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Association and causal mediation between marital status and depression in seven countries

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Depression represents a significant global public health challenge, and marital status has been recognized as a potential risk factor. However, previous investigations of this association have primarily focused on Western samples with substantial heterogeneity. Our study aimed to examine the association between marital status and depressive symptoms across countries with diverse cultural backgrounds using a large-scale, two-stage, cross-country analysis. We used nationally representative, de-identified individual-level data from seven countries, including the USA, the UK, Mexico, Ireland, Korea, China and Indonesia (106,556 cross-sectional and 20,865 longitudinal participants), representing approximately 541 million adults. The follow-up duration ranged from 4 to 18 years. Our analysis revealed that unmarried individuals had a higher risk of depressive symptoms than their married counterparts across all countries (pooled odds ratio, 1.86; 95% confidence interval (CI), 1.61–2.14). However, the magnitude of this risk was influenced by country, sex and education level, with greater risk in Western versus Eastern countries ($\beta = 0.36$; 95% CI, 0.16–0.56; $P < 0.001$), among males versus females ($\beta = 0.25$; 95% CI, 0.003–0.47; $P = 0.047$) and among those with higher versus lower educational attainment ($\beta_2 = 0.34$; 95% CI, 0.11–0.56; $P = 0.003$). Furthermore, alcohol drinking causally mediated increased later depressive symptom risk among widowed, divorced/separated and single Chinese, Korean and Mexican participants (all $P < 0.001$). Similarly, smoking was as identified as a causal mediator among single individuals in China and Mexico, and the results remained unchanged in the bootstrap resampling validation and the sensitivity analyses. Our cross-country analysis suggests that unmarried individuals may be at greater risk of depression, and any efforts to mitigate this risk should consider the roles of cultural context, sex, educational attainment and substance use.

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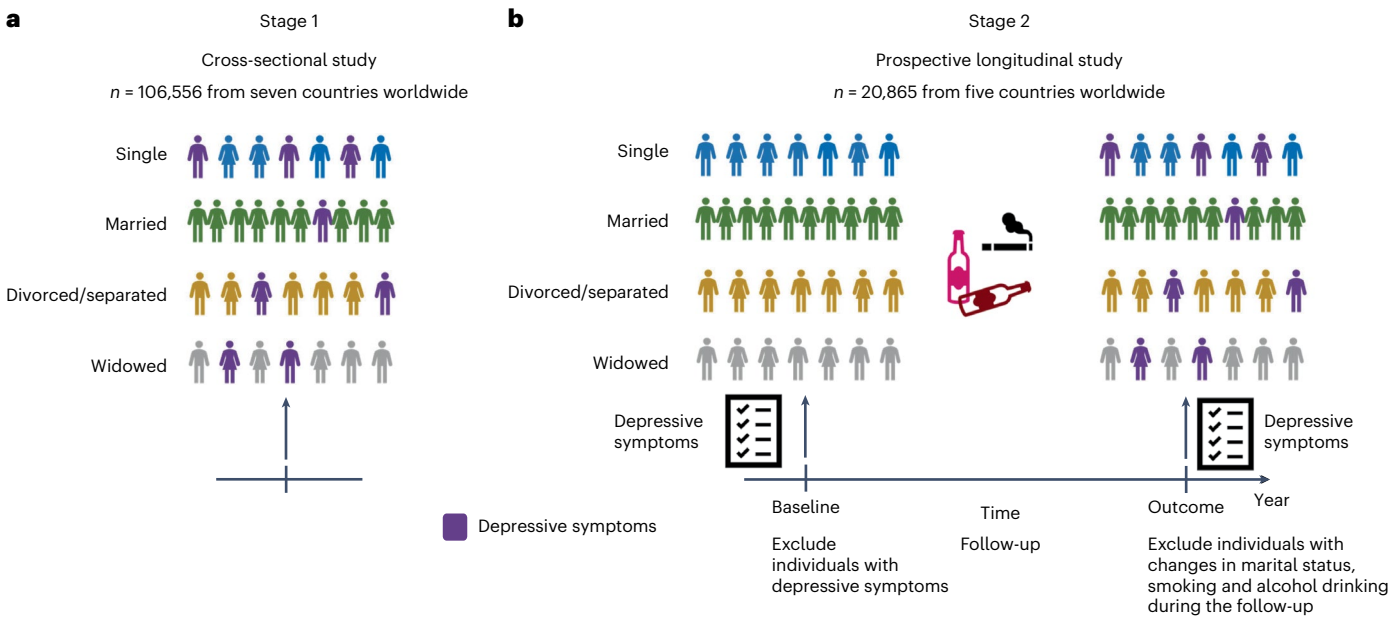

Fig. 1 | Study design. a,**b**, The study design comprising a cross-sectional stage (**a**) and a prospective longitudinal stage (**b**) for this large-cohort, multi-country analysis.

Depression has emerged as a pressing global public health issue, with an estimated prevalence of 5% among adults worldwide[1]. This figure is projected to increase to over 10% by 2025 in the post-pandemic era[2,3]. Beyond profound psychic pain, depression is associated with an increased risk of somatic conditions such as coronary heart disease[4] and shows strong links to disability burden and suicide worldwide[5]. Given its multifaceted and complex nature, depression has diverse interrelated risk factors. Elucidating potentially modifiable risk factors for depressive symptoms as a typical manifestation of depression constitutes a major research priority. Identifying such causative factors holds substantial public health implications and can inform prevention and treatment efforts against this serious mental health condition.

Humans have developed complex social structures and often rely on cooperation with others to achieve their goals and navigate the world[6]. Marriage is a complex social bond that links two individuals to one another. Recent studies indicate the association of marital status with various health conditions such as cancer[7], diabetes[8], cardiovascular diseases[9] and total mortality[10].

While marital status has also been found to be linked to mental health, most current studies examining the association between marital status and depression used data from single countries, primarily Western samples, and generally indicate that being married has a protective effect against depression[11–14]. However, these patterns may not generalize globally, as other countries around the world differ from Western nations in many ways. Variations in culture, socio-economic development and education can uniquely shape marital behaviours across countries[15]. For example, studies conducted in Korea and Kenya found no association between marital status and depression in females[16,17]. Even within Europe, research shows that the psychological outcomes associated with widowhood vary extensively due to limited sample sizes[18]. Large-scale, cross-country analyses are therefore critically needed to clarify these complex associations.

Regarding moderators, previous studies have reported inconsistent conclusions about the moderating effect of sex on the link between marital status and depression risk[11,19–21]. Additional potential moderating variables that may contribute to variations in the strength of the association between marital status and depressive symptoms across diverse populations remain underexplored, particularly country, age and educational attainment. Furthermore, the causality and underlying mechanisms that mediate the relationship between marital status and increased risk of developing depressive symptoms are still unclear. While behavioural factors such as alcohol drinking[22], cigarette smoking[23], income[24] and body mass index (BMI)[25,26] have been reported to be associated with depression, their potential causal mediating roles in the relationship between marital status and depressive symptom onset have not yet been investigated.

To address the aforementioned gaps, the objective of this study was to assess the association between marital status and risk of depressive symptoms using an integrated cross-sectional and longitudinal cohort analysis. This multi-country investigation analysed individual-level data to quantify both current and future risk of depressive symptoms. Large-scale, nationally representative samples from seven culturally diverse countries were leveraged to determine the association. Given the complex, multifactorial nature of depression, potential modifying factors and causal mediators of the association were explored.

Results

Participant characteristics in the global cohort

This study used a two-stage design that integrated cross-sectional and longitudinal analyses. The cross-sectional stage comprised 106,556 participants (49,547 males) from eight cohorts in seven countries, with 22,490 individuals having depressive symptoms (Fig. 1a and Table 1). The proportion of participants who reported being married varied by cohort, ranging from 64.3% (18,867) in the NHANES cohort (USA) to 87.6% (12,758) in the CHARLS cohort (China). Additionally, there were differences in educational attainment among participants across countries and cohorts. More details on the participants in each cohort are presented in Supplementary Tables 1–8.

The prospective longitudinal stage included 20,865 participants (10,502 males) from five countries (Fig. 1b and Table 2). The mean duration of follow-up ranged from 4 years in the KLoSA cohort to 18 years in the WLS cohort. During the follow-up, 4,486 participants with depressive symptoms were identified. Other baseline characteristics of the participants in each cohort are shown in Tables 1 and 2.

Marital status and depressive symptoms across countries

In the multivariable-adjusted model, being unmarried was associated with a higher risk of depressive symptoms than being married across all cohorts in the seven countries (Table 3). The pooled odds ratio (OR) for

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Table 1 | The characteristics of the participating cohorts in the cross-sectional stage

	NHANES* (*n*=31,271)	WLS (*n*=7,077)	APMS* (*n*=6,672)	MHAS* (*n*=10,355)	KLoSA* (*n*=5,037)	TILDA* (*n*=5,296)	CHARLS* (*n*=14,523)	IFLS (*n*=26,325)
Country	USA	USA	UK	Mexico	Korea	Ireland	China	Indonesia
Year of study	2005–2018	2004–2005	2007	2018	2020	2009–2011	2015	2014–2015
Participants with depressive symptoms, *n* (%)	2,701 (7.5)	627 (8.9)	222 (2.9)	2,772 (28.0)	1,059 (20.7)	555 (11.5)	4,906 (33.0)	9,648 (36.7)
Marital status								
Married, *n* (%)	18,867 (64.3)	5,692 (80.4)	3,854 (67.0)	6,927 (68.5)	3,700 (75.0)	3,888 (71.6)	12,758 (87.6)	21,459 (81.5)
Single, *n* (%)	5,515 (17.4)	255 (3.6)	1,119 (17.8)	520 (5.6)	38 (1.3)	433 (8.2)	91 (0.7)	2,887 (11.5)
Divorced/separated, *n* (%)	4,471 (12.6)	639 (9.0)	829 (7.9)	589 (7.3)	133 (4.0)	323 (6.2)	151 (1.0)	720 (2.2)
Widowed, *n* (%)	2,418 (5.7)	491 (6.9)	870 (7.3)	2,319 (17.3)	1,166 (19.7)	652 (14.0)	1,523 (10.7)	1,259 (4.8)
Age, median (IQR)	47.0 (33.0, 60.0)	65.0 (64.0, 65.0)	47.0 (34.0, 62.0)	63.0 (58.0, 71.0)	68.0 (63.0, 76.0)	61.0 (55.0, 70.0)	59.0 (51.0, 66.0)	37.0 (29.0, 48.0)
Male, *n* (%)	15,192 (48.4)	3,135 (44.3)	2,928 (49.5)	4,387 (42.3)	2,108 (46.4)	2,428 (48.7)	6,801 (47.0)	1,2494 (47.5)
Education								
Low levels of education, *n* (%)	7,393 (15.1)	–	2,109 (26.6)	7,308 (66.9)	2,987 (50.0)	1,316 (33.7)	10,899 (74.7)	14,691 (55.8)
Moderate levels of education, *n* (%)	7,238 (23.4)	3,561 (50.3)	1,876 (28.8)	2,017 (23.5)	1,526 (36.0)	2,202 (45.5)	2,384 (16.7)	7,255 (27.6)
High levels of education, *n* (%)	16,640 (61.5)	3,516 (49.7)	2,687 (44.6)	1,030 (9.6)	524 (14.0)	1,778 (20.8)	1,240 (8.6)	4,379 (16.6)
Income, *n* (%)								
Low levels of income, *n* (%)	9,509 (21.9)	1,767 (25.0)	1,341 (18.0)	–	1,334 (24.9)	3176 (62.0)	–	–
Moderate levels of income, *n* (%)	11,577 (30.0)	3,540 (50.0)	2,814 (40.5)	–	2,757 (50.1)	519 (9.3)	–	–
High levels of income, *n* (%)	7,306 (33.0)	1,770 (25.0)	1,293 (21.0)	–	946 (25.0)	1601 (28.7)	–	–
Missing	2,879 (9.1)	–	1,224 (20.5)	–	–	–	–	–
BMI (kg m^{-2}), median (IQR)	28.0 (24.2, 32.6)	27.0 (24.0, 30.0)	25.5 (22.8, 28.6)	27.1 (24.3, 30.4)	23.4 (21.9, 25.1)	28.2 (25.4, 31.5)	23.6 (21.3, 26.2)	23.2 (20.4, 26.4)
Under/normal weight, *n* (%)	8,919 (29.8)	1,864 (26.4)	3,020 (45.8)	3,461 (32.1)	3,787 (73.8)	1,200 (21.1)	7,776 (53.7)	17,169 (65.2)
Overweight, *n* (%)	10,256 (32.5)	3,131 (44.2)	2,410 (35.8)	4,133 (40.7)	1,169 (24.5)	2,287 (43.2)	4,816 (33.3)	6,811 (25.9)
Obesity, *n* (%)	12,096 (37.7)	2,082 (29.4)	1,242 (18.4)	2,761 (27.2)	81 (1.7)	1,809 (35.3)	1,931 (13.0)	2,345 (8.9)
Current smoking, *n* (%)	5,443 (17.1)	744 (10.5)	1,499 (22.9)	1,072 (12.5)	359 (9.4)	801 (16.6)	5,155 (35.2)	8,783 (33.4)
Current drinking, *n* (%)	7,347 (27.4)	747 (10.6)	5,380 (82.0)	2,570 (25.7)	1,423 (33.4)	4,016 (74.3)	5,158 (36.1)	–
Diabetes, *n* (%)	4,072 (9.7)	634 (9.0)	395 (5.2)	2,811 (24.2)	1,160 (22.2)	379 (7.5)	753 (5.1)	639 (2.4)
Hypertension, *n* (%)	11,298 (32.1)	3,139 (44.4)	1,729 (22.5)	5,085 (43.0)	2,512 (47.4)	1,894 (36.8)	3,018 (20.5)	3,332 (12.7)
Heart attack/diseases, *n* (%)	1,315 (3.3)	835 (11.8)	418 (5.0)	469 (3.4)	579 (10.4)	240 (4.8)	1,575 (10.4)	445 (1.7)
Stroke, *n* (%)	1,142 (2.7)	143 (2.0)	169 (2.0)	298 (2.8)	339 (6.2)	77 (1.6)	275 (1.9)	170 (0.7)
Cancer, *n* (%)	3,063 (10.4)	684 (9.7)	387 (4.7)	327 (2.6)	411 (7.8)	338 (6.5)	142 (1.0)	182 (0.7)

Education was categorized as low (less than high school in the NHANES, MHAS, KLoSA and IFLS; less than CSE/GCSE/equivalent in the UK; primary/equivalent in TILDA; elementary school/others/no formal education/illiterate in China), moderate (high school in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE/GCSE/equivalent in the UK; intermediate/junior/group certificate/equivalent in TILDA; middle school in China) and high (more than high school/college/equivalent in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE higher/GCSE higher/equivalent in the UK; college/higher degree in TILDA; high school/college/higher degree/equivalent in China). Income was categorized as low (lower quartile), moderate (interquartile range (IQR)) and high (upper quartile) on the basis of country-specific income rankings. *Percentages and medians were estimated using population-weighted population, except for the WLS and IFLS. An en dash (–) indicates not available.

all cohorts in the seven countries was 1.86 (95% confidence interval (CI), 1.61–2.14; $P < 0.001$) for unmarried versus married participants (Fig. 2a).

We further examined the associations between subcategories of unmarried status and depressive symptoms. Compared with married participants, being unmarried of any status was associated with an increased risk of having depressive symptoms, with pooled ORs of 1.79 (95% CI, 1.46–2.20; $P < 0.001$) for single (Fig. 2b), 1.99 (95% CI, 1.53–2.53; $P < 0.001$) for divorced/separated (Fig. 2c) and 1.64 (95% CI, 1.28–2.11; $P < 0.001$) for widowed individuals (Fig. 2d). The association between marital status and depressive symptoms remained significant in two different sensitivity analyses (Supplementary Figs. 1a,b and 2a,b).

Moderators of the relationship between marital status and depression

We examined variables to identify the potential moderators that influenced the association between marital status and depressive symptoms. Through our analysis, we identified three moderators that demonstrated strong evidence ($P < 0.05$) in at least six countries: country, sex and educational attainment (Fig. 3a–c).

Our findings revealed that the association between marital status and depressive symptoms varied by country of residence. Specifically, we observed that unmarried individuals in Western countries (the USA, the UK and Ireland) displayed a significantly higher risk of depressive

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Table 2 | The baseline characteristics of the participating cohorts in the longitudinal analysis

	WLS (*n*=2,981)	MHAS* (*n*=4,706)	KLoSA* (*n*=4,052)	TILDA* (*n*=3,495)	CHARLS* (*n*=5,631)
Country	USA	Mexico	Korea	Ireland	China
Follow-up years of study	1992–1994, 2004–2005 and 2011	2012, 2015 and 2018	2016, 2018 and 2020	2009–2011, 2012–2013 and 2014–2015	2013, 2015 and 2018
Person-years of follow-up, depression/total	3,348/53,658	11,245,224/56,586,588	4,225,278/36,620,703	150,030/2,192,749	436,682,458/955,705,455
Participants with depressive symptoms, *n* (%)	186 (6.2)	910 (19.8)	509 (11.4)	236 (6.8)	2,645 (45.7)
Marital status, *n* (%)					
Married	2,622 (88.0)	3,954 (83.5)	3,262 (81.4)	2,696 (77.5)	5,153 (90.9)
Single	87 (2.9)	285 (9.7)	62 (2.3)	397 (10.9)	34 (0.7)
Divorced/separated	221 (7.4)	230 3.9)	62 (2.1)	81 (2.2)	38 (0.9)
Widowed	51 (1.7)	237 (2.9)	666 (14.2)	321 (9.4)	406 (7.5)
Age, median (IQR)	53.0 (53.0, 53.0)	58.0 (53.0, 64.0)	64.0 (59.0, 71.0)	60.0 (55.0, 77.0)	58.0 (51.0, 65.0)
Male, *n* (%)	1,458 (44.8)	2,627 (55.0)	1,743 (47.3)	1,679 (51.5)	2,995 (52.9)
Education					
Low levels of education, *n* (%)	–	3,641 (70.2)	2,317 (48.0)	702 (25.8)	3,459 (57.1)
Moderate levels of education, *n* (%)	1,340 (45.0)	675 (19.7)	1,283 (37.3)	1,481 (49.0)	1,363 (25.4)
High levels of education, *n* (%)	3,516 (55.0)	390 (10.1)	452 (14.7)	1,312 (25.2)	809 (17.5)
BMI (kg m^{-2}), median (IQR)	26.0 (23.0, 28.0)	27.1 (24.6, 30.1)	23.4 (21.8, 25.1)	28.1 (25.4, 31.2)	24.3 (22.3, 25.5)
Under/normal weight, *n* (%)	861 (28.8)	1,418 (28.9)	3,026 (74.2)	779 (21.1)	2,333 (40.0)
Overweight, *n* (%)	1,364 (45.8)	2,806 (44.0)	990 (25.0)	1,572 (45.3)	2,671 (49.9)
Obesity, *n* (%)	756 (25.4)	1,202 (27.1)	36 (0.8)	1,144 (33.6)	627 (10.5)
Current smoking, *n* (%)	285 (9.6)	1,993 (42.5)	364 (11.7)	406 (12.4)	1,736 (29.5)
Current drinking, *n* (%)	442 (14.8)	1,399 (30.6)	1,330 (38.1)	463 (13.9)	2,249 (41.2)
Diabetes, *n* (%)	39 (1.3)	855 (16.2)	744 (17.5)	213 (6.3)	268 (5.2)
Hypertension, *n* (%)	535 (17.9)	1,723 (30.9)	1,713 (39.9)	1,172 (33.8)	1,206 (22.4)
Heart attack/diseases, *n* (%)	111 (3.7)	115 (2.1)	335 (7.8)	141 (4.0)	501 (9.0)
Stroke, *n* (%)	–	64 (1.3)	178 (3.8)	40 (1.2)	81 (1.4)
Cancer, *n* (%)	86 (2.9)	67 (0.6)	231 (5.1)	207 (5.8)	42 (0.8)

Education was categorized as low (less than high school in the NHANES, MHAS, KLoSA and IFLS; less than CSE/GCSE/equivalent in the UK; primary/equivalent in TILDA; elementary school/others/no formal education/illiterate in China), moderate (high school in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE/GCSE/equivalent in the UK; intermediate/junior/group certificate/equivalent in TILDA; middle school in China) and high (more than high school/college/equivalent in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE higher/GCSE higher/equivalent in the UK; college/higher degree in TILDA; high school/college/higher degree/equivalent in China). Income was categorized as low (lower quartile), moderate (IQR) and high (upper quartile) on the basis of country-specific income rankings. *Percentages and medians were estimated using population-weighted population, except for WLS. An en dash (–) indicates not available.

symptoms than those in Eastern countries (Korea, China and Indonesia) (β = 0.36; 95% CI, 0.16–0.56; P < 0.001) (Fig. 3a), especially divorced/separated individuals (β = 0.61; 95% CI, 0.43–0.79; P < 0.001) (Supplementary Fig. 3a). However, we did not observe any significant moderating effects of country on depressive symptoms among individuals who were single (β = 0.20; 95% CI, −0.16 to 0.55; P = 0.275) or widowed (β = 0.40; 95% CI, −0.01 to 0.80; P = 0.050) (Supplementary Fig. 3b,c).

Moreover, we found that the relationship between marital status and depressive symptoms was significantly modified by sex, with a higher risk observed in males than in females (β = 0.25; 95% CI, 0.003–0.47; P = 0.047) (Fig. 3b), particularly for single individuals (β = 0.39; 95% CI, 0.05–0.74; P = 0.026) (Supplementary Fig. 4a). However, we did not observe any significant moderating effects of sex on depressive symptoms among individuals who were divorced/separated (β = 0.23; 95% CI, −0.14 to 0.60; P = 0.222) or widowed (β = 0.26; 95% CI, −0.01 to 0.54; P = 0.062) (Supplementary Fig. 4b,c).

When stratified by educational attainment, the difference in risk of depressive symptoms between unmarried and married individuals was greatest among those with higher educational attainment across all eight cohorts and seven countries (β_2 = 0.34; 95% CI, 0.11–0.56; P = 0.003) (Fig. 3c), especially for divorced/separated (β_2 = 0.41; 95% CI, 0.02–0.80; P = 0.039) (Supplementary Fig. 5a) and widowed individuals (β_2 = 0.38; 95% CI, 0.05–0.71; P = 0.025) (Supplementary Fig. 5b). Conversely, we did not observe significant moderating effects of educational attainment on depressive symptoms among individuals who were single (β_2 = 0.06; 95% CI, −0.23 to 0.35; P = 0.693) (Supplementary Fig. 5c).

Finally, our multi-country analysis found that age and income were not significant moderators of the association between marital status and current depressive symptom risk (age: β = 0.07; 95% CI, −0.21 to 0.35; P = 0.619; income: β_2 = 0.05; 95% CI, −0.32 to 0.42; P = 0.785) (Supplementary Figs. 6a–d and 7a–d).

Alcohol and smoking as potential causal mediators

We further explored the potential causal relationship between marital status and later risk of depressive symptoms, as well as the underlying mediating mechanisms, using longitudinal cohorts from five countries. Probit-regression-based causal mediation analysis revealed significant direct and indirect causal effects of marital status on later risk of depressive symptoms in participants from China, Korea and Mexico (Fig. 4a–k). Specifically, our analysis identified alcohol drinking as a significant causal mediator, accounting for 3.2% (95% CI, 2.6–3.8%;

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Table 3 | The association between marital status and depressive symptoms revealed by the survey-weighted, multivariate logistic regression model

Dataset	Being married		Marital status			
	Yes (*n*=77,145)	No (*n*=28,650)	Married (*n*=77,145)	Single (*n*=10,858)	Divorced/separated (*n*=7,555)	Widowed (*n*=10,237)
NHANES (USA)*						
Events, *n* (%)	1,235 (5.6)	1,466 (10.8)	1,235 (5.6)	552 (9.1)	669 (13.6)	245 (9.9)
OR (95% CI)	Ref.	1.47 (1.31–1.65)	Ref.	1.32 (1.14–1.54)	1.80 (1.57–2.05)	1.17 (0.91–1.50)
P		<0.001		<0.001	<0.001	0.222
WLS (USA)						
Events, *n* (%)	424 (7.5)	203 (14.7)	424 (7.5)	33 (12.9)	95 (14.9)	75 (15.3)
OR (95% CI)	Ref.	2.11 (1.74–2.55)	Ref.	1.83 (1.24–2.71)	2.09 (1.63–2.69)	2.28 (1.72–3.03)
P		<0.001		0.003	<0.001	<0.001
APMS (UK)*						
Events, *n* (%)	73 (1.9)	149 (5.0)	73 (1.9)	62 (4.7)	55 (6.6)	32 (3.9)
OR (95% CI)	Ref.	2.29 (1.69–3.08)	Ref.	2.02 (1.33–3.05)	2.92 (1.98–4.31)	2.32 (1.33–3.69)
P		<0.001		0.001	0.002	<0.001
MHAS (Mexico)*						
Events, *n* (%)	1,681 (24.7)	1,091 (35.8)	1,681 (24.7)	138 (23.8)	189 (47.3)	764 (34.9)
OR (95% CI)	Ref.	1.58 (1.22–2.05)	Ref.	1.05 (0.68–1.63)	2.70 (1.61–4.54)	1.44 (1.12–1.86)
P		<0.001		0.819	<0.001	0.006
KLoSA (Korea)*						
Events, *n* (%)	678 (18.1)	381 (28.5)	678 (18.1)	12 (33.1)	32 (26.7)	337 (28.6)
OR (95% CI)	Ref.	1.47 (1.19–1.82)	Ref.	2.43 (1.09–5.42)	1.82 (1.12–2.98)	1.44 (1.16–1.79)
P		<0.001		0.031	0.016	0.001
TILDA (Ireland)*						
Events, *n* (%)	326 (9.0)	229 (17.8)	326 (9.0)	60 (16.2)	62 (20.2)	107 (17.6)
OR (95% CI)	Ref.	2.14 (1.70–2.69)	Ref.	2.00 (1.45–2.75)	1.99 (1.39–2.86)	2.37 (1.75–3.21)
P		<0.001		<0.001	<0.001	<0.001
CHARLS (China)*						
Events, *n* (%)	4,084 (31.2)	822 (45.8)	4,084 (31.2)	44 (48.7)	69 (41.2)	709 (46.0)
OR (95% CI)	Ref.	1.52 (1.34–1.72)	Ref.	2.46 (1.45–4.19)	1.96 (1.34–2.87)	1.62 (1.41–1.86)
P		<0.001		<0.001	0.019	<0.001
IFLS (Indonesia)						
Events, *n* (%)	7,523 (35.1)	2,125 (43.7)	7,523 (35.1)	1,458 (50.5)	303 (42.1)	364 (28.9)
OR (95% CI)	Ref.	1.28 (1.20–1.37)	Ref.	1.29 (1.19–1.41)	1.39 (1.20–1.62)	1.18 (1.03–1.35)
P		<0.001		<0.001	<0.001	0.020

Events are participants with depressive symptoms. The model was adjusted for age, sex, education, income (except for the MHAS, CHARLS and IFLS), smoking status, alcohol drinking status (except for the IFLS), BMI, history of hypertension, history of diabetes, history of heart attack/diseases, history of stroke and history of cancer. *Percentages were estimated using population-weighted population, except for the WLS and IFLS.

$P < 0.001$), 34.1% (95% CI, 32.3–36.0%; $P < 0.001$) and 27.4% (95% CI, 23.9–30.8%; $P < 0.001$) of the total later risk of developing depressive symptoms among single Mexicans, Koreans and Chinese, respectively (Fig. 4a–c). For divorced/separated individuals, the proportion mediated by alcohol drinking was 16.5% (95% CI, 9.5–23.6%; $P < 0.001$) for Mexicans, 29.3% (95% CI, 19.6–39.1%; $P < 0.001$) for Koreans and 21.2% (95% CI, 11.6–30.9%; $P < 0.001$) for Chinese (Fig. 4d–f). Additionally, alcohol drinking mediated 13.4% (95% CI, 9.8–25.0%; $P < 0.001$), 5.9% (95% CI, 1.9–10.0%; $P < 0.001$) and 12.0% (95% CI, 9.0–16.0%; $P < 0.001$) of the total later risk of developing depressive symptoms in widowed Mexicans, Koreans and Chinese (Fig. 4g–i). Smoking emerged as another significant causal pathway, mediating 22.1% (95% CI, 16.3–27.9%; $P < 0.001$) and 43.8% (95% CI, 38.6–49.1%; $P < 0.001$) of the risk in single individuals from Mexico and China (Fig. 4j,k). In contrast, the causal mediating effects of alcohol drinking and smoking were not significant for unmarried Americans (mediation proportion, 0.8–11.0%; all $P > 0.05$) or Irish (mediation proportion, 0.3–13.6%; all $P > 0.05$) (Supplementary Fig. 8a–p).

Additional causal mediation analyses were conducted using alcohol consumption frequency as a continuous variable, after excluding non-drinkers. Similar to the binary drinking variable, monthly alcohol consumption frequency demonstrated a significant mediating effect among divorced/separated participants in Mexico (mediation proportion, 11.5%; $P < 0.001$) and China (mediation proportion, 43.4%; $P < 0.001$) and among divorced/separated, widowed and single participants in Korea (mediation proportion, 3.7–21.0%; all $P < 0.05$) (Supplementary Fig. 9). These results further substantiate the mechanistic role of alcohol intake in the relationship between marital status and

depressive symptoms. Moreover, we identified nonlinear relationships between drinking frequency and depressive symptoms, with inflection points of two to three times per month for unmarried Irish, four times for unmarried Mexicans, five times for unmarried Chinese, and six times for unmarried Americans and Koreans (Supplementary Fig. 10). After exceeding these thresholds, the risk of depressive symptoms increased dramatically.

Bootstrap random sampling was performed to examine the robustness of the probit-regression causal mediation analysis. The results were consistent with the main findings (mediation proportion, 2.3–11.6%, all $P < 0.001$ for Mexico; mediation proportion, 2.1–11.6%; all $P < 0.001$ for Korea; and mediation proportion, 4.3–24.3%; all $P < 0.001$ for China) (Fig. 5a–k and Supplementary Fig. 11a–k). In addition, a sensitivity analysis was conducted by excluding participants with changes in marital status, alcohol habits or smoking habits during the follow-up period. The results were consistent with our primary analyses, providing further support for the mediating roles of alcohol drinking and smoking in the relationship between marital status and depressive symptom risk (mediation proportion, 22.3–45.6%; all $P < 0.001$ for Mexico; mediation proportion, 7.1–18.3%, all $P < 0.001$ for Korea; and mediation proportion, 6.9–25.2%; all $P < 0.001$ for China) (Supplementary Fig. 12a–k).

Discussion

We conducted a large-scale, two-stage, cross-country study to examine the association between marital status and both current and future risk of developing depressive symptoms, while also identifying potential moderator and causal mediator variables (Supplementary Fig. 13). Our investigation included data from 106,556 individuals in seven countries for the cross-sectional analysis and from 20,865 individuals in five countries for the longitudinal analysis, weighted to represent about 541 million and 210 million adults, respectively. We found that unmarried individuals had an overall higher risk of developing depressive symptoms than married ones. This association was moderated by country, sex and educational attainment such that the difference in risk between unmarried and married people was greatest among highly educated, male participants in Western countries, including the USA, the UK and Ireland. Moreover, we found that alcohol drinking and smoking partially and causally mediated the increased risk of depressive symptoms among unmarried participants from China, Korea and Mexico.

While scattered and regional findings have previously indicated an increased risk of depressive symptoms in unmarried individuals[27–30], our analysis is unique in several aspects. We used large-scale, nationally representative data from multiple countries across Asia, Europe and North America, which were weighted to represent approximately 541 million adults with different socio-economic and cultural practices. By the use of two distinct study designs, our research has further reinforced previous findings and enabled us to draw conclusions about the link between marital status and depressive symptoms. The health benefits of marriage may be mediated through various mechanisms, such as enhanced access to economic resources[31], the exchange of social support[32] and the positive influence of spouses on each other's mental well-being[33]. Moreover, our study offers insights into the association between specific subcategories of unmarried individuals and depressive symptoms. Contrary to earlier findings with small sample sizes[30], we found no significant differences in depressive symptom risk among the three unmarried subcategories (single, divorced/separated and widowed).

Cross-national variation in the prevalence of depression has been reported in previous research[34,35]. Our study investigated the disparities in depressive symptom risk among unmarried individuals across multiple countries, revealing a higher risk in the USA, the UK and Ireland. This finding implies that cultural, societal and economic factors unique to certain countries may influence the relationship between marital status and depressive symptoms. A recent study highlighted the significance of cultural differences in managing negative emotions, which can profoundly impact mental health[36]. Eastern cultures tend to tolerate higher levels of emotional distress before it becomes problematic, which may partially explain the lower risk of depressive symptoms in unmarried participants from these countries[37]. The adoption of 'Asian-style' psychological therapy in other parts of the world emphasizes cultivating a greater tolerance for contradiction[38]. Further research is needed to understand the cultural and societal differences that contribute to the increased risk of depressive symptoms for unmarried people in European and American countries compared with their Asian counterparts. Furthermore, while this study revealed overall differences between broad Eastern and Western country classifications, granular investigation of dimensions such as stigma, sex norms or emotional expression styles could offer tailored insights across diverse populations from the seven studied countries.

In terms of sex, it has been reported that single or separated Canadian males have a higher risk of depressive symptoms than married females, while the association between marital status and depressive symptoms is less pronounced for females in Canada[19]. We extend this finding by demonstrating that this phenomenon is not limited to Canadians or Western populations. Our study revealed that single/separated males in the USA, the UK, China and Korea also exhibited a higher risk of depressive symptoms. One potential explanation for this sex difference is that females tend to have larger and stronger social support networks than males, particularly among never-married individuals[39]. Previous studies have primarily explored the intricate relationship between educational attainment and depressive symptoms in later life[40,41], with limited information on how educational attainment modifies the association between marital status and depressive symptoms. The current study found that unmarried individuals with high levels of education had a significantly increased risk of depressive symptoms compared with their married counterparts, particularly those with lower educational attainment. This elevated risk of depressive symptoms in highly educated unmarried individuals may be attributable to experiencing heightened psychological distress and pressure resulting from various factors such as societal stigma, pressure to conform to traditional marital norms, lack of spousal support and difficulty balancing multiple roles without a partner's support[42]. Additionally, the pursuit of career success, financial stability and professional recognition, which is often pronounced among highly educated persons, can impose extra stressors and demands that negatively impact their psychological well-being.

The existing body of literature has consistently demonstrated that married adults exhibit lower rates of alcohol and tobacco consumption

Fig. 2 | Unmarried individuals have a significantly higher risk of depressive symptoms than their married counterparts (all $P < 0.01$). **a**, Meta-analysis comparing the risk of having depressive symptoms in unmarried individuals versus married individuals. **b**, Same as **a**, but for single individuals versus married individuals. **c**, Same as **a**, but for divorced/separated individuals versus married individuals. **d**, Same as **a**, but for widowed individuals versus married individuals. The individual estimates were obtained from each survey and pooled by meta-analysis using a random-effects model. The meta-analysis results were validated using covariate-adjusted, sample-weighted logistic regression analysis (ORs and 95% CIs are shown in Table 3). The number of participants per dataset is indicated to the left of the forest plots. Each square size in the forest plots represents the effect size for that dataset, and the horizontal bars indicate 95% CIs. The summary data on the right shows the mean effects (ORs), 95% CIs and weights. In each plot, the dashed line is the overall estimated effect, and the solid diamond denotes the overall estimated effect and 95% CI calculated using a random-effects model. All statistical tests were two-sided ($n = 8$ datasets), and $P < 0.05$ was considered statistically significant. DPN, individuals with depressive symptoms.

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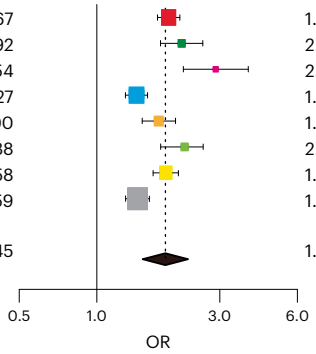
a

Dataset (n = 8)	All others		Married				
	DPN	Total	DPN	Total	OR	95% CI	Weight
NHANES (USA)	1,466	12,404	1,235	18,867	1.91	(1.77–2.07)	13.7%
WLS (USA)	203	1,385	424	5,692	2.13	(1.78–2.55)	11.8%
APMS (UK)	149	2,818	73	3,854	2.89	(2.18–3.84)	9.3%
MHAS (Mexico)	1,091	3,428	1,681	6,927	1.46	(1.33–1.59)	13.6%
KLoSA (Korea)	381	1,337	678	3,700	1.78	(1.54–2.05)	12.5%
TILDA (Ireland)	229	1,408	326	3,888	2.12	(1.77–2.54)	11.7%
CHARLS (China)	822	1,765	4,084	12,758	1.85	(1.67–2.05)	13.4%
IFLS (Indonesia)	2,125	4,866	7,523	21,459	1.44	(1.35–1.53)	13.9%
Total		29,411		77,145	1.86	(1.61–2.14)	100.0%

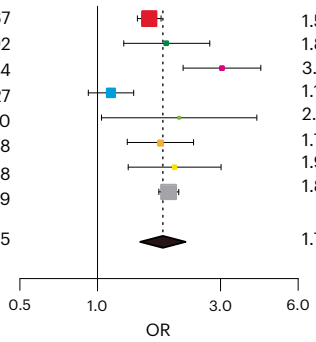
Heterogeneity: I^2 = 91%, t^2 = 0.037, P < 0.001
n = 8, random-effects model



b

Dataset (n = 8)	Single		Married				
	DPN	Total	DPN	Total	OR	95% CI	Weight
NHANES (USA)	552	5,515	1,235	18,867	1.59	(1.43–1.76)	16.8%
WLS (USA)	33	255	424	5,692	1.85	(1.26–2.70)	10.9%
APMS (UK)	62	1,119	73	3,854	3.04	(2.15–4.29)	11.6%
MHAS (Mexico)	138	520	1,681	6,927	1.13	(0.92–1.38)	14.9%
KLoSA (Korea)	12	38	678	3,700	2.06	(1.03–4.10)	5.8%
TILDA (Ireland)	60	433	326	3,888	1.76	(1.31–2.36)	12.8%
CHARLS (China)	44	91	4,084	12,758	1.99	(1.32–3.00)	10.1%
IFLS (Indonesia)	1,458	2,887	7,523	21,459	1.89	(1.75–2.04)	17.1%
Total		10,858		77,145	1.79	(1.46–2.20)	100.0%

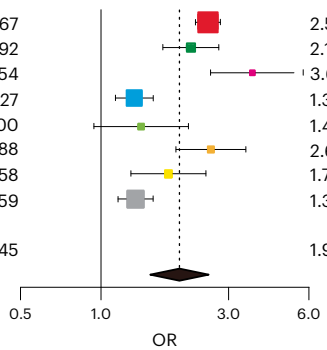
Heterogeneity: I^2 = 80%, t^2 = 0.06, P < 0.001
Random-effects model



c

Dataset (n = 8)	Divorced/separated		Married				
	DPN	Total	DPN	Total	OR	95% CI	Weight
NHANES (USA)	669	4,471	1,235	18,867	2.51	(2.27–2.78)	14.4%
WLS (USA)	95	639	424	5,692	2.17	(1.71–2.76)	12.9%
APMS (UK)	55	829	73	3,854	3.68	(2.57–5.27)	11.1%
MHAS (Mexico)	189	589	1,681	6,927	1.33	(1.13–1.56)	13.6%
KLoSA (Korea)	32	133	678	3,700	1.41	(0.94–2.12)	10.4%
TILDA (Ireland)	62	323	326	3,888	2.60	(1.92–3.50)	12.0%
CHARLS (China)	69	151	4,084	12,758	1.79	(1.29–2.47)	11.7%
IFLS (Indonesia)	303	720	7,523	21,459	1.35	(1.16–1.56)	14.0%
Total		7,855		77,145	1.99	(1.53–2.53)	100.0%

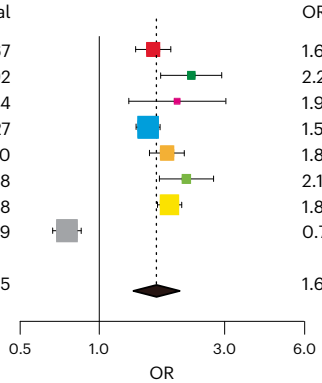
Heterogeneity: I^2 = 91%, t^2 = 0.10, P < 0.001
Random-effects model



d

Dataset (n = 8)	Widowed		Married				
	DPN	Total	DPN	Total	OR	95% CI	Weight
NHANES (USA)	245	2,418	1,235	18,867	1.61	(1.39–1.86)	13.1%
WLS (USA)	75	491	424	5,692	2.24	(1.72–2.92)	11.8%
APMS (UK)	32	870	73	3,854	1.98	(1.30–3.02)	9.8%
MHAS (Mexico)	764	2,319	1,681	6,927	1.53	(1.38–1.70)	13.4%
KLoSA (Korea)	337	1,166	678	3,700	1.81	(1.56–2.11)	13.0%
TILDA (Ireland)	107	652	326	3,888	2.15	(1.69–2.72)	12.2%
CHARLS (China)	709	1,523	4,084	12,758	1.85	(1.66–2.06)	13.4%
IFLS (Indonesia)	364	1,259	7,523	21,459	0.75	(0.66–0.85)	13.2%
Total		10,698		77,145	1.64	(1.28–2.11)	100.0%

Heterogeneity: I^2 = 96%, t^2 = 0.12, P < 0.001
Random-effects model



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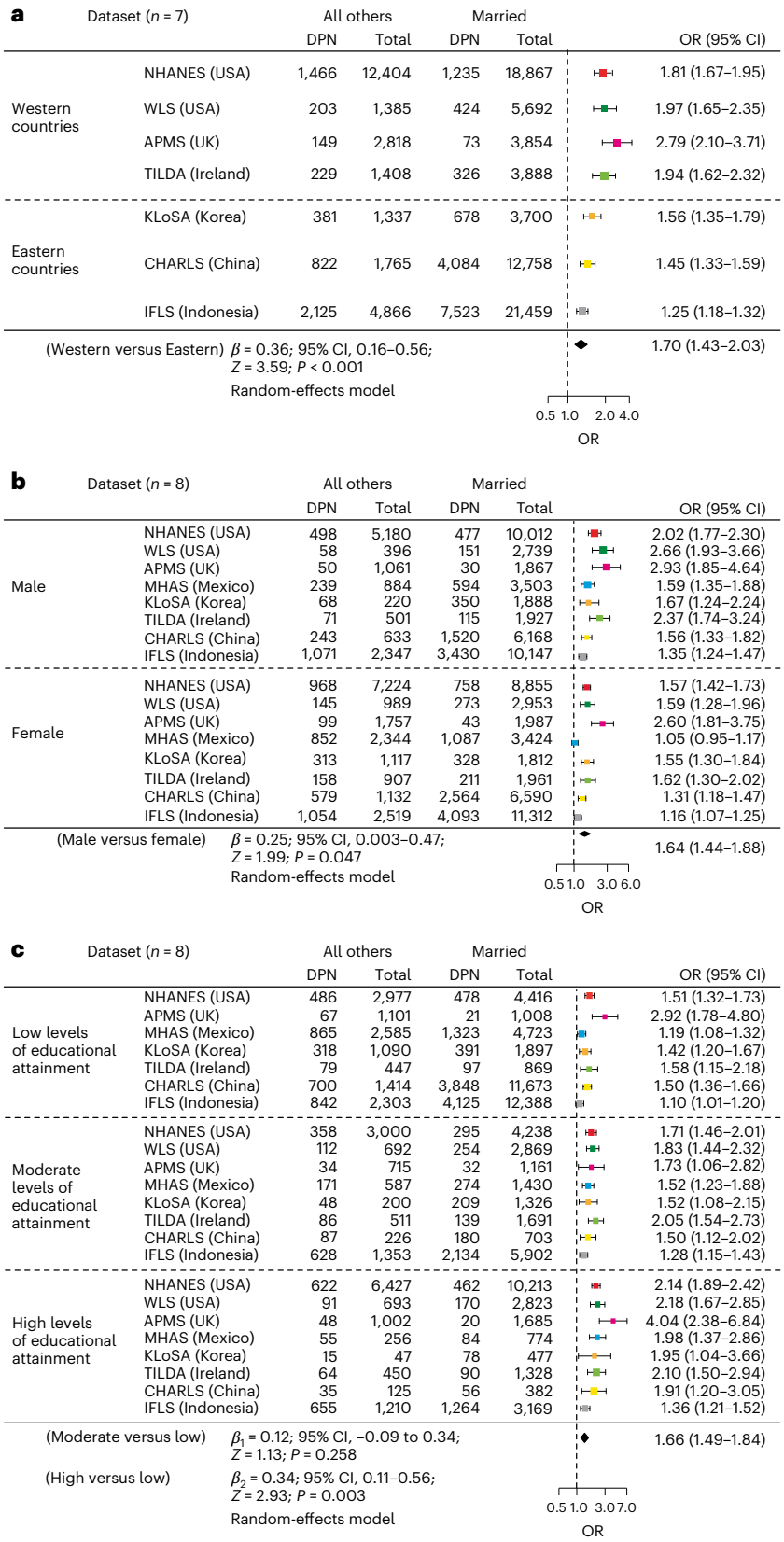

Fig. 3 | Modification effects on the association between marital status and depressive symptom risk. (**a**) Country. (**b**) Sex. (**c**) Educational attainment. The number of participants per dataset is indicated to the left of the forest plots. Each square size in the forest plots represents the effect size for that dataset, and the horizontal bars indicate 95% CIs. The summary data on the right shows the mean effects (ORs) and 95% CIs. The solid diamond at the bottom of each forest plot denotes the overall estimated effect and 95% CI calculated using a random-effects model. The β coefficients reflect the differences in the association between marital status and depressive symptoms between country (**a**), sex (**b**) and educational attainment (**c**). All statistical tests were two-sided ($n = 8$ datasets), and $P < 0.05$ was considered statistically significant.

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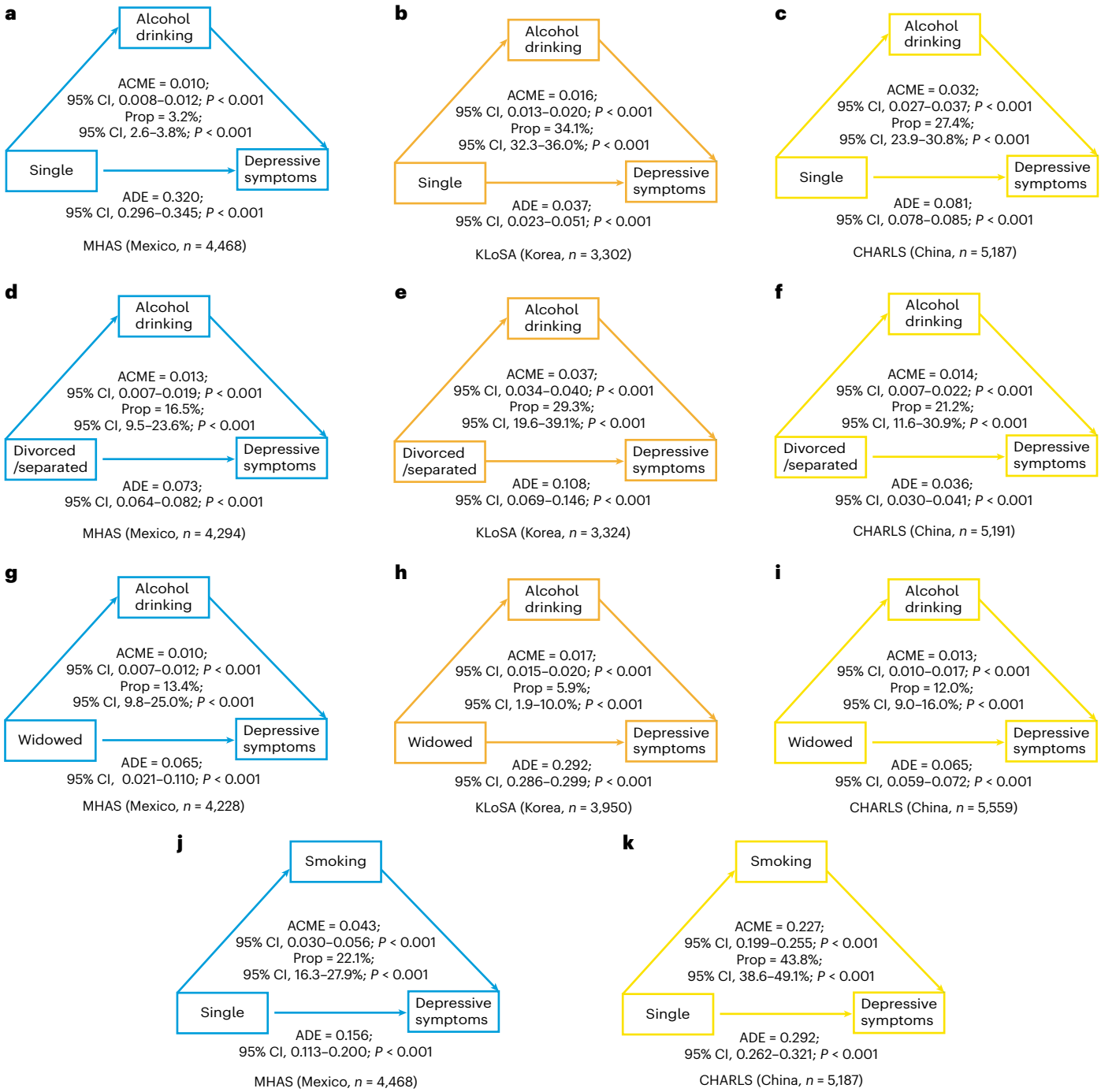

Fig. 4 | The direct and indirect causal associations between marital status and later risk of developing depressive symptoms, mediated by alcohol drinking and smoking. a,**d**,**g**, The average causal mediation/indirect effect (ACME) of alcohol drinking among single, divorced/separated and widowed Mexicans. **j**, ACME of smoking status among single Mexicans. **b**,**e**,**h**, ACME of alcohol drinking status among single, divorced/separated and widowed Koreans. **c**,**f**,**i**, ACME of alcohol drinking status among single, divorced/separated and widowed Chinese. **k**, ACME of smoking status among single Chinese. The average direct effect (ADE) represents the portion of the total effect that is independent of the mediator. The ACME denotes the portion of the total effect that can be explained by the mediator. The mediation proportion (Prop) was calculated by ACME/(ADE + ACME) × 100%. Probit analysis was employed in the causal mediation modelling to estimate both ACME and ADE, where ACME is derived from the product of the effect of the independent variable on the mediator and the effect of the mediator on the dependent variable. The values for ACME and ADE are expressed as β coefficients (slopes) with 95% CIs from the probit regression. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant. The variable *n* indicates the number of participants included.

than their single or divorced counterparts[43,44]. The deleterious effects of alcohol and tobacco on the structural and functional integrity of the brain are well established and are known to contribute to the development of psychological symptoms[45,46]. Previous research has identified the association of alcohol consumption and smoking with depression, independent of the amount consumed[47,48]. Our study corroborates these findings by highlighting the crucial role of these factors as important mediators in the association between marital status and depressive symptoms. Our study investigated the underlying mechanisms that drive the relationship between marital status and depressive

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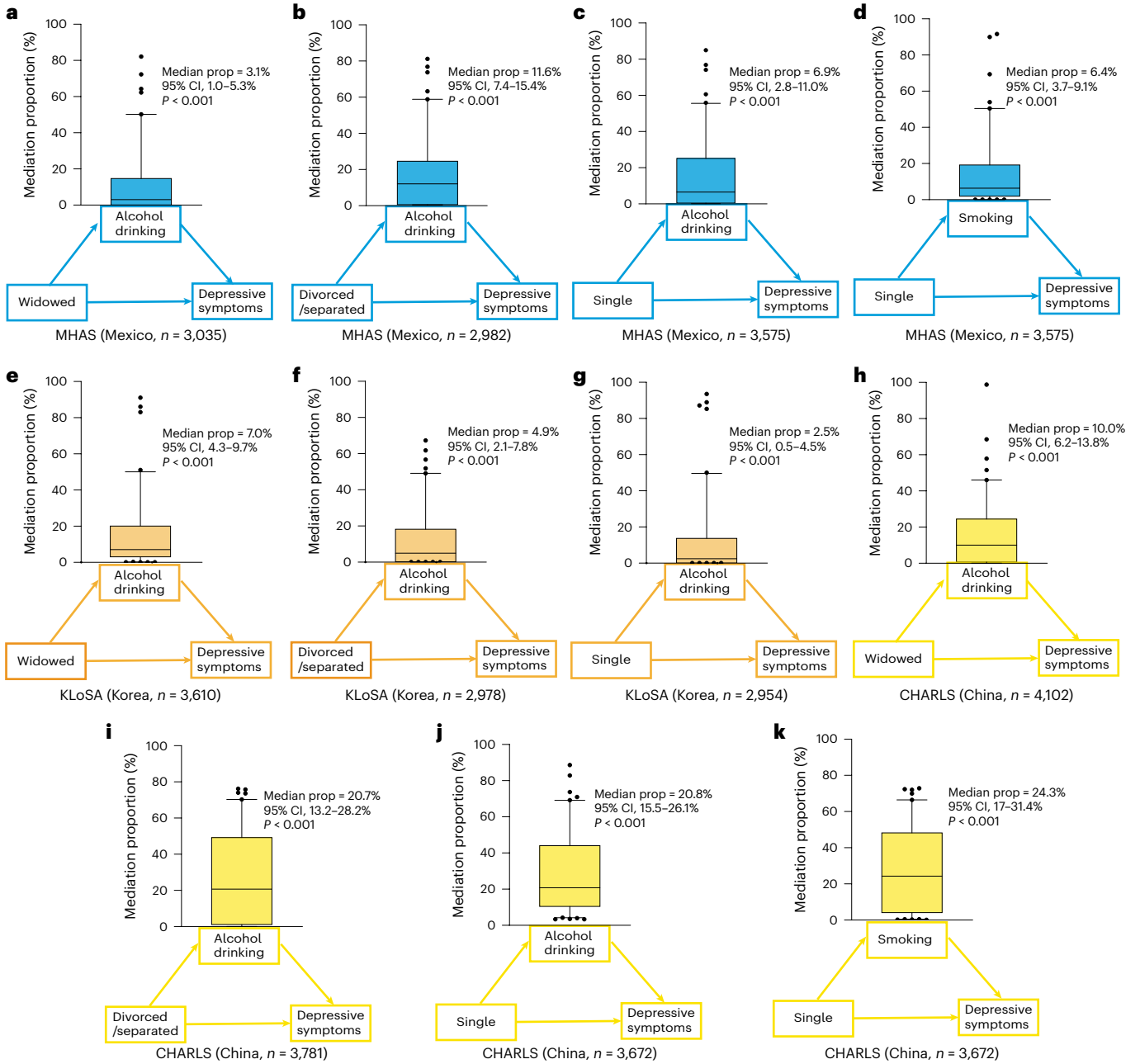

Fig. 5 | Bootstrap resampling (n = 100 times) demonstrating the robustness of probit-regression-based causal mediation analysis. a–**c**, Bootstrap analysis for the ACME of alcohol drinking status among widowed, divorced/separated and single Mexicans. **d**, ACME of smoking status among single Mexicans. **e**–**g**, ACME of alcohol drinking status among widowed, divorced/separated and single Koreans. **h**–**j**, ACME of alcohol drinking status among widowed, divorced/separated and single Chinese. **k**, ACME of smoking status among single Chinese. Bootstrap analysis was performed by randomly extracting 80% of samples from each dataset for causal mediation analysis (n = 100 times). The ADE represents the portion of the total effect that is independent of the mediator. The ACME denotes the portion of the total effect that can be explained by the mediator. The mediation proportion (prop) was calculated by ACME/(ADE + ACME) × 100%. Probit analysis was employed in the causal mediation modelling to estimate ADE and ACME, expressed as β coefficients (slopes) from the probit regression. The box plots show the median (centre line), the 25th and 75th percentiles (box bounds), and the minimum and maximum values (whiskers) of the mediation proportion for 100 bootstrap iterations. The 95% CIs for the mediation proportions were calculated using the formula $\pm 1.57 \times \mathrm{IQR}/\sqrt{n}$. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant. The variable n indicates the number of participants included.

symptoms, highlighting the significant role of alcohol and tobacco use in this association.

Limitations

Our study has several limitations that should be acknowledged. First, our reliance on self-reported depressive symptoms captured through validated questionnaires rather than clinical diagnoses limited the ability to distinguish between first-onset and recurrent depressive symptoms, reliably identify prevalent versus incident cases during follow-up, or separate treated versus untreated depression. While the questionnaires capture current symptoms, they are not equivalent to clinical assessment. The self-reported nature and potential recall bias should thus be considered when interpreting the findings[49]. Second, this cross-country comparative study may introduce ecological bias arising from social, economic and cultural differences between countries. Third, because this is an observational study,

residual confounding and period effects from pooling data across different years cannot be ruled out. Fourth, our analysis was limited to heterosexual couples or cohabitants due to the unavailability of data on same-sex marriage, underscoring the need to examine the health implications in this population.

Conclusion

This large-scale, two-stage study combining cross-sectional and prospective cohort analyses across diverse countries found that being unmarried, regardless of subcategories, was associated with a higher risk of having depressive symptoms. This heightened vulnerability emerged especially among single, highly educated males in Western nations. Furthermore, alcohol drinking played an important mediating role in the association between marital status and later risk of developing depressive symptoms for widowed, divorced/separated and single individuals in China, Korea and Mexico. Smoking also causally mediated increased risk among unmarried Chinese and Mexican participants. Collectively, these findings underscore the importance of considering cultural, socio-economic and behavioural contexts in future research to better understand and address the mental health disparities associated with marital status.

Methods

We briefly describe the methods here. The full details of the methodological approaches are provided in Supplementary Information.

Study design and participants

This study analysed de-identified, nationally representative, individual-level data from seven countries with diverse cultural backgrounds: the USA (National Health and Nutrition Examination Survey (NHANES), 2005–2018, n = 31,271 participants, ≥20 years old; Wisconsin Longitudinal Study (WLS), 2003–2005, n = 7,077 participants, ≥40 years old; and WLS, 1993–1994, 2003–2005 and 2011, n = 2,981 participants, ≥40 years old), the UK (Adult Psychiatric Morbidity Survey (APMS), 2007, n = 6,672 participants, ≥20 years old), Mexico (Mexican Health and Aging Study (MHAS), 2018, n = 10,572 participants, ≥20 years old; MHAS, 2012, 2015 and 2018, n = 4,706 participants, ≥20 years old), Korea (Korean Longitudinal Study of Aging (KLoSA), 2020, n = 5,037 participants, ≥45 years old; KLoSA, 2016, 2018 and 2020, n = 4,052 participants, ≥45 years old), Ireland (Irish Longitudinal Study on Ageing (TILDA), 2009–2011, n = 5,296 participants, ≥50 years old; TILDA, 2009–2010, 2011–2012 and 2014–2015, n = 3,495 participants, ≥50 years old), China (China Health and Retirement Longitudinal Study (CHARLS), 2015, n = 14,523 participants, ≥45 years old; CHARLS, 2013, 2015 and 2018, n = 5,631 participants, ≥45 years old) and Indonesia (Indonesian Family Life Survey (IFLS), 2014–2015, n = 26,325 participants, ≥20 years old).

In the first stage, we conducted a cross-sectional analysis using representative population-based data from each country to examine the relationship between marital status and depressive symptoms. To increase statistical power in the NHANES, we combined data across seven cycles (2005–2018) and adjusted the sample weights to maintain representativeness when pooling multiple cycles. Participants with missing data on depression status, marital status or major covariates were excluded (n = 9,243 for the NHANES; n = 11,969 for the WLS; n = 731 for the APMS; n = 6,542 for the MHAS; n = 3,208 for TILDA; n = 680 for KLoSA; n = 6,444 for CHARLS; n = 10,066 for the IFLS), leaving 106,556 participants in the analyses (Fig. 1a, Supplementary Fig. 14a and Supplementary Tables 1–8).

In the second stage, a prospective longitudinal study was conducted to examine the underlying causal mechanisms between marital status and later risk of depressive symptoms using multivariate causal mediation analysis with bootstrap resampling. Participants with incomplete information on depressive symptoms at the baseline and on outcome, marriage and major covariates were excluded (n = 16,065 for the WLS; n = 11,017 for the MHAS; n = 4,447 for TILDA; n = 2,762 for KLoSA; n = 12,974 for CHARLS). Participants with depressive symptoms at the baseline based on self-reported questionnaires were also excluded, leaving a final sample of 20,865 participants for the causal mediation analyses (Fig. 1b and Supplementary Fig. 14b). These participants were followed over time, and the depressive symptoms were assessed again at the end of the follow-up.

All surveys used multistage probability sampling to represent the civilian, non-institutionalized population. Detailed data sources are described in Supplementary Information. Written or electronic informed consent was obtained from all participants during the survey. The study protocol was approved by the Ethics Committee of Macao Polytechnic University (no. CI237/DEI/2022).

Exposure

Marital status was categorized into four groups on the basis of participants' self-reported status at the time of the survey: married or in married-like relationships (including both currently married and cohabiting individuals), single, divorced/separated and widowed. This classification was adapted from a previous study on the associations between marital status and health outcomes[50]. Individuals identifying as separated were grouped with the divorced category, reflecting their similar status of having ended a close intimate relationship.

Mediators

Alcohol consumption was assessed both as a binary variable of current drinker versus non-current drinker and as a continuous frequency variable (times drinking per month). Smoking habits were defined as a binary variable of current smoker versus non-current smoker. Information on alcohol consumption and smoking habits was collected through self-administered questionnaires.

Outcome

Depressive symptoms were assessed using standardized instruments across the seven countries. In the NHANES and WLS, the Patient Health Questionnaire-9 (PHQ-9) and a 20-item version of the Center for Epidemiological Studies Depression scale (CES-D) were used[51,52]. In the APMS, the Clinical Interview Schedule Revised (CIS-R) was used to assess symptoms of depression[53]. In the MHAS, the modified CES-D was used to assess symptoms of depression over the past week[54]. In KLoSA, CHARLS and the IFLS, the depressive symptoms were measured by the short Korean, Chinese and African versions of the CESD-10 (refs. 55–57). In TILDA, a modified 20-item version of the CES-D and an eight-item version of the CESD-8 were used to assess depressive symptoms over the past week for the cross-sectional and longitudinal analysis, respectively[58]. To improve the comparability of depressive symptoms across the studies, we defined the presence of depressive symptoms as a dummy variable in our study. Participants were considered to have depressive symptoms if they had a PHQ-9 score ≥10 in the NHANES; a CES-D score ≥16 in the WLS and TILDA (in the cross-sectional analysis); a modified CES-D score ≥5 in the MHAS; a CESD-10 score ≥10 in KLoSA, CHARLS and the IFLS; and a CESD-8 >3 in the longitudinal analysis of TILDA[59].

Covariates

Age, sex (male and female) and educational attainment (low, moderate and high levels) were obtained. Educational attainment was categorized as low (less than high school in the NHANES, MHAS, KLoSA and IFLS; less than CSE/GCSE/equivalent in the UK; primary/equivalent in TILDA; elementary school/others/no formal education/illiterate in China), moderate (high school in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE/GCSE/equivalent in the UK; intermediate/junior/group certificate/equivalent in TILDA; middle school in China) and high (more than high school/college/equivalent in the NHANES, WLS, MHAS, KLoSA and IFLS; CSE higher/GCSE higher/equivalent in the UK; college/higher

degree in TILDA; high school/college/higher degree/equivalent in China). Income was categorized as low (lower quartile), moderate (IQR) and high (upper quartile) on the basis of country-specific income rankings. BMI was calculated on the basis of the World Health Organization standard (BMI = weight (in kg)/height^2 (in m^2)) and categorized as under/normal weight, overweight or obese[60]. Self-reported medical histories of diabetes, hypertension, heart attack/diseases, stroke and cancer were recorded.

Statistical analysis

We provide descriptive statistics for the baseline characteristics of the study population. Categorical variables are expressed as numbers and proportions, while continuous variables are reported as median and IQR.

Survey-weighted logistic regression analysis or conventional logistic regression analysis was used to investigate the association between marital status and depressive symptoms (Supplementary Table 9). The models yielded ORs and 95% CIs, adjusted for the covariates listed above. Survey weights were incorporated in the analysis according to the guidelines from each national survey (the details are described in Supplementary Methods). This allowed for logistic regression modelling that accounts for the complex survey methodology and design, yielding nationally representative estimates for those cohorts. We performed two sensitivity analyses to validate the logistic regression analysis and minimize the influence of underlying health conditions: (1) the original model was adjusted for other mental-health-related factors, including other mental issues, antidepressant use, anxiety, stress, phobia, drug dependence and brain damage/mental retardation, depending on data availability in each cohort; and (2) we excluded the participants with hypertension, diabetes, heart attack/diseases, stroke and cancer in the original model.

A meta-analysis was conducted using the meta package in R to pool the association between marital status and depressive symptoms across cohorts. Heterogeneity was assessed with Cochran's Q test and Higgins's I^2 statistic. A random-effects model was used if heterogeneity was present ($I^2 \geq 50\%$); otherwise, a fixed-effects model was used ($I^2 < 50\%$)[61]. The synthesized estimates from the meta-analysis were compared with ORs obtained from covariate-adjusted, sample-weighted logistic regression models fitted separately for each individual cohort. Additionally, moderator analyses were performed using the rma function in the metafor package in R to identify potential moderators influencing the pooled estimates in the meta-analysis, including country, age, sex, educational attainment and income. A random-effects model was used for the moderator analysis to account for heterogeneity among cohorts. A significant moderator variable coefficient (β, $P < 0.05$) indicates the presence of a moderation effect.

Probit (for binary variables) and Poisson (for continuous variables) regression-based multivariate causal mediation analyses[62] were performed to investigate the mechanisms underlying the association between marital status and depressive symptoms. The mediation package (v.4.5.0) in R was used for the analysis. Briefly, the mediation model was constructed using the longitudinal data from the WLS, MHAS, KLoSA, TILDA and CHARLS studies. The model tested the mediating effect of alcohol drinking status and smoking status, separately, adjusting for confounding variables, including age, sex, educational attainment, BMI, history of hypertension, history of diabetes, history of heart attack/diseases, history of stroke and history of cancer. To account for potential nonlinearity, additional mediation models were run by treating alcohol consumption frequency as a continuous variable (times per month), excluding non-drinkers. The ADE represents the portion of the total effect that is independent of the mediator. The ACME denotes the portion of the total effect that can be explained by the mediator. The mediation proportion was calculated by ACME/(ADE + ACME) × 100%. To evaluate the robustness of the probit-regression-based causal mediation analysis, we implemented bootstrap resampling. This involved randomly selecting distinct proportions (50% and 80% of samples, $n = 100$ times) from the cumulative sample. We also conducted another sensitivity analysis by excluding participants who had changes in marital status, smoking habits or alcohol consumption during follow-up. The SAS and R code for the logistic regression analysis, causal mediation analysis and validation with the bootstrap resampling method have been uploaded to GitHub (https://github.com/Li-OmicsLab/Causal_NHB).

All analyses were conducted using SAS v.9.4, R v.4.2.1 or GraphPad Prism v.9.0, unless otherwise specified. A two-sided $P < 0.05$ was considered statistically significant.

Reporting summary

Further information on research design is available in Nature Portfolio Reporting Summary linked to this article.

Data availability

Data from the NHANES are available at https://www.cdc.gov/nchs/nhanes/index.htm. Data from the WLS are available on the application at https://wls.wisc.edu/. Data from the APMS are available on the application at https://ukdataservice.ac.uk/find-data/. Data from the MHAS are available on the application at https://www.mhasweb.org/Home/index.aspx. Data from KLoSA are available on the application at https://survey.keis.or.kr/eng/klosa/klosa01.jsp. Data from TILDA are available on the application at https://tilda.tcd.ie/. Data from CHARLS are available on the application at https://charls.pku.edu.cn/. Data from the IFLS are available on the application at https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html.

Code availability

The computational code for causal mediation analysis with bootstrap resampling is shared at https://github.com/Li-OmicsLab/Causal_NHB.

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Author contributions

X.Z., L.S.W., C.W. and K.L. conceived and designed the study. X.Z., H.H.Y.T., A.X., C.K.L., Y.S., G.L., W.M., M.Z., Y.H. and J.L. collected and analysed the data. X.Z., H.H.Y.T., A.X. and K.L. drafted the paper. M.Z., Y.H., L.S.W., C.W. and K.L. critically reviewed and edited the paper. All authors reviewed and approved the final version.

Competing interests

The authors declare no competing interests.

Additional information

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Software and code

Policy information about availability of computer code

Data collection	In our study, all data were from the public datasets, including NHANES, WLS, APMS, MHAS, KLoSA, TILDA, CHARLS, and IFLS.
Data analysis	All analyses were conducted using SAS software version 9.4, R version 4.2.1 ('meta' package and 'mediation' package), or GraphPad Prism 9.0, unless specified. The SAS and R codes for the logistic regression analysis, causal mediation analysis, and validation with the bootstrap resampling method were uploaded to GitHub site (https://github.com/Li-OmicsLab/Causal_NHB).

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Reporting on sex and gender	Since all participants self-reported as either male or female, it is appropriate to use the terms sex differences and categories of male/female throughout the manuscript.
Reporting on race, ethnicity, or other socially relevant groupings	Our study was a large-scale, cross-country study, including US, UK, Mexico, Ireland, Korea, China, and Indonesia.
Population characteristics	This study utilized a two-stage design that integrated cross-sectional and longitudinal analyses. The cross-sectional phase comprised 106,556 participants (49,547 males) from eight cohorts in seven countries, with 22,490 individuals having depressive symptoms. The proportion of participants who reported being married varied by cohort, ranging from 64.3% (18,867) in the NHANES cohort (US) to 87.6% (12,758) in the CHARLS cohort (China). Additionally, there were differences in education levels among participants across countries and cohorts. The prospective longitudinal phase included 20,865 participants (10,502 males) from five countries. The mean duration of follow-up ranged from 4 years in the KLoSA cohort to 18 years in the WLS cohort. During the follow-up, total 4,486 cases with depressive symptoms were identified.
Recruitment	All participants come from public databases, including NHANES, WLS, APMS, MHAS, TILDA, KLoSA, CHARLS, and IFLS. Written or electronic informed consent was obtained from all participants during the survey.
Ethics oversight	The study protocol was approved by the Ethics Committee of Macao Polytechnic University (No: CI237/DEI/2022).

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Behavioural & social sciences study design

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Study description	This was a large-scale, two-stage study combining cross-sectional and prospective cohort analyses across diverse countries, and data are quantitative method.
Research sample	This study utilized a two-stage design that integrated cross-sectional and longitudinal analyses. The cross-sectional phase comprised 106,556 participants (49,547 males) from eight cohorts in seven countries, with 22,490 individuals having depressive symptoms. The proportion of participants who reported being married varied by cohort, ranging from 64.3% (18,867) in the NHANES cohort (US) to 87.6% (12,758) in the CHARLS cohort (China). Additionally, there were differences in education levels among participants across countries and cohorts. The prospective longitudinal phase included 20,865 participants (10,502 males) from five countries. The mean duration of follow-up ranged from 4 years in the KLoSA cohort to 18 years in the WLS cohort. During the follow-up, total 4,486 cases with depressive symptoms were identified. 1.National Health and Nutrition Examination Survey (NHANES) The NHANES is a large-scale, multistage, ongoing, nationwide probability sampling survey conducted by National Center for Health Statistics (NCHS). NHANES is based on the selection of counties, blocks, households, and persons within households to represent the civilian, non-institutionalized USA population. All NHANES data are available at https://wwwn.cdc.gov/nchs/nhanes/Default.aspx. Representativeness: (1) NHANES uses a complex, multistage probability sampling design to select participants. (2) This involves selecting a representative sample of counties, blocks, households, and individuals within households. (3) The sampling design ensures the sample is representative of the target population in terms of demographics, geography, and other key characteristics. (4) Weighting adjustments are also applied to the data to account for non-response and to ensure the sample matches the overall

U.S. population distributions, which allows NHANES data to be generalized and used to make inferences about the health and nutritional status of the entire civilian, non-institutionalized U.S. population.
Rationale for the chosen study sample:
(1) Multistage, Probability Sampling:
a. NHANES uses a multistage, probability sampling design to select participants.
b. This approach involves the selection of counties, blocks, households, and individuals within households.
c. Probability sampling ensures that the selected participants are representative of the target population.
(2) Civilian, Non-institutionalized Population:
a. NHANES focuses on the civilian, non-institutionalized U.S. population.
b. This excludes individuals living in institutions such as nursing homes, prisons, or long-term care facilities.
c. Targeting the civilian, non-institutionalized population ensures the sample represents the majority of the U.S. population.
(3) Nationwide Coverage:
a. NHANES is a nationwide survey, covering multiple geographic regions and communities across the United States.
b. The nationwide scope helps capture the diversity and heterogeneity of the U.S. population.
(4) Ongoing, Continuous Data Collection:
a. NHANES is an ongoing, continuous survey, with data collected and updated regularly.
b. The continuous nature of data collection allows for the monitoring of trends and changes in the health and nutrition of the U.S. population over time.

2.Wisconsin Longitudinal Study (WLS)
The Wisconsin Longitudinal Study (WLS) started in 1957 as a random sample of one third of the students graduating from Wisconsin high schools that year. Initially, it was a study of social stratification and intergenerational mobility. As the participants have aged, the study has transitioned into a focus on aging and health. Data were collected during adolescence by paper-and-pencil questionnaires, and participants have been followed primarily via telephone, mail, and in-person surveys. All WLS data can be accessed at https://wls.wisc.edu/.
Representativeness:
The WLS sample is a random sample of one-third of the students graduating from Wisconsin high schools in 1957. This means the sample is representative of high school graduates from Wisconsin in that specific year, but may not be representative of the broader U.S. population.
Rationale for the Chosen Sample:
(1) Focus on a Specific Population:
a. The WLS was initially designed to study social stratification and intergenerational mobility.
b. Selecting a random sample of Wisconsin high school graduates in 1957 allowed the researchers to focus on a specific population and examine the life course of that cohort.
(2) Longitudinal Approach:
a. The longitudinal nature of the WLS, following the same participants over time, provides valuable insights into how this specific population has aged and experienced changes in health and well-being.
(3) Expansion to Siblings and Spouses:
The expansion of the sample to include one sibling of the graduate, and the graduate's spouse and sibling's spouse, adds a valuable intergenerational and family-focused dimension to the study.
(4) Depth of Data:
The WLS collects extensive data on the participants, covering a wide range of topics, including social background, education, employment, family events, and health.
This depth of data allows for a comprehensive understanding of the life course of the WLS participants.

3.Adult Psychiatric Morbidity Survey (APMS)
The Adult Psychiatric Morbidity Survey (APMS) is a population-based, multi-stage probability sampling survey for adults living in private households. Well-trained survey interviewers identified private households after randomly selecting one person in the household to minimize selection bias. The sample was stratified by region and socioeconomic characteristics and weighted for survey design and non-response. During phase 1 of the survey, socio-demographic characteristics were collected and suitability for phase 2 was established with a detailed questionnaire. In phase 2, clinically trained researchers carried out interviews using the Revised Clinical Interview Schedule (CIS-R) to establish the presentation of prevalent current mental disorders. All data are available at https://ukdataservice.ac.uk/find-data/.
Representativeness:
(1) The APMS uses a population-based, multi-stage probability sampling approach, which ensures the sample is representative of the target population.
(2) The sample is stratified by region and socioeconomic characteristics, further enhancing its representativeness.
(3) The data is also weighted for survey design and non-response to account for potential biases.
Rationale for the chosen sample:
(1) The APMS focuses on adults living in private households, as this is the target population of interest for understanding the prevalence of mental disorders in the general adult population.
(2) Excluding individuals not living in private households (e.g., those in institutions, homeless individuals) is a common approach in population-based surveys, as it allows for efficient and cost-effective data collection.
(3) Private households represent the majority of the adult population, and this sampling approach ensures the data can be used to draw inferences about the general adult population in the UK.

4.Mexican Health and Aging Study (MHAS)
The Mexican Health and Aging Study (MHAS) is a population-based cohort of individuals aged 50 years or older and their spouses. Currently, the survey has five assessments, with the first conducted in 2001, and the most recent in 2018. The survey is composed of a set of questionnaires that thoroughly investigate social and health topics. For sub-samples of respondents, anthropometric measurements and biomarkers were collected and physical performance tests were performed. All data are available at https://www.mhasweb.org/Home/index.aspx.
Representativeness:
(1) The MHAS appears to have a nationally representative sample of Mexican adults aged 50 and older, which is well-suited to the study's objectives.
(2) The baseline survey in 2001 was designed to have national and urban/rural representation of adults born in 1951 or earlier,