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Association between digital exclusion and depressive symptoms among middle-aged and older Chinese adults: a cross-sectional analysis of CHARLS 2020

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Abstract

Background

Depressive symptoms are a major public health concern among middle-aged and older adults in China. Previous studies have linked digital exclusion to poorer mental health in this population. However, whether different levels of digital engagement are differentially associated with depressive symptoms remains unclear.

Methods

This cross-sectional study used data from 6,367 participants in the 2020 wave of the China Health and Retirement Longitudinal Study (CHARLS). Depression was assessed by the Centre for Epidemiological Studies Depression Scale. Multivariable logistic regression was used to examine the association between digital exclusion and depression. Subgroup analyses were conducted by gender and area of residence, and propensity score matching (PSM) was performed to assess the robustness of the findings.

Results

In the fully adjusted model, compared with participants with no digital exclusion, those with partial digital exclusion and those with digital exclusion had higher odds of depression (OR = 1.30, 95% CI: 1.07–1.58, *P* = 0.009; OR = 1.33, 95% CI: 1.18–1.51, *P* < 0.001, respectively). The results of the subgroup analyses showed that the association between digital exclusion and depression was no longer significant in the male group (OR = 1.19, 95%CI: 0.98–1.45, *P* = 0.086). The estimated ORs also varied across residential subgroups, with the highest point estimate observed among participants living in transitional zones(OR = 1.92, 95%CI: 1.35–2.72, *P* <0.001).

Conclusion

Digital exclusion was associated with higher odds of depression among middle-aged and older Chinese adults. The findings highlight the importance of promoting inclusive access to digital services, particularly among groups that may face barriers to digital engagement. However, longitudinal studies are needed to clarify the temporal relationship between digital exclusion and depression.

1. Introduction

Depression is a serious mental illness whose symptoms include abnormal mood, lack of pleasure, Mental retardation, and suicidal tendencies, and is the third leading cause of disability worldwide(1, 2). Meanwhile, according to the World Health Organization, depression is expected to rank first in terms of disease burden by 2030(3). Older adults may be at increased risk of depression because of a

combination of biological, psychological, and social factors(4–6). Luppa's study showed that the prevalence of depression among persons aged 50 years and over was 19.5 percent, while the prevalence of depression among persons aged 75 years and over was about 17.1 percent(7). China has the largest older population in the world, and the prevalence of depression among the older adults is equally bleak(8, 9). Tan Tang et al. conducted a meta-analysis of the prevalence of depression in Chinese older adults and found that the overall prevalence of depression in Chinese older adults was 20.0 percent(10). Altogether, the increasing incidence of depression in the middle-aged and older adults has become a major public health problem in China, and it is important to examine factors associated with elevated depressive symptoms and to identify potential avenues for prevention and intervention.

Digital exclusion is often defined as inequality in access to and use of information and communication technologies such as the Internet(11). In recent years, with the development of information technology in society, the Internet access situation of middle-aged and older adults has been improving. However, due to physical and psychological barriers, lack of technological knowledge and skills, economic factors, geographical limitations, and other factors(12–14), middle-aged and older adults are still commonly faced with the problem of digital exclusion(15–17). Presently, in China, there are over 126 million non-internet users aged 60 and above(18). However, owing to the lack of ability to use the Internet and Internet tools, their quality of life may be detrimentally impacted(19). It is also worth noting that, similar to Facebook or Twitter internationally, WeChat and Alipay are the multi-functional social media and online payment platforms that currently dominate in China(20, 21). Therefore, their usage status can be used as indices to evaluate the digital exclusion of middle-aged and older adults in China. Furthermore, existing research shows the relevance of digital exclusion for physical and mental health in old age(22). Results from a survey of 108,621 older adults in 23 countries by Lu et al. show that older adults with digital exclusion are more likely to develop functional dependence(11). Simultaneously, Another study found a positive correlation between digital exclusion and cognitive impairment(23). Nevertheless, the current association between digital exclusion and depression in middle-aged and older is unclear.

Therefore, using data from the China Health and Retirement Longitudinal Study (CHARLS)(24), this study examined the association between digital exclusion and elevated depressive symptoms among middle-aged and older Chinese adults. We further conducted subgroup analyses by gender and area of residence and performed propensity score matching analyses to assess the robustness of the findings. By examining these associations, this study aims to provide additional evidence on the relationship between digital engagement and mental health in middle-aged and older adults in China.

2. Materials and Methods

2.1 Participants

The China Health and Retirement Longitudinal Study (CHARLS) is a nationwide longitudinal survey of Chinese residents aged 45 and over, aimed at analyzing interdisciplinary research on population aging. According to the official CHARLS Wave 5 User Guide, most fieldwork had been completed by the end of

September 2020. Written informed consent was obtained from all participants before the CHARLS survey interviews. The CHARLS study was approved by the relevant institutional biomedical ethics committee. The study was conducted in accordance with the principles of the Declaration of Helsinki. The CHARLS 2020 data used in this study were accessed on January 20, 2025. The authors did not have access to any personally identifiable information of individual participants during or after data collection. More information can be found in other topics(25).

The present study used data from the fifth wave of CHARLS (2020). First of all, 2030 participants whose records could not be linked across the CHARLS data files required for this study were excluded from the analysis(n = 2030); Furthermore, participants who lacked information on digital exclusion (n = 10393) and depression (n = 481) were excluded; In addition, participants who lacked information on covariates were excluded (n = 51); Finally, patients who were younger than 45 years of age were excluded (n = 73). A total of 6,367 participants were ultimately included in the analyses. Figure 1 shows the specific process of inclusion and exclusion of these participants. Comparison of baseline characteristics between the exclusion group and the inclusion group is detailed in Table S1.

2.2 Digital exclusion

Based on previous research, digital exclusion was operationalized using two self-reported items from CHARLS: (1) whether participants used mobile payment services, such as Alipay. (2) whether they used WeChat. Participants were classified into three mutually exclusive categories: no digital exclusion (use of both services), partial digital exclusion (use of only one service), and digital exclusion (use of neither service). This context-specific operationalization was adopted because mobile payment and WeChat use represent two forms of digital engagement relevant to everyday life in China, and these items were available in CHARLS(19, 23).

2.3 Depression assessment

Depression was assessed by the Centre for Epidemiological Studies Depression Scale (CES-D-10)(26, 27). The CES-D-10 scale comprises 10 items, each with 4 response options: rarely (< 1 day), some days (1–2 days), occasionally (3–4 days), and most of the time (5–7 days). The 4 response option values range from 0 to 3 and the CES-D-10 total score ranges from 0 to 30. Lower CES-D-10 scores indicate lower levels of depressive symptoms. Participant scores greater than or equal to 10 indicated depression.(28). The Cronbach alpha for this scale was 0.815, indicating good internal consistency(29). In this study, depression refers to a positive screening result for depressive symptoms based on a CES-D-10 score of ≥ 10, rather than a clinical diagnosis of depression.

2.4 Covariates

To ensure accurate and reliable results, covariates that may influence depression were included in this study: gender (male or female), age (< 60 years, 60–69 years, ≥ 70 years), education (junior high school and below, senior high school and above), marital status (married and never married/separated/widowed), drinking (more than once a month, no more than once a month, none of

these), residence (rural, transitional zone, urban), hospitalization status(yes or no), social activity status (yes or no), and basic activity of daily living disability (yes or no). In this study, we categorized participants' marital status as married or never married/separated/widowed according to whether they received social support from their spouses(30).

In addition, transitional zones are areas between urban and rural areas, characterized by a blend of urban and rural features, with a gradual transition from rural to urban in land use, social, demographic, economic, and cultural aspect(31); The assessment of social activities in the CHARLS are detailed in Table S2; And the assessment of basic activities of daily living in the CHARLS are detailed in Table S3.

2.5 Statistical analysis

This study used Stata version 18.0 for statistical analyses. GraphPad version 9.0 was used to visualize the results of subgroup analyses. The association between digital exclusion and depression was assessed using univariate and multivariate logistic regression analyses with cumulative adjustment for confounders. Model 1 was not adjusted for any variables. Model 2 was adjusted for gender, age, marital status, residence, and education. Model 3 was additionally adjusted for frequency of alcohol consumption in the last year, hospitalization, social activities, and basic activities of daily living disability based on Model 2. Finally, subgroup analyses based on Model 3 were conducted to investigate whether the association between digital exclusion and depression differed across gender and residence. 1:1 Individual Matching, K-Nearest Neighbor Matching, Caliper Matching and Kernel Matching to test the robustness of propensity score matching (PSM) results. Statistical significance was set at $p < 0.05$ for a two-sided test.

3. Results

3.1 Characteristics of the participants

Note

(a) Age distribution; (b) CES-D-10 score distribution. The violin plots illustrate the distributions of the two variables across the three digital exclusion groups.

Figure 2 Distributions of age and CES-D-10 scores across digital exclusion groups.

Table 1 provides the baseline characteristics of the participants. A total of 6,367 participants with complete information were included in this study, of which 3,215 (50.5%) were male and 3,152 (49.5%) were female. A total of 1,910 (30.0%) had depression, and 4,457 (70.0%) did not have depression(Fig. 2). A total of 3,909 people (61.4%) used both WeChat and mobile payment, while 1,902 people (29.9%) used only one of the two options. 556 (8.7%) of the participants had digital exclusion. The results showed that there were statistically significant differences in depression among middle-aged and older adults in terms of gender, digital exclusion, education, marital status, drinking, residence, hospitalization status in the past year, social activities, and basic activities of daily living disability ($p < 0.05$).

Table 1
Characteristics of the participants.

Variables	Total (N = 6367)	Depression	No depression	χ2	*P*-value
Gender, n(%)				174.43	< 0.001
Male	3215(50.5)	723(37.9)	2492(55.9)		
Female	3152(49.5)	1187(62.1)	1965(44.1)		
Age, n(%)				0.87	0.646
< 60 years	2814(44.2)	833(43.6)	1981(44.4)		
60–69 years	2508(39.4)	769(40.3)	1739(39.0)		
≥ 70 years	1045(16.4)	308(16.1)	737(16.5)		
Digital exclusion, n(%)				86.65	< 0.001
No digital exclusion	3909(61.4)	1008(52.7)	2901(65.1)		
Partial digital exclusion	1902(29.9)	708(37.1)	1194(26.8)		
Digital exclusion	556(8.7)	194(10.2)	362(8.1)		
Education, n(%)				90.88	< 0.001
Junior high school and below	4886(76.7)	1613(84.5)	3273(73.4)		
Senior high school and above	1481(23.3)	297(15.5)	1184(26.6)		
Marital status, n(%)				72.29	< 0.001
Married	5148(80.9)	1422(74.5)	3726(83.6)		
Unmarried/separated/widowed	1219(19.1)	488(25.5)	731(16.4)		
Drinking, n(%)				114.63	< 0.001
Drinking more than once a month	2035(32.0)	441(23.1)	1594(35.8)		
Drinking but less than once a month	842(13.2)	238(12.5)	604(13.6)		
None of these	3490(54.8)	1231(64.5)	2259(50.7)		

Note: The chi-square test was used to compare differences in the distribution of categorical variables between the depression group and the non-depression group.

Variables	Total (N = 6367)	Depression	No depression	χ2	*P*-value
Residence, n(%)				67.44	< 0.001
Urban	2148(33.7)	523(27.4)	1625(36.5)		
Transitional zone	897(14.1)	243(12.7)	654(14.7)		
Rural	3322(52.2)	1144(59.9)	2178(48.9)		
Hospitalization status, n(%)				54.87	< 0.001
Yes	972(15.3)	389(20.4)	583(13.1)		
No	5395(84.7)	1521(79.6)	3874(86.9)		
Social activities, n(%)				6.37	0.012
Yes	2672(42.0)	756(39.6)	1916(43.0)		
No	3695(58.0)	1154(60.4)	2541(57.0)		
Basic activities of daily living disability, n(%)				364.72	< 0.001
Yes	856(13.44)	495(25.9)	361(8.1)		
No	5511(86.56)	1415(74.1)	4096(91.9)		

Note: The chi-square test was used to compare differences in the distribution of categorical variables between the depression group and the non-depression group.

3.2 Association between digital exclusion and depression in middle-aged and older adults

Model 1 (Table 2) showed that middle-aged and older adults with partial digital exclusion and digital exclusion had a higher risk of depression compared to middle-aged and older adults without digital exclusion. (OR = 1.71, $p<0.001$; OR = 1.54, $p < 0.001$). Subsequently, we constructed Models 2 and 3 by including covariates. In Model 3, after adjustment for all covariates, partial digital exclusion and digital exclusion remained associated with higher odds of screening positive for elevated depressive symptoms compared with no digital exclusion (OR = 1.30, 95% CI: 1.07–1.58, $p = 0.009$; OR = 1.33, 95% CI: 1.18–1.51, $p < 0.001$, respectively). To further examine the association between digital exclusion and depressive symptoms while accounting for the information loss that may result from dichotomizing CES-D-10 scores, we additionally conducted multivariable linear regression analyses using the total CES-D-10 score as a continuous outcome. After adjustment for the same covariates included in Model 3, both partial digital exclusion and digital exclusion were significantly associated with higher CES-D-10 scores compared with no digital exclusion (β = 0.975, 95% CI: 0.651–1.298, p < 0.001; β = 1.020, 95% CI: 0.509–

1.530, $p < 0.001$, respectively). These findings were consistent with the results of the logistic regression analyses. Detailed results are presented in Supplementary Table S4.

Table 2
Association between digital exclusion and depression in middle-aged and older adults.

Variables	Model 1		Model 2		Model 3	
	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value
Digital exclusion						
No digital exclusion	Reference		Reference		Reference	
Partial digital exclusion	1.71 (1.52–1.92)	< 0.001	1.39 (1.23–1.57)	< 0.001	1.30 (1.07–1.58)	0.009
Digital exclusion	1.54 (1.28–1.86)	< 0.001	1.36 (1.12–1.65)	0.002	1.33 (1.18–1.51)	< 0.001
Gender						
Male			Reference		Reference	
Female			1.95 (1.74–2.19)	< 0.001	1.77 (1.56–2.02)	< 0.001
Age						
< 60 years			Reference		Reference	
60–69 years			1.14 (1.01–1.29)	0.044	1.03 (0.91–1.18)	0.627
≥ 70 years			1.07 (0.90–1.27)	0.450	0.87 (0.73–1.05)	0.139
Education						
Junior high school and below			Reference		Reference	
High school and above			0.69 (0.59–0.80)	< 0.001	0.68 (0.59–0.80)	< 0.001
Marital status						
Married			Reference		Reference	

Variables	Model 1		Model 2		Model 3	
	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value
Unmarried/separated/widowed			1.67 (1.46–1.91)	< 0.001	1.68 (1.47–1.92)	< 0.001
Residence						
Urban			Reference		Reference	
Transitional zone			1.12 (0.93–1.35)	0.22	1.14 (0.94–1.37)	0.180
Rural			1.53 (1.34–1.75)	< 0.001	1.56 (1.36–1.78)	< 0.001
Drinking						
Drinking more than once a month					Reference	
Drinking but less than once a month					1.18 (0.97–1.43)	0.099
None of these					1.32 (1.14–1.53)	< 0.001
Hospitalization						
Yes					Reference	
No					0.57 (0.49–0.66)	< 0.001
Social activities						
Yes					Reference	
No					0.95 (0.85–1.07)	0.420

Variables	Model 1		Model 2		Model 3	
	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value
Basic activities of daily living disability					Reference	
Yes						
No					0.31 (0.26–0.36)	< 0.001

Note: OR, Odds Ratio; CI—Confidence Interval.

Model 1 is not adjusted for covariates; Model 2 adjusted for gender, age, marital status, residence, and education; Model 3 adjusted for gender, age, marital status, residence, education, drinking, hospitalization, social activities, and basic activities of daily living disability.

Model 3 likelihood ratio test results indicate :χ^2=677.66, $p < 0.001$. Pseudo R^2= 0.0871.

3.3 Gender and regional differences in the association between digital exclusion and depression

To further examine the association between digital exclusion and depression across different population subgroups, we conducted stratified analyses by gender and area of residence (Figs. 3). In the gender-stratified analyses, digital exclusion was significantly associated with higher odds of depression among women (OR = 1.45, $p < 0.001$), whereas the association did not reach statistical significance among men ($p = 0.086$). In the analyses stratified by area of residence, the estimated ORs varied across residential subgroups, with the point estimate for participants living in transitional zones reported as 1.92 ($p < 0.001$).

Figure 3 Association between digital exclusion and depression among middle-aged and older adults based on gender and residence subgroups.

3.4 Propensity score matching

Because this study was not a randomized trial, participants were not randomly assigned to an intervention or control group. Personal characteristics may not only influence depression in middle-aged and older adults but also whether or not they use mobile devices regularly. Therefore, we used propensity score matching (PSM) to improve the comparability of the digital-exclusion and control groups with respect to observed covariates and to assess the robustness of the observed association. Participants with digital exclusion were assigned to the treated group, while those with partial and no digital exclusion were assigned to the control group. After the kernel matching method, the specifics of standard errors and error elimination of the control variables before and after matching are shown in Table 3 and Figure S1.

Table 3
Error reduction before and after matching for each variable.

Variable	Matching Status	Mean			Reduction	T-test	*P*-value
		Treated	Control	Bias(%)	Bias(%)	t	
Gender	Unmatched	1.473	1.495	-4.5		-1.00	0.315
	Matched	1.473	1.475	0.3	92.5	0.06	0.956
Age	Unmatched	2.081	1.693	53.6		12.16	<0.001
	Matched	2.081	2.056	3.4	93.6	0.55	0.581
Education	Unmatched	1.1230	1.237	-28.1		-5.79	<0.001
	Matched	1.1230	1.123	1.7	94.1	0.32	0.749
Marital status	Unmatched	1.155	1.195	-9.7		-2.11	0.035
	Matched	1.155	1.139	0.7	93.0	0.12	0.905
Drinking	Unmatched	2.317	2.220	10.1		2.28	0.023
	Matched	2.317	2.309	-2.1	79.5	-0.35	0.726
Residence	Unmatched	2.462	2.158	34.3		7.39	<0.001
	Matched	2.462	2.464	-1.7	94.9	-0.31	0.757
Hospitalization	Unmatched	0.176	0.150	6.8		1.58	0.114
	Matched	0.176	0.162	-2.1	69.3	-0.34	0.736
Social activities	Unmatched	0.345	0.423	-16.0		-3.55	<0.001
	Matched	0.345	0.340	0.9	93.1	0.19	0.851
Basic activities of daily living disability	Unmatched	0.184	0.131	14.6		3.49	<0.001
	Matched	0.184	0.180	1.0	93.3	0.15	0.878
Sample	Ps R^2	LR chi2	*p*>chi2	Mean Bias	Med Bias	B	R
Unmatched	0.075	282.59	0.000	19.7	14.6	78.1*	0.81
Matched	0.000	0.75	1.000	1.6	1.7	5.2	1.01

Variable	Matching Status	Mean			Reduction	T-test	*P*-value
		Treated	Control	Bias(%)	Bias(%)	t	

Note: * if B > 25%, R outside [0.5;2]; Ps R^2: Pseudo R-squared; LR chi2: chi-square statistic, B: absolute standard deviation; R: standard deviation ratio.

In the PSM analysis, we excluded 377 control group samples based on the common support condition of propensity scores. The treated group comprised 556 participants, while the control group consisted of 5,434 participants.

To compare the treatment and control groups, we used 1:1 individual matching, K nearest-neighbor matching, caliper matching, and kernel matching, and subsequently calculated the treatment effect. The estimated results using the PSM method are shown in Table 4. After propensity score matching, the balance of measured covariates between the digital-exclusion group and the control group improved. Across the matching approaches, the estimated average treatment effect on the treated (ATT) ranged from 0.039 to 0.047. These findings were consistent with a positive association between digital exclusion and depression; however, residual confounding and the cross-sectional design limit causal interpretation.

Table 4
Propensity score matching estimates of the association between digital exclusion and elevated depressive symptoms among middle-aged and older adults.

Method	Treat Group	Control Group	ATT	Stand Error
1:1 Individual Matching	0.349	0.305	0.044*	0.021
K-Nearest Neighbor Matching	0.349	0.305	0.044*	0.022
Caliper Matching	0.349	0.310	0.039*	0.020
Kernel Matching	0.349	0.302	0.047*	0.021

Note: * $p < 0.05$. K = 3; ATT, average treatment effect on the treated; SE, standard error. ATT represents the average treatment effects on treated.

4. Discussion

This study investigated the relationship between digital exclusion and depression in middle-aged and older Chinese adults. Concurrently, the study showed that female, unmarried/separated/widowed, and living in a rural area were positively associated with depression, while not having been hospitalized in the last year and being highly educated were negatively associated with depression. Moreover, this study identified gender and residence differences in the association between digital exclusion and depression among middle-aged and older adults.

Our research suggests that middle-aged and older adults with digital exclusion are at higher risk of developing depression. Prior research corroborates our findings. First of all, previous research has argued

that social determinants of health such as loneliness, stigma, housing, employment, and social welfare are significantly associated with depression(32, 33). And Middle's study discovered that digital exclusion not only fosters a sense of isolation and stigmatization among patients but also impacts critical social determinants of health, such as housing, employment, and access to social benefits(15). Thus, digital exclusion may affect the risk of depression in middle-aged and older adults by influencing the aforementioned factors.

Furthermore, mobile payment use influences depression risk among middle-aged and older adults. Mobile payment refers to any online transaction initiated, authorized, registered and verified by a mobile terminal device(34, 35). And the ability to use mobile payments as a key indicator of digital exclusion among individuals(36). Previous research suggests that certain factors, such as nutritional status and transaction costs, may mediate the association between mobile payment and depression. On the one hand, mobile payment helps to increase the diversity of food in a family's daily diet, thus ensuring a more balanced nutritional intake for individuals(37). Simultaneously, a sound and balanced nutritional status may positively influence the emotional health of older adults. For example, Li et al. reported that the Geriatric Nutritional Risk Index (GNRI) is negatively and non-linearly correlated with the prevalence of depression in older adults(38). On the other hand, the use of mobile payment can reduce transaction costs and facilitate access to online private insurance and health services. Meanwhile, prior studies have shown that health insurance and the quality of health services are key factors in alleviating depression among middle-aged and older adults(39). Therefore, digital exclusion may affect depression in middle-aged and older adults through mobile payments.

At last, social media use can also influence depression risk among middle-aged and older adults. Gilmour et al. found that social media has a positive impact on many aspects of health, including reducing anxiety and loneliness, alleviating depression, increasing well-being, and promoting physical health(40). For example, Grieve et al.' s(41, 42) study finds lower levels of depression and anxiety among users with higher Facebook contact frequency. WeChat is a popular social media mobile app in China(43). While chatting with family and friends through WeChat enables middle-aged and older adults to gain more social support and reduce loneliness, which plays an important role in alleviating depression among middle-aged and older adults(44, 45). Taken together, these findings suggest that reduced opportunities for social interaction and support may be among the pathways linking digital exclusion to depressive symptoms.

Additionally, our study found that no drinking was associated with an elevated risk of depression in middle-aged and older adults. Previous studies have indicated that moderate alcohol consumption may reduce the risk of depression(46). For example, the study by Visontay et al. suggests a potential causal relationship between moderate alcohol consumption and reduced risk of depression(47). Nevertheless, the data on drinking in this study do not permit an examination of the effect of moderate drinking on the risk of depression in middle-aged and older adults. This is because the data on drinking in this study relate only to the drinking frequency of participants, but not to the specific amount. Therefore, this study

could not determine whether participants drank moderately or not, nor could it make valid inferences about the effects of moderate drinking on depression risk in middle-aged and older adults.

Meanwhile, it is worth noting that depression may also, in turn, affect older adults' ability to use digital technology. This may stem from the negative impact of depression on their physical and mental health and functioning. Fiske et al. demonstrated that older adults with depression typically exhibit fewer affective symptoms but are more likely to experience cognitive changes, somatic symptoms, and loss of interest(48). Among them, cognitive decline impairs older people's learning, understanding, and memory of digital knowledge, thereby hindering their acquisition of Internet operating skills(49); Somatic symptoms such as headaches, fatigue, and insomnia, which may be present in individuals with depression, can influence the durability and effectiveness of older adults' use of digital technology and the Internet(50); Moreover, loss of interest can cause them to lose interest in carrying out digitally related activities(51).

The present study also examined the associations between various covariates and depression in middle-aged and older adults, with results consistent with prior research. For example, our study found that being unmarried/separated/widowed was positively associated with depression in middle-aged and older adults. This may be due to married people generally face fewer physical and mental health problems and are less likely to suffer from mental disorders(52, 53). Yu et al. identified subjective well-being as the main factor contributing to this phenomenon, and marital status plays an important role in subjective well-being(54). Married and cohabiting people tend to have higher subjective well-being and relatively lower levels of depression than those who are separated, divorced, widowed, or have never been married(55–57). In addition, a good marriage establishes a stable social relationship that fulfills the basic conditions for perceived social support, thus reducing the risk of depression among married people(58).

Meanwhile, Our study reported that not being hospitalized for nearly a year was negatively associated with depression in middle-aged and older adults. Self-assessed health is a subjective feeling that people have based on their actual health status and interacts with their mental health. The better the self-assessed health status of middle-aged and older adults, the more likely they are to develop positive attitudes toward life, thus preventing the development of psychological disorders(59). And hospitalization is often based on the deterioration of patients' physical health, prompting them to revise their self-assessed health and leading to their increased risk of depression. Kuo et al. noted that the risk of depression was much higher in hospitalized patients than in the general public, with 12 percent of the total number of hospitalized patients having depression(60). In addition, hospitalized patients are often faced with the pain of illness and heavy medical costs, which also increases the risk of depression in hospitals(61).

Notably, the gender-stratified analyses showed that digital exclusion was significantly associated with depression among women, whereas the association did not reach statistical significance among men. The estimated association among women was stronger than that observed in the overall population. However, because no formal interaction test was performed, these findings do not establish that the association between digital exclusion and depression differs significantly by gender. Previous studies

have reported a higher prevalence of depression among women than men (62, 63), which may partly contextualize the observed association. In addition, prior research suggests that women may be more likely than men to use social media for emotional communication and social interaction (64). If women rely more heavily on platforms such as WeChat to maintain social connections and share personal experiences with family and friends, digital exclusion may limit these opportunities for social support and emotional expression. By contrast, if men use WeChat relatively more for information exchange than for interpersonal interaction, the consequences of digital exclusion may differ. These explanations remain speculative, however, and further research is needed to determine whether gender differences in digital media use contribute to the observed patterns.

In addition, we stratified participants according to their area of residence. We found significant associations between digital exclusion and depression in middle-aged and older adults living in urban, transitional and rural areas. In the analyses stratified by area of residence, digital exclusion was associated with higher odds of depression across the residential subgroups. Firstly, the difference in this correlation between middle-aged and older adults in transition zones and those in urban areas may be attributed to economic conditions. Yang et al.'s study highlights that economically disadvantaged older adults are more likely to encounter obstacles in accessing and using digital devices(65). In China, the income and consumption levels of urban older adults are significantly higher than those in other regions(66, 67). Secondly, the differences in this association between middle-aged and older adults in transition zones and those in rural areas can be attributed to variations in their living environments. Rural middle-aged and older adults exhibit a relatively low demand for accessing and utilizing digital devices(68). Middle-aged and older adults residing in transition zones encounter greater challenges in adapting to the rapid pace of urban life and the swift development of digital technology compared to their rural counterparts.

5. Strengths and limitations.

This study possesses several strengths. First of all, data from a nationwide survey, and the large sample increases the reliability of our conclusions. Furthermore, this study extends prior research by further examining the effects of digital exclusion on depression across different subgroups, thereby enriching the literature in this field. Lastly, propensity score matching was used to assess the robustness of the findings after improving balance in observed covariates. However, there are limitations to this study. To begin with, the present study was a cross-sectional survey and therefore no causal relationship can be inferred between digital exclusion and depression. Secondly, during the data cleaning phase, a significant portion of participants were excluded due to missing information related to digital exclusion, which may introduce selection bias; In addition, although propensity score matching improved the balance of measured covariates, residual confounding and potential reverse causation cannot be ruled out. Finally, digital exclusion was assessed using only two self-reported indicators: mobile payment use and WeChat use. Although these indicators reflect relevant forms of digital engagement in the Chinese context, they do not capture all dimensions of digital exclusion, such as access to digital devices and the internet,

digital skills, frequency and purpose of use, and the ability to use digital services independently. Therefore, the findings should be interpreted in relation to this study-specific operational definition.

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Figures

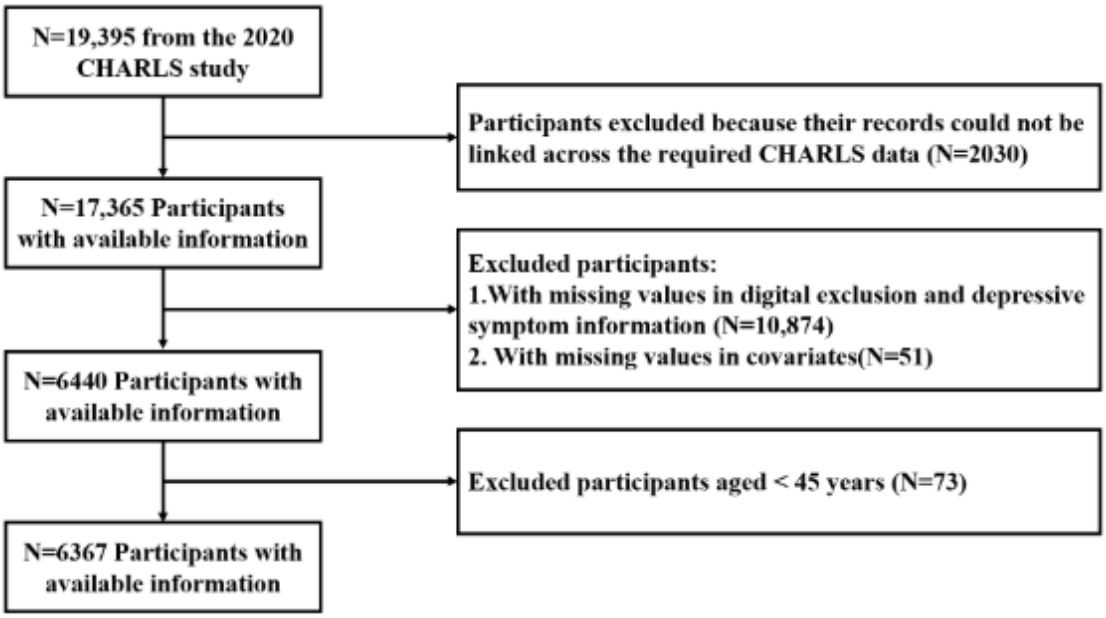

Figure 1

Flowchart of Participants Screening.

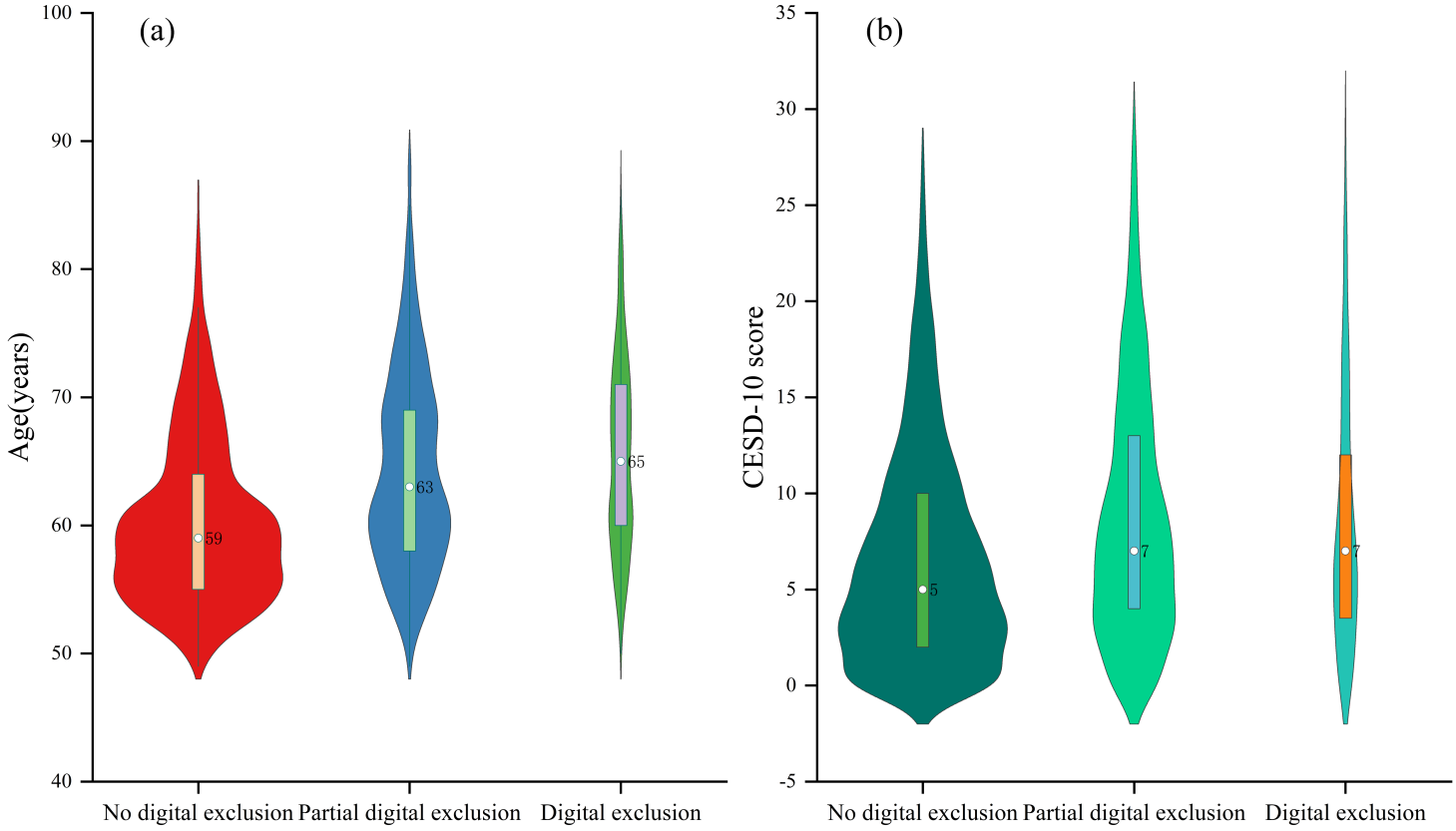

Figure 2

Distributions of age and CES-D-10 scores across digital exclusion groups.

Note: (a) Age distribution; (b) CES-D-10 score distribution. The violin plots illustrate the distributions of the two variables across the three digital exclusion groups.

Dependent Variable	Factors	OR	95%LCI	95%UCI	*P*-value
Digital Exclusion	Overall	1			
		1.30	1.07	1.58	0.009
		1.33	1.18	1.51	<0.001
	Male	1			
		1.16	0.86	1.55	0.330
		1.19	0.98	1.45	0.086
	Female	1			
		1.45	1.10	1.90	0.007
		1.45	1.23	1.70	<0.001
	Urban	1			
		1.15	0.74	1.80	0.532
		1.31	1.04	1.65	0.024
	Transitional Zone	1			
		2.02	1.16	3.53	0.013
		1.92	1.35	2.72	<0.001
	Rural	1			
		1.24	0.97	1.57	0.085
		1.24	1.06	1.46	0.009

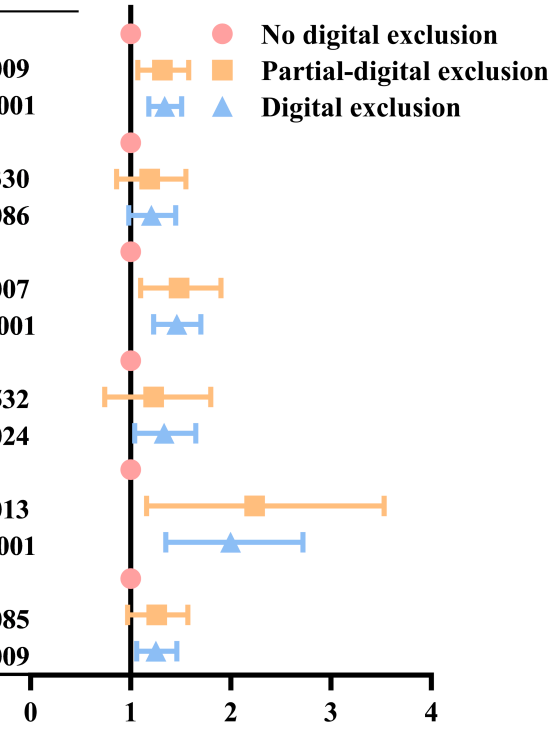

Figure 3

Association between digital exclusion and depression among middle-aged and older adults based on gender and residence subgroups.

Supplementary Files

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- Supplementarymaterial.doc