yes	1210 (23.58)	248 (29.95)		780 (16.34)	143 (29.42)	
IADL[c] functional disability			<0.001			<0.001
No	1831 (35.69)	216 (26.09)		2669 (55.91)	140 (28.81)	
Yes	3300 (64.31)	612 (73.91)		2105 (44.09)	346 (71.19)	
Marital status			0.009			<0.001
Married and living with spouse	1674 (32.63)	226 (27.29)		2936 (61.50)	245 (50.41)	
Widower	3377 (65.82)	589 (71.14)		1622 (33.98)	210 (43.21)	
Other[d]	80 (1.55)	13 (1.57)		216 (4.52)	31 (6.38)	
Living status			<0.001			<0.001
Living with household members	4020 (78.35)	594 (71.74)		4019 (84.19)	371 (76.34)	
Alone	934 (18.20)	199 (24.03)		624 (13.07)	95 (19.55)	
Nursing home	177 (3.45)	35 (4.23)		131 (2.74)	20 (4.12)	
Social activity			<0.001			<0.001
No	1509 (29.41)	319 (38.53)		1028 (21.53)	154 (31.69)	
Yes	3622 (70.59)	509 (61.47)		3746 (78.47)	332 (68.31)	
Annual physical examination			0.057			0.434
No	1584 (30.87)	283 (34.18)		1219 (25.53)	132 (27.16)	
Yes	3547 (69.13)	545 (65.82)		3555 (74.47)	354 (72.84)	

[a] BMI: body mass index.
[b] ADL: activities of daily living.
[c] IADL: instrumental activities of daily living.
[d] Other: includes married but not living with a spouse, divorced, and never married.

used to compare the two groups. The factors of DS in different genders were analyzed using logistic regression analysis, with inclusion and exclusion criteria of 0.10 and 0.05, respectively. We used IBM SPSS 26.0 for all reported analyses. All statistical tests were two-tailed. When $P < 0.05$, the difference was considered statistically significant.

Table 4
Logistic regression analysis of DS reported by male and female respondents.

Variable	Female			Male		
	P	OR	[95%CI]	P	OR	[95%CI]
Age						
<80	Reference			Reference		
≥80	0.002	0.714	(0.577,0.883)	<0.001	0.526	(0.410,0.677)
Education level						
0	Reference			Reference		
1–6	0.996	1.001	(0.815,1.228)	0.510	0.918	(0.711,1.185)
≥7	0.526	0.935	(0.759,1.152)	0.034	0.745	(0.567,0.978)
Residence						
Rural	Reference			Reference		
Town	0.159	1.131	(0.953,1.343)	0.305	1.127	(0.897,1.416)
City	0.008	0.726	(0.572,0.920)	0.011	1.464	(1.091,1.964)
Annual income						
Very poor	Reference			Reference		
Poor	0.807	0.973	(0.779,1.215)	0.416	0.880	(0.647,1.197)
Middle	0.005	0.675	(0.512,0.891)	0.142	0.773	(0.548,1.090)
Rich	0.206	0.877	(0.715,1.075)	0.119	0.808	(0.619,1.056)
Smoking						
No	Reference			Reference		
Yes	0.247	0.788	(0.526,1.180)	0.777	1.034	(0.820,1.304)
Drinking						
No	Reference			Reference		
Yes	0.543	0.898	(0.636,1.269)	0.173	0.841	(0.656,1.079)
Sleeping times						
6.0–7.9	Reference			Reference		
<4.0	<0.001	4.520	(3.342,6.113)	<0.001	4.116	(2.613,6.484)
4.0–5.9	<0.001	2.569	(2.106,3.135)	<0.001	2.519	(1.928,3.291)
8.0–9.9	0.003	0.710	(0.565,0.892)	0.065	0.776	(0.593,1.016)
≥10	0.020	0.742	(0.577,0.954)	0.085	0.765	(0.563,1.038)
Exercise						
No	Reference			Reference		
Yes	0.021	0.797	(0.657,0.966)	<0.001	0.630	(0.501,0.792)
BMI[a]						
18.5–23.9	Reference			Reference		
<18.5	0.117	1.175	(0.960,1.437)	<0.001	1.616	(1.248,2.093)
24.0–27.9	0.884	0.985	(0.799,1.213)	0.123	0.816	(0.630,1.057)
≥28.0	0.437	1.109	(0.854,1.439)	0.153	0.756	(0.515,1.110)
ADL[b] functional disability						
No	Reference			Reference		
Yes	0.007	1.309	(1.078,1.589)	0.003	1.440	(1.128,1.840)
IADL[c] functional disability						
No	Reference			Reference		
Yes	0.003	1.363	(1.107,1.678)	<0.001	3.013	(2.338,3.882)
Marital status						
Married and living with spouse	Reference			Reference		
Widower	0.335	1.110	(0.898,1.372)	0.392	1.117	(0.867,1.440)
Other[d]	0.682	1.141	(0.607,2.147)	0.514	1.167	(0.734,1.854)
Living status						
Living with household members	Reference			Reference		
Alone	0.004	1.353	(1.099,1.666)	0.017	1.447	(1.069,1.958)
Nursing home	0.467	1.163	(0.775,1.746)	0.946	0.982	(0.573,1.682)
Social activity						
No	Reference			Reference		
Yes	0.002	0.751	(0.627,0.901)	0.987	1.002	(0.791,1.270)
Annual physical examination						
No	Reference			Reference		
Yes	0.527	0.946	(0.797,1.123)	0.066	1.238	(0.986,1.555)

[a] BMI: body mass index.
[b] ADL: activities of daily living.
[c] IADL: instrumental activities of daily living.
[d] Other: includes married but not living with a spouse, divorced, and never married.

2.5. Fairlie decomposition analysis (FDA)

FDA was conducted using the StataMP 16.0 statistical software to identify the gender differences in DS among older adults and its underlying cause. The decomposition analysis was adopted to identify and quantify inter-group differences. FDA was proposed by Professor Fairlie in 1995. It identifies the contribution of independent variables to explain the differences across groups by calculating the average predicted probability change resulting from replacing one independent variable at a time for one group while other variables remain constant for the other group [40]. Studies suggested that FDA for nonlinear regression models can better quantify the contribution and significance level of different variables [30,41–44] The Fairlie decomposition model divides the study results into two segments: explained and unexplained [30,45] The formula can be expressed as:

$$\overline{Y}^{a} - \overline{Y}^{b} = \left[\sum_{i-1}^{N^{a}} \frac{F\left(X_i^{a}\beta^{a}\right)}{N^{a}} - \sum_{i-1}^{N^{b}} \frac{F\left(X_i^{b}\beta^{a}\right)}{N^{b}}\right] + \left[\sum_{i-1}^{N^{b}} \frac{F\left(X_i^{b}\beta^{a}\right)}{N^{b}} - \sum_{i-1}^{N^{b}} \frac{F\left(X_i^{b}\beta^{b}\right)}{N^{b}}\right]$$

The first half of the formula is the explained segment, caused by the observed variables in the study, whereas the second half is the unexplained segment, caused by the differences in measured grouping variables and unmeasured variables [41–44].

3. Results

3.1. Baseline characteristics of the respondents

The descriptive statistical analysis results comparing older Chinese male and female adults are shown in Table 2. We found that 11.71 % of older adults met CES-D-10 criteria for DS (the score of CES-D-10 $\geq$ 10), while 88.29 % did not (the score of CES-D-10 < 10).

Female adults <80 years accounted for 37.09 % of the female respondents. For their male counterparts, 44.05 % of the male respondents. The proportion of female adults >80 years was higher than that of male adults. Furthermore, 45.29 % of the included respondents lived with their spouses, 51.68 % were widowed, and 16.51 % lived alone. The proportion of ADL functional disability and instrumental activities of daily living (IADL) functional disability were 21.22 % and 56.72 %, respectively.

The result of chi-squared test showed that of the 16 factors included in our study, 15 (except the factor of residence) had statistically significant gender differences. Compared with female adults, male adults experienced lower levels of DS, higher education level, higher prevalence of smoking or drinking, lower probability of suitable sleeping time, more exercise, more standard BMI, less functional disability of ADL and IADL, higher probability of living with their spouses or household members, more frequent social activities, and more annual physical examinations.

3.2. Distribution of DS variables based on gender

Table 3 shows the differences in the distribution of DS variables based on gender. The results suggested statistically significant differences in the distribution of specific DS variables based on gender. There were statistically significant differences in the distribution of age and drinking in DS in the male older adults' group; however, these differences were not statistically significant in the female group. Furthermore, statistically significant differences were found in the distribution of residence in the female older adults'

Table 5
FDA of DS reported by different genders.

Terms of decomposition	DS			
Difference	0.0465541			
Explained (%)	0.0352135 (75.64 %)			
Non-explained (%)	0.0113405 (24.36 %)			
Explained				
Contribution to difference	P	β	Contribution to total difference (%)	(95 % CI)
Age	<0.001	−0.0082807	−17.79	(-0.0115013,-0.0050600)
Education level	0.001	0.0081041	17.41	(0.0033281,0.0128802)
Residence	0.960	−0.0000014	−0.01	(-0.0000549,0.0000521)
Annual income	0.035	−0.0003476	−0.75	(-0.0006700,-0.0000251)
Smoking	0.340	0.0023236	4.99	(-0.0024540,0.0071013)
Drinking	0.014	0.0042439	9.12	(0.0008621,0.0076257)
Sleeping times	0.215	−0.0002064	−0.44	(-0.0005329,0.0001201)
Exercise	<0.001	0.0034353	7.38	(0.0019547,0.0049160)
BMI[a]	0.779	−0.0000069	−0.02	(-0.0000552,0.0000414)
ADL[b] functional disability	0.002	0.0028590	6.14	(0.0010759,0.0046421)
IADL[c] functional disability	<0.001	0.0156435	33.60	(0.0118426,0.0194445)
Marital status	0.020	0.0043861	9.42	(0.0006895,0.0080827)
Living status	0.005	0.0010050	2.16	(0.0002962,0.0017137)
Social activity	0.013	0.0022699	4.88	(0.0004738,0.0040660)
Annual physical examination	0.713	−0.0002150	−0.46	(-0.0013600,0.0009299)

[a]BMI: body mass index; [b]ADL: activities of daily living; [c]IADL: instrumental activities of daily living.

group, but not in the male older adults' group.

3.3. Multivariate analysis of DS and gender differences

Table 4 shows the logistic regression analysis results on DS reported by older Chinese male and female adults. Age, residence, sleeping time, exercise, ADL functional disability, IADL functional disability, and living status influenced DS as reported by male and female respondents. In addition, differences existed in the factors that influenced DS in female and male older adults. For example, "high education level" and "low BMI" were significant only in male, whereas "middle annual income" and "exercising" were only significant in female.

3.4. FDA

We conducted a quantitative analysis of the contribution level of different influencing factors to explain the differences in DS reported by older Chinese male and female adults. The specific results for decomposition of DS differences are shown in Table 5. The FDA results showed that 75.64 % of the differences in DS were caused by the observed variables, whereas gender differences and unmeasured variables caused 24.36 % of the differences. Among the variables causing the explained part of the differences, age, educational level, annual income, drinking, exercise, ADL functional disability, IADL functional disability, marital status, living status, and social activity were the influencing factors that reached the level of significance ($p < 0.05$), with contribution levels of −17.79 %、17.41 %、-0.75 %、9.12 %、7.38 %、6.14 %、33.60 %、9.42 %、2.16 %、4.88 %, respectively.

4. Discussion

Our study examined the factors affecting the DS reported by Chinese male and female older individuals and focused on gender disparities in DS among adults 65 and older across the country. It conducted a quantitative analysis of the contribution level of various influencing factors to explain these gender differences. The FDA is highly interpretable and can offer theoretical references to relevant government departments to help formulate policies for older adults' physical and mental health promotion.

The results of our study revealed that the proportion of DS was 11.71 %, which is greater than the global prevalence rate of geriatric depression of 7 % [46] but lower than the prevalence of DS among older adults in China reported in 2012 [47] at 22.70 %. The findings of our investigation also indicated significant gender differences in DS among Chinese older adults. Consistent with previous research, older female (13.89 %) had a higher incidence of DS than older male (9.24 %) [16,26]. These findings may be related to female unique physiological, psychological, and sociological characteristics in this age group, including estrogen level changes, sensitivity to negative events, changes in social roles. Moreover, the proportion of DS in females ≥80 years is higher than that in males, which may be related to the higher life expectancy of female older adults [48]. This result is consistent with the "gender paradox" of older adults' health status, which states that female enjoy longer life expectancy, but worse self-rated health compared to male [49,50]. Our findings showed that the rate of DS also exhibited a similar "gender paradox" phenomenon. Gender difference in depressive symptoms do not exist only in older adults, but also in other age subgroups [51]. Before mid-puberty, boys are more likely than girls to be depressed, whereas between 15 and 19 years, the prevalence of DS doubles in girls. This trend persists until 54 years and declines during older age [52]. The lifetime prevalence of affective disorders was higher, and approximately doubled, in females [53,54]. There are multiple hypotheses that attempt to explain this gender difference, but they are inconclusive. Our study attempts to explain gender differences in older adults' depressive symptoms.

Results from univariate and multivariate analyses indicate that there are gender variations in the characteristics that affect older male and female persons' likelihood of having DS. **First**, age was a common influencing factor for both male and female older adults and increasing age, a protective factor ($OR_{female} = 0.714$, $OR_{male} = 0.526$). Furthermore, the age distribution of DS was significantly different in the male older adults group. This may be related to the experiences of ageism, which is associated with the poor mental health of older adults, especially male. However, this effect may gradually weaken with the increase of age [55]. **Second,** residence was a common influencing factor for both male and female older adults. For female older adults, living in the city was a protective factor compared to rural areas ($OR_{female} = 0.726$). This may be because female older adults in rural areas are more vulnerable to poverty, low educational attainment, violence, and gender inequality [56]. However, for male older adults, living in the city was a risk factor compared to rural areas ($OR_{male} = 1.464$). This is possibly because older male adults living in the city have a higher retirement age (≥60 years). Therefore, the retirement problems they face include changes in social and life roles, loss of power, and decline of status, which generate a psychological burden. In contrast, most rural older adults in China do not face the problem of retirement [30]. **Third**, ADL and IADL functional disability were influencing factors in DS ($OR_{ADL\text{-}female} = 1.309$, $R_{ADL\text{-}male} = 1.440$, $OR_{IADL\text{-}female} = 1.363$, $OR_{IADL\text{-}male} = 3.013$), consistent with previous results [20,57–59]. Daily activity restrictions will have a significant negative impact on older individuals' self-esteem and raise their psychological burden [60]. This study supported the association between ADL and IADL functional disability and DS, showing that older persons with an ADL or IADL functional disability were more likely to develop DS in accordance with earlier studies [61,62]. **Fourth**, low BMI was a risk factor for older males; studies have shown a bidirectional relationship between BMI and DS in older adults [63]. Middle annual income was a protective factor for female older adults. To a certain extent, higher annual income symbolizes stronger risk resistance, which in turn affects the occurrence of DS. The study by Zhao et al., which discovered that older adults from lower socioeconomic status had an 8.294 times higher chance of developing DS than older adults from better socioeconomic status, lends credence to this [64]. **Lastly**, sleep time and exercise reflected personal health behaviors and were important influencing factors in DS in older adults. Longer sleep time and exercise behavior are

protective factors, consistent with previous studies [17,18,65]. The result that physical activity was linked to a lower risk for DS was supported by data from earlier research [66,67]. According to additional research, mild to moderate exercise can help older persons' cognitive performance, which benefits their physical and mental health [68,69]. This finding demonstrates the bidirectional relationship between DS and sleep quality [70].

According to the FDA findings, gender variations in DS were influenced by IADL functional impairment (33.60 %), age (−17.79 %), and education level (17.41 %) and were statistically significant. This was consistent with the findings of earlier research in that it showed that demographic factors and health status were related to DS in older male and female [71–73]. Considering age and education level, the participants generally had low education levels due to the limitations of educational resources and living standards when they were young and female, as a vulnerable group, had less education (46.40 %) than male (80.67 %). Low education level limits social and economic status and stable financial security, which in turn reduces the ability to cope with major stress and shock [15]. Considering age and IADL functional disability, the higher the age, the higher the incidence of IADL and ADL functional disability [74]. It should be emphasized that although IADL and ADL both reflect the ability of daily living of older adults, the contribution rate of IADL functional disability to DS is much higher than that of ADL functional disability (6.14 %). The reason is that IADL focuses more on the independent living ability and social function of older adults [58]. These results suggest that independent living ability and social function may influence DS in older adults, which is supported by the contribution of social activities (4.88 %). This important finding can provide a basis for relevant Chinese government departments to address the problem of DS in older adults from a more holistic perspective.

In conclusion, our study results have substantial policy implications. Government and its relevant departments should do the following: **First**, focus on the problem of older adults' DS, especially older female adults who are at a young age, live in rural areas or with ADL and (or) IADL functional disability. **Second**, promote education on sleep and exercise to encourage the adoption of a healthy lifestyle among older adults. **Third**, strengthen social support for older adults and reduce their loneliness by strengthening the construction of activity centers and organizing communication activities. Importantly, the differences in DS between male and female older adults in China are not only reflected in demographic characteristics, health behaviors, health status and family, and social support, but also require multidimensional focus on sociocultural aspects such as discrimination (age and social).

5. Limitation

Our study has a few limitations. **First**, we used data from the eighth wave of CLHLS, a cross-sectional study not inclusive of older adults in all regions of China. **Second**, CES-D-10 was used to assess DS; however, it only functions as a screening tool and cannot diagnose depression. **Third**, this is a descriptive study, contributing factors do not necessarily cause depressive symptoms. The study design and data set do not support the search for cause and effect. **Fourth**, in the contribution analysis, FDA regarded each variable as a whole. In-depth analysis could not be conducted on the contribution of dummy variables of each variable. **Lastly**, the DS of older adults was influenced by several factors, and we only measured some of these. Notwithstanding these limitations, our results may offer new insights into the differences in DS among older Chinese adults based on gender. In subsequent studies, we will collect additional data and include more factors in the analysis to verify this study's validity.

6. Conclusion

We found that female older adults experienced a higher rate of DS than their male counterparts. The main reasons for this difference include IADL functional disability, age, and education level. Furthermore, residence and annual income, representing socioeconomic status; sleep time and exercise, representing healthy behaviors; BMI and ADL functional disability, representing health conditions, were also the focus. Therefore, the relevant Chinese government departments should attach great importance to reduce the gender gap in DS and decrease it in the older adult population. Our findings provide a base for the relevant Chinese government departments to formulate policies for the prevention and control of DS and improve older adults' physical and mental health and happiness.

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Ethical statement

This investigation was approved by the Research Ethics Committee of Peking University, China (IRB00001052-13074).

Consent for publication

Not applicable.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Lei Yuan: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Boyang Yu:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Yan Bing:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Formal analysis, Data curation, Conceptualization. **Maolin Du:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Zhe Zhao:** Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Jinhai Sun:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviation

DS	Depressive symptoms
FDA	Fairlie decomposition analysis
BMI	Body mass index
ADL	Activities of daily living
IADL	Instrumental activities of daily living

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