



OPEN Depression, anxiety, stress symptoms among overweight and obesity in medical students, with mediating effects of academic burnout and internet addiction

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This study aimed to explore the mediating effects of academic burnout and internet addiction on the associations between BMI (normal weight and overweight/obesity) and depressive, anxiety, and stress symptoms among medical students. This study included 610 medical students aged 18–24 years in 2023. Regression analysis was used to explore the mediating effects of academic burnout and internet addiction on the associations between BMI and depressive/anxiety/stress symptoms. The bootstrap method was used to examine the statistical significance of the mediating effects. According to the mediation model incorporated academic burnout and internet addiction as mediators of overweight/obese status and depressive/anxiety/stress symptoms, the direct effects of overweight/obesity on symptoms of depression ($b = 0.452$, $p < 0.001$), anxiety ($b = 0.449$, $p < 0.001$), and stress ($b = 0.466$, $p < 0.001$) among medical students were statistically significant. Our results showed that overweight/obesity medical students were directly related to academic burnout and internet addiction, and to the further development of depression/anxiety/stress symptoms. Medical students with overweight/obesity status might be at high risk for depressive/anxiety/stress symptoms. It is possible to relieve these symptoms by preventing academic burnout and providing early intervention for internet addiction. The risk of depression/anxiety/stress resulting from overweight/obesity status in medical students should be reduced.

Keywords Depressive/anxiety/stress symptoms, Medical students with overweight/Obesity status, Academic burnout, Internet addiction, Mediation analysis

In the past ten years, an increasing number of students have developed mental health problems. Although there is no consensus on the definition of health, people generally believe that it involves a satisfactory experience of physical and mental health and a sense of a satisfactory and meaningful life mission. The combination of intense work demands, pressure of exams, competitiveness, stigma and a culture where students feel they must ‘suck up’ the challenges because that is what is expected in a medical career, triggered or exacerbated existing vulnerabilities to mental ill-health¹. Medical students have a greater chance of developing depression than the general population² or students in other professions³. In addition to depression, many studies have reported a high incidence of anxiety symptoms and stress symptoms in medical students^{4,5}. In Asian countries, 31.9% of medical students were found to exhibit depressive symptoms, 32.9% had anxiety symptoms, and 14.6% had stress symptoms⁶.

Obesity is a major risk factor for various diseases, including anxiety, depression and stress⁷. Obesity is now widely considered a major global epidemic⁸. Moreover, obesity is an important issue for medical personnel because it is not only accompanied by many physical and psychological problems but also contributes to the

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health of the population. The prevalence of obesity (BMI) greater than 30 kg/m² has been increasing globally among different age groups, particularly among young people⁹. Studies have reported that by 2030, half of the population will be obesity or overweight status^{9,10}. On September 3, 2021, the Ministry of Education released the results of the eighth national survey on students' physique and health, the National Student Constitution and Health Survey. This survey revealed that the overall physical health of college students is low¹¹, and the prevalence of obesity among college students was continuing to rise¹². Therefore, overweight/obesity medical students may greater psychological burdens. It is necessary to investigate the mediating effect of overweight/obesity on medical students' depression, anxiety and stress.

Academic burnout is a type of occupational burnout that is acquired by students in the academic environment. Lian et al. defined academic burnout as a state of negative emotions about learning, inappropriate learning behavior and a decreased sense of academic accomplishment¹³. Studies have shown that the negative effects of academic burnout on students are reflected mainly in physical and mental health (such as insomnia and weakness), emotional adaptation (such as anxiety and depression), and behavior (such as aggressiveness and dropout)^{14,15}. Therefore, academic burnout has a considerable effect on the mental health of medical students^{16–18}. An analytical study revealed that the detection rate of academic burnout among medical students was approximately 44.2%¹⁹, and in China, the detection rate in some areas has reached 83.49%²⁰. Therefore, this issue should be taken seriously. Studies have also shown that overweight/obese people are more likely to develop academic burnout²¹. However, there are no relevant reports on whether medical students with overweight/obesity status experience more academic burnouts. Therefore, it is important to investigate the effect of academic burnout on the association between overweight/obesity and stress, anxiety and depression in medical students.

Internet addiction (IA) can be defined as the excessive use of the internet that results in impairment of an individual's psychological state (mental and emotional) as well as impairment of the individual's studies or occupation and social interactions²². Once individuals are addicted to the internet, they may struggle to maintain real-life interpersonal relationships and experience impaired daily activities²³. One of the most obvious features of this disorder is the presence of psychological problems. IA is significantly associated with mental health problems^{24–26}, such as lower life satisfaction, mood disorders, anxiety disorders, and depressive symptoms. Steffen et al. reported that an increase in IA might exacerbate preexisting depression²⁷. Studies have also shown that burnout is a risk factor for behavioral addiction symptoms, including internet addiction, drug misuse, and alcohol dependence²⁸. Burnout due to learning is a potential trigger for various addictive internet behaviors in adolescents; moreover, as their burnout symptoms escalate, so does their inclination toward online addiction²⁹. According to a previous study on the association between internet use and body weight, adolescents with internet addiction disorders are more likely to be overweight or obese³⁰. Peltzer et al.³¹ showed that being overweight or obese is associated with heavy internet use. Therefore, the effects of internet addiction on the association of overweight/obesity with stress, anxiety and depression in medical students require further exploration.

We hypothesize that overweight/obesity status among medical students is directly related to depression/anxiety/stress risk and is indirectly affected by academic burnout and internet addiction. In contrast to previous studies, in our study, we considered the combined effect of all these factors rather than the effect of any single factor. Therefore, we constructed a serial mediation model to explore the relationships between overweight/obesity status and depression/stress/anxiety in medical students. This model can be used to elucidate and prevent depression, anxiety, and stress in medical students with overweight/obesity status.

Methods

Participants

This study recruited volunteers from April to July 2023. With respect to the calculation of the sample content, based on literature³², the overweight/obesity ratio was understood to be approximately $\pi = 20\%$. The overweight/obese status of medical students was investigated using simple random sampling. There was a total of $N = 1800$ students. It was hoped that the error would not exceed $\delta = 3\%$. According to the formula $n = \frac{\mu^2_{0.05/2} \times \pi (1-\pi)}{\delta^2}$

$= 682$, $n_{\text{c}} = \frac{n}{1+n/N} = 494$, $\alpha = 0.05$, $\mu_{0.05/2} = 1.96$. Effect size (d) = 0.5 (medium effect size according to Cohen's guidelines), Statistical power = 80% (which corresponds to a Z_{β} value of 0.84), Significance level = 0.05 (which corresponds to a $Z_{\alpha/2}$ value of 1.96), $\sigma = 10$. $n = \frac{2 \times (Z_{\alpha/2} + Z_{\beta})^2 \times \sigma^2}{\Delta^2} = 63$. In our study, the sample size per

group is greater than 63. The exclusion criteria for individuals were as follows: (1) diagnosed with heart disease, hypertension, diabetes, anemia, allergic asthma or other chronic diseases; (2) unable to complete the physical examination and questionnaire on time; (3) verbally declined to participate in the survey; (4) BMI < 18.5; and (5) diagnosed with neurological conditions and emotional or behavioral problems. Finally, 623 questionnaires were received, of which 610 were eligible participants, with an effective response rate of 97.91%. The final sample of participating medical students included 610 people. The required sample size was met or exceeded. The four majors represented were pharmaceutical preparations, medical laboratory technology, medical imaging technology and preventive medicine. The sample included 204 men and 406 women aged 18 to 24 years. All participants were informed of the aims, the participation in this study was voluntary, and the data were collected anonymously, once the volunteers agreed to participate, they gave their informed consent. This study was approved by the Ethics Committee of Inner Mongolia Minzu University and was performed in accordance with the Declaration of Helsinki.

Materials and procedure

Weight and height were assessed at school with shoes and coats removed for all participants. Weight and height were measured twice with a measurement device (MSG003SC, Meilen, Shenzhen, China; accurate to 0.01 m and 0.01 kg for height and weight, respectively), and the average of the 2 values was calculated. BMI was calculated as

weight (kg)/height (m)². The categories were normal weight (BMI 18.5–23.9 kg/m²), overweight (BMI 24.0–27.9 kg/m²) and obesity (BMI ≥ 28 kg/m²)³³.

The students completed paper questionnaires (current students) and electronic questionnaires (*wenjuanxing*, intern students). The contents of the questionnaire included the following:

1. (1) Basic information: Basic demographic characteristics (age, sex, grade, major, and place of origin) were investigated.
2. (2) Academic Burnout Scale (ABS):

The ABS was developed by Maslach and Goldberg³⁴ and translated into Chinese by Lian et al. (2005). The scale has 20 items and three dimensions, namely, rejection (8 items), inappropriate behaviors (6 items), and reduced personal acquisition (6 items). These items are scored on a 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree). The total score ranges from 20 to 100, with higher scores indicating greater academic burnout. In terms of incidence, the total score was < 60³⁵. The Cronbach's α was 0.87 in Lian et al.'s¹³ study and 0.871 in this study. The KMO value was 0.904, and Bartlett's test confirmed that factor analysis was appropriate ($p < 0.001$).

3. Internet Addiction Test (IAT):

We assessed the internet addiction of college students with the Chinese version of the Internet Addiction Test (IAT), the most widely used questionnaire for the assessment of internet addiction. The IAT includes 20 items on 5-point Likert scales and has good psychometric properties³⁶. We employed a cutoff score of 40 to identify individuals with internet addiction according to Boysan's criteria³⁷. The Cronbach's α was 0.54–0.82 in a previous study³⁸ and 0.888 in this study. The KMO value was 0.906, and Bartlett's test confirmed that factor analysis was appropriate ($p < 0.001$).

4. Depression, Anxiety, and Stress Scale-21 (DASS-21):

We adopted the Chinese version of the Depression Anxiety and Stress Scale-21 (DASS-21) to measure psychological distress among college students in the present study. DASS-21 consists of three subscales, namely, depression, anxiety, and stress, each comprising 7 items³⁹. Each item is rated on a 4-point Likert scale to indicate the applicability of the statement to the respondent over the past week⁴⁰. A higher total score indicated that the respondent had more severe psychological distress. The DASS-21 has been extensively applied to Chinese samples⁴¹. Because DASS-21 is a short version of the original 42-item DASS instrument, the DASS-21 scores were multiplied by 2 to characterize the severity of the disease relative to the population. The cutoff scores indicating the presence of clinical depression, anxiety, or stress were 5 or more, 4 or more, or 8 or more, respectively³⁹. It has been demonstrated that the Chinese version of this instrument has good internal consistency ($\alpha = 0.89$) among Chinese college students⁴². In the present study, the internal consistency scores of the DASS-21 subscales were as follows: stress, Cronbach's $\alpha = 0.771$; anxiety, Cronbach's $\alpha = 0.768$; and depression, Cronbach's $\alpha = 0.831$. The KMO value was 0.933, and Bartlett's test confirmed that factor analysis was appropriate ($p < 0.001$).

Statistical analysis

Categorical variables are expressed as percentages and were analyzed using SPSS 26.0. The χ^2 test was used to compare the different types of datasets. Binary logistic regression analysis was performed to analyze the correlations of depression/anxiety/stress symptoms with overweight/obesity, academic burnout, and internet addiction. The odds ratio (OR) and the corresponding 95% confidence interval (CI) were calculated to identify the risk factors for depression/anxiety/stress. In the model, OR > 1.0 and $P < 0.05$ indicated that the parameter was a risk factor for depression/anxiety/stress. In contrast, OR < 1.0 and $P < 0.05$ indicated that the parameter was a protective factor against depression/anxiety/stress. The Kolmogorov–Smirnov test was used to test the normality of the data. Pearson's correlation coefficient was used for normally distributed data, and Spearman's who was used for nonnormally distributed data. The correlations between BMI and academic burnout, internet addiction, and other psychological factors were analyzed. Harman's univariate analysis multicollinearity.

Mplus 8.0 was used to implement a path analysis with maximum likelihood estimations to test our hypothetical model. Multiple fit indicators were used to evaluate the model with the following qualification criteria: $\chi^2/df < 3$, SRMR < 0.05, RMSEA < 0.05, CFI > 0.90, and TLI > 0.90. In addition, standardized coefficients of both direct and indirect effects were estimated with 95% confidence intervals (CIs) based on the bias-corrected percentile method. To investigate the hypothesis that the association between academic burnout and internet addiction mediated the association between weight and depression/anxiety/stress, we used three serial mediation models. Normal weight was used as a reference and was set to 0, overweight/obese weight was set to 1 as the independent variable, academic burnout and internet addiction were set as the two mediators, and depression/anxiety/stress was set as the dependent variable. Two mediators and the dependent variable used standardized values⁴³. One thousand bootstrap samples were used. Bootstrapping is a nonparametric method that bypasses the issue of nonnormal distribution and allows us to test indirect effects⁴⁴, even in small samples⁴⁵. $P < 0.05$ indicated statistically significant differences.

Results

Study population characteristics

Among the 610 medical students, the mean age was 20.25 ± 1.33 years. There were 167 (27.38%) freshmen, 208 (34.10%) sophomores, 188 (30.82%) juniors, and 47 (7.70%) seniors. According to the univariate analysis, overweight/obesity ($p < 0.001$), the presence of academic burnout ($p < 0.001$), and the presence of internet addiction ($p < 0.001$) were significantly associated with depression/anxiety/stress (Table 1). Among medical students, those with depression were more likely to be male ($p < 0.001$) and to live in the city ($p = 0.042$). People with anxiety were more likely to major in pharmaceutical preparations ($p = 0.001$) or live in cities ($p = 0.039$).

Variable		Depression (n/%)		P	Anxiety (n/%)		P	Stress (n/%)		P
		no	yes		no	yes		no	yes	
Total		427(70.00)	183(30.00)		306(50.16)	304(49.84)		403(66.07)	207(33.93)	
Sex	Male	117(57.35)	87(42.65)	$p < 0.001$	91(44.61)	113(55.39)	0.052	118(57.84)	86(42.16)	0.002
	Female	310(76.35)	96(23.65)		215(52.96)	191(47.04)		285(70.20)	121(29.80)	
Age (years)	18–19	132(69.84)	57(30.16)	0.871	89(47.09)	100(52.91)	0.553	126(66.67)	63(33.33)	0.931
	20–21	218(70.78)	90(29.22)		157(50.97)	151(49.03)		204(66.23)	104(33.77)	
	22–24	77(68.14)	36(31.86)		60(53.10)	53(46.90)		73(64.60)	40(35.40)	
Academic year	Freshman	118(70.66)	49(29.34)	0.749	77(46.11)	90(53.89)	0.569	116(69.46)	51(30.54)	0.226
	Sophomore	149(71.63)	59(28.37)		109(52.40)	99(47.60)		137(65.87)	71(34.13)	
	Junior	126(67.02)	62(32.98)		94(50.00)	94(50.00)		125(66.49)	63(33.51)	
	Senior	34(72.34)	13(27.66)		26(55.32)	21(44.68)		25(53.19)	22(46.81)	
Major	Pharmaceutical Preparation	32(72.73)	12(27.27)	0.227	15(34.09)	29(65.91)	0.001	26(59.09)	18(40.91)	0.014
	Medical Laboratory Technology	143(66.20)	73(33.80)		92(42.59)	124(57.41)		127(58.80)	89(41.20)	
	Medical Imaging Technology	117(68.42)	54(31.58)		94(54.97)	77(45.03)		123(71.93)	48(28.07)	
	Preventive Medicine	135(75.42)	44(24.58)		105(58.66)	74(41.34)		127(70.95)	52(29.05)	
Residence	City	154(65.25)	82(34.75)	0.042	106(44.92)	130(55.08)	0.039	140(59.32)	96(40.68)	0.005
	Rural	273(72.99)	101(27.01)		200(53.48)	174(46.52)		263(70.32)	111(29.68)	
Weight	Normal weight	296(82.91)	61(17.09)	$p < 0.001$	219(61.34)	138(38.66)	$p < 0.001$	284(79.55)	73(20.45)	$p < 0.001$
	Overweight/Obesity	131(51.78)	122(48.22)		87(34.39)	166(65.61)		119(47.04)	134(52.96)	
Academic burnout	no	312(82.11)	68(17.89)	$p < 0.001$	220(57.89)	160(42.11)	$p < 0.001$	275(72.37)	105(27.63)	$p < 0.001$
	yes	115(50.00)	115(50.00)		86(37.39)	144(62.61)		128(55.65)	102(44.35)	
Internet addiction	no	224(83.58)	44(16.42)	$p < 0.001$	172(64.18)	96(35.82)	$p < 0.001$	211(78.73)	57(21.27)	$p < 0.001$
	yes	203(59.36)	139(40.64)		134(39.18)	208(60.82)		192(56.14)	150(43.86)	

Table 1. Characteristics of the study participants according to the DASS-21 score. ($n = 610$).

People with stress were more likely to be male ($p = 0.002$), majoring in medical laboratory technology ($p = 0.014$) and living in cities ($p = 0.005$).

The results of the binary logistic regression are shown in Fig. 1. Compared with medical students with normal weight, medical students with overweight/obesity were at greater risk for depression (OR = 2.736, 95% CI = 1.817–4.119), anxiety (OR = 2.198, 95% CI = 1.524–3.169), and stress (OR = 3.100, 95% CI = 2.100–4.577). The risk of depression (OR = 3.399, 95% CI = 2.289–5.047) and anxiety (OR = 1.597, 95% CI = 1.109–2.300) was greater for medical students with academic burnout than for those without academic burnout. The rates of depression (OR = 2.242, 95% CI = 1.455–3.456), anxiety (OR = 2.056, 95% CI = 1.435–2.947) and stress (OR = 1.988, 95% CI = 1.336–2.958) were higher in medical students with internet addiction than in medical students without internet addiction. There was a lower risk of depression in women (OR = 0.528, 95% CI = 0.351–0.793) than in men. The risk of anxiety (OR = 0.382, 95% CI = 0.183–0.796) was lower for medical preparation students than for pharmaceutical preparation students. These data suggest that overweight/obesity, academic burnout and internet addiction plays an important role in depression, anxiety and stress.

Correlation analysis

The data of 610 medical-related students were tested for normality using the Kolmogorov-Smirnov test ($Z_{BMI} = 0.136, p < 0.001$; $Z_{academic burnout} = 0.046, p < 0.01$; $Z_{internet addiction} = 0.085, p < 0.001$; $Z_{depression} = 0.241, p < 0.001$; $Z_{anxiety} = 0.183, p < 0.001$; $Z_{stress} = 0.142, p < 0.001$), which revealed that the variables were not normally distributed. Therefore, correlational analyses were performed using Spearman’s Rho. The results of the correlation analyses are shown in Fig. 2 for each variable, including BMI, academic burnout, internet addiction, depression, anxiety and stress.

Harman’s univariate analysis

In this study, no multicollinearity was found because the variance explained by the first factor was 20.138%, which was below the 40% critical value⁴⁶.

Direct effects

As shown in Fig. 3, when normal body weight was used as the reference and sex was entered into the models as a covariate, overweight/obesity status significantly affected academic burnout ($b = 0.544, p < 0.001$), internet addiction ($b = 0.386, p < 0.001$), depression ($b = 0.452, p < 0.001$), anxiety ($b = 0.449, p < 0.001$) and stress ($b = 0.466, p < 0.001$).

Indirect effects

Using the normal weight group as the reference group, we detected six statistically significant pathways. The results of the experiment showed Table 2. Gender was entered into the models as a covariate. AB (indirect effect

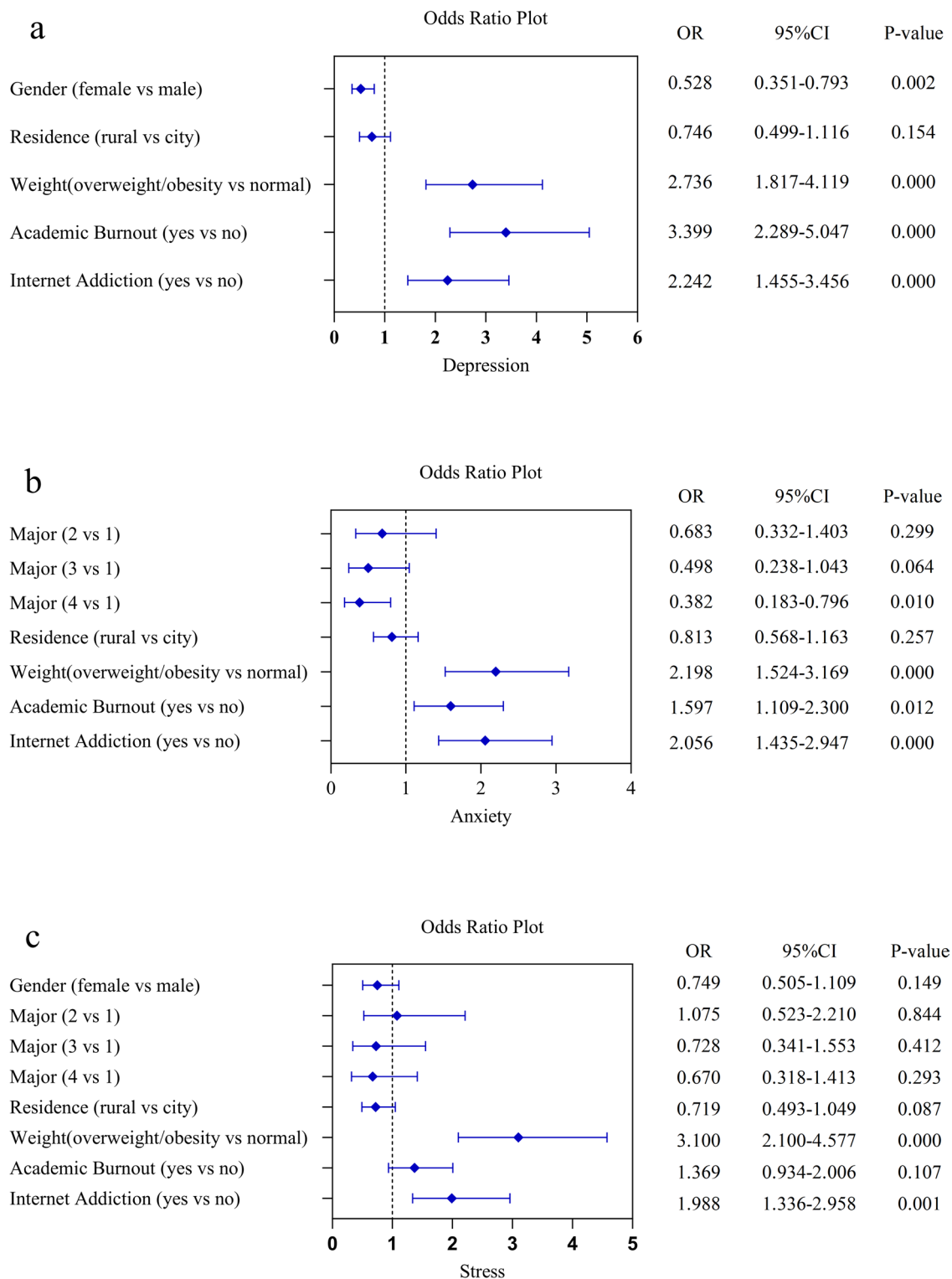


Fig. 1. Factors Associated with Depression-Anxiety-Stress: Binary Logistic Regression. Note: Dependent variables: Depression (no = 0, yes = 1), Anxiety (no = 0, yes = 1), Stress (no = 0, yes = 1); Independent variables: Gender (male = 0, female = 1), Major (pharmaceutical preparation = 1, medical laboratory technology = 2, medical imaging technology = 3, preventive medicine = 4), Residence (city = 0, town = 1), BMI (normal = 0, overweight/obesity = 1), Academic Burnout (no = 0, yes = 1), Internet Addiction (no = 0, yes = 1). (a) Model using depression as the dependent variable; (b) Model using anxiety as the dependent variable; (c) Model using stress as the dependent variable.

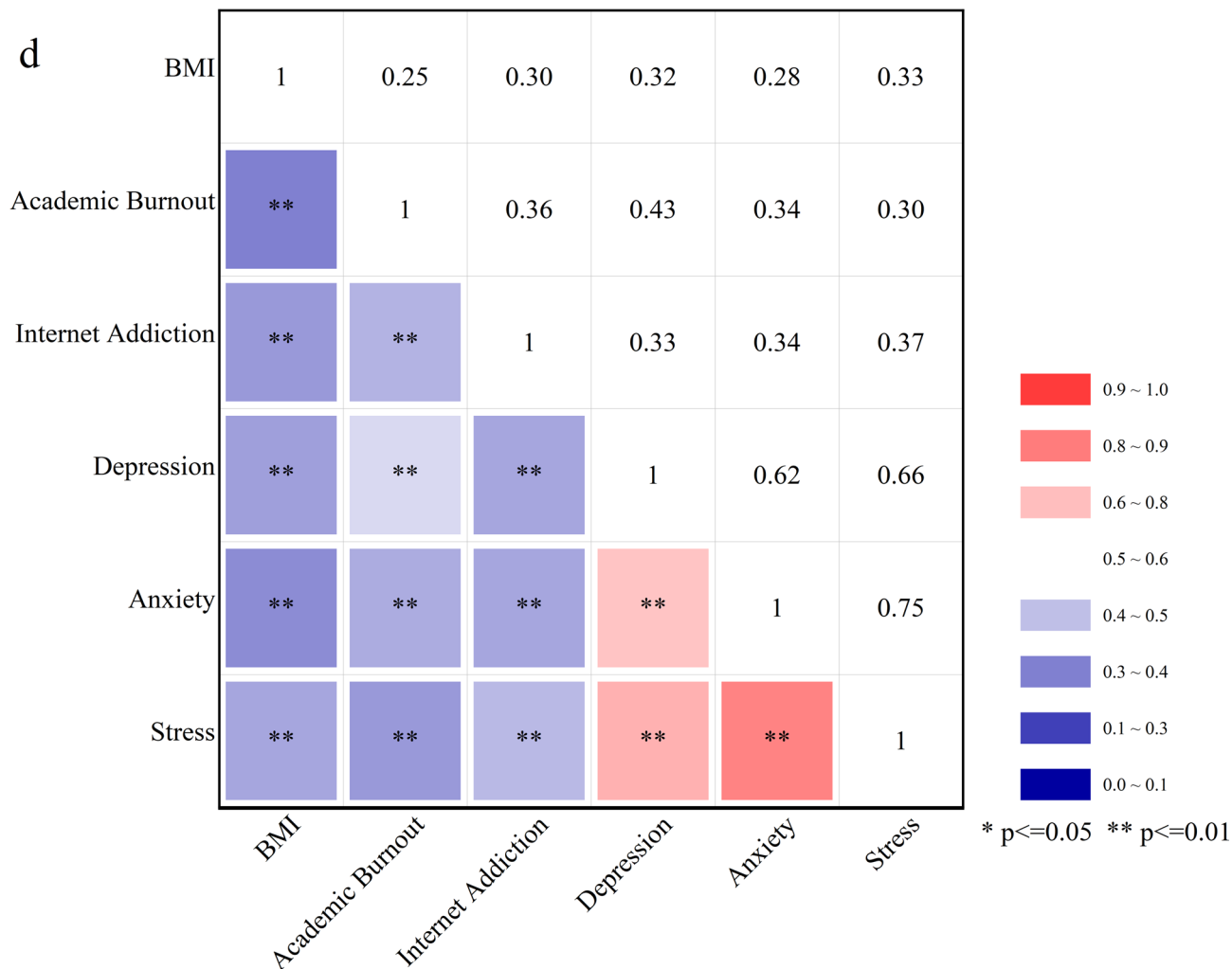


Fig. 2. Correlational analyses (Spearman's rho). Note: d) Model using BMI, Academic Burnout, Internet Addiction, Depression, Anxiety, Stress. Harman's univariate analysis.

1 = 0.163, 95% bootstrap interval [CI] = 0.101–0.233) and IA (indirect effect 2 = 0.061, 95% bootstrap interval [CI] = 0.023–0.108) played mediating roles between overweight/obesity and depression and were positively correlated. In addition, AB-AI (indirect effect 3 = 0.025, 95% bootstrap interval [CI] = 0.010–0.046) together played a mediating role between overweight/obesity and depression, revealing a positive correlation. The 95% bootstrap interval (CI) of all indirect effects did not contain 0 and was statistically significant ($p < 0.01$), indicating that the mediating effect was significant. We also found that the mediating effect of indirect effect 1 was greater than that of indirect effect 2, which was statistically significant ($p = 0.009$). The mediating effect of indirect effect 1 was significantly greater than that of indirect effect 3 ($p < 0.001$), suggesting that academic burnout has a mediating effect on the relationship between overweight/obesity and depression. As a mediator, academic burnout accounted for 23.3% of the total effect, with the mediating effect accounting for the largest proportion. These data indicate academic burnout and internet addiction play a mediating role in the relationship between overweight/obesity status and depression risk.

Using the normal weight group as the reference group, we identified six statistically significant pathways. The results of the experiment are shown in Table 3. Sex was entered in the models as a covariate. AB (indirect effect 1 = 0.130, 95% bootstrap interval [CI] = 0.074–0.198) and IA (indirect effect 2 = 0.074, 95% bootstrap interval [CI] = 0.033–0.121) played mediating roles between overweight/obesity and anxiety and positively correlated. In addition, AB-AI (indirect effect 3 = 0.030, 95% bootstrap interval [CI] = 0.014–0.051) together played a mediating role between overweight/obesity and anxiety and were positively correlated. The 95% confidence intervals (CIs) of all indirect effects did not contain 0 and were statistically significant ($p < 0.01$), indicating that the mediating effect was significant. Moreover, we found that the mediating effect of indirect effect 1 was greater than that of indirect effect 3, indicating statistical significance. Furthermore, the mediating effect of indirect effect 2 was greater than that of indirect effect 3 and was statistically significant ($p = 0.034$). Therefore, the mediating effect of academic burnout and internet addiction separately on the relationship between overweight/obesity and anxiety were greater than those of the mediating effects of academic burnout and internet addiction. As a mediator, academic burnout accounted for 19.1% of the total effect, with the mediating effect accounting

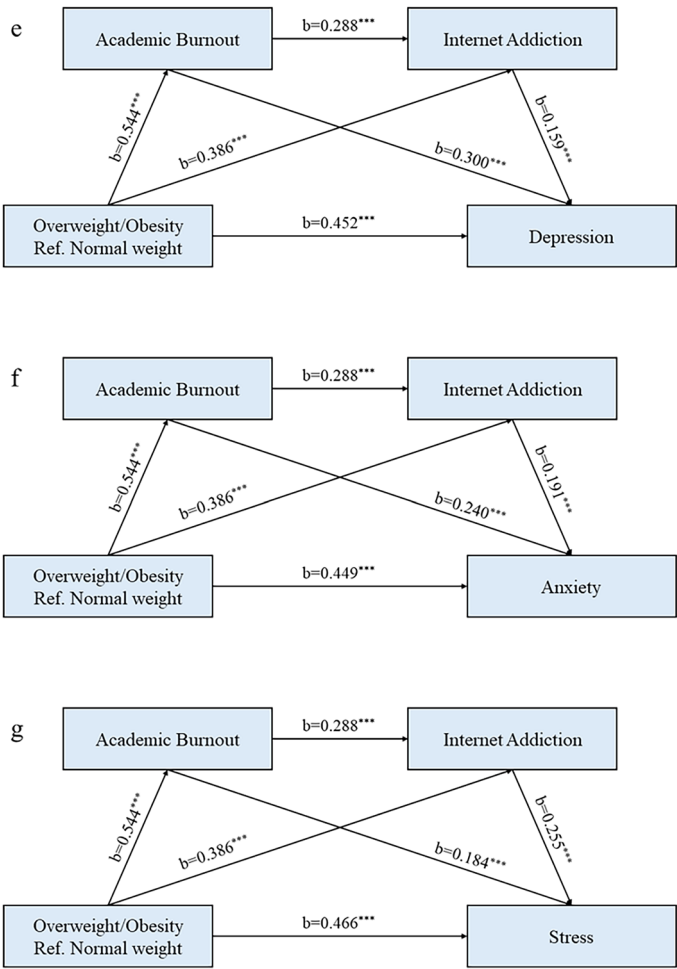


Fig. 3. Regression results for the serial mediation model. Note: e) Serial mediation model using the depression as the dependent variable; f) Serial mediation model using the anxiety as the dependent variable; g) Serial mediation model using the stress as the dependent variable.

	b	SE	Z	Boot (95 CI)	P	Proportion
Reference: normal weight						
Indirect effect						
Ind1: Overweight/obesity→AB→Depression	0.163	0.035	4.691	0.101–0.233	0.000	0.233
Ind2: Overweight/obesity→IA→Depression	0.061	0.022	2.758	0.023–0.108	0.006	0.088
Ind3: Overweight/obesity→AB→IA→Depression	0.025	0.009	2.699	0.010–0.046	0.007	0.036
Total effects	0.702	0.088	7.959	0.534–0.882	0.000	1.000
Direct effect	0.452	0.074	6.070	0.310–0.598	0.000	0.643
Total indirect effects	0.250	0.250	5.069	0.160–0.349	0.000	0.357
Diff1 = Ind1-Ind2	0.102	0.039	2.600	0.027–0.181	0.009	—
Diff2 = Ind1-Ind3	0.138	0.033	4.238	0.080–0.205	0.000	—
Diff3 = Ind2-Ind3	0.037	0.019	1.938	0.004–0.076	0.053	—
Model Fit	χ^2/df	CFI	TLI	RMSEA	SRMR	
	1.127	0.999	0.997	0.014	0.013	

Table 2. Indirect effects of overweight/obesity and depression through different mediators. Note: CI = confidence interval; AB = academic burnout; IA = internet addiction. Total effects = ind1 + ind2 + ind3 + c1; Direct effect = c1; c1: overweight/obesity directly affects depression; Total indirect effects = ind1 + ind2 + ind 3.

	b	SE	Z	Boot (95 CI)	P	Proportion
Reference: normal weight						
Indirect effect						
Ind1: Overweight/obesity→AB→Anxiety	0.130	0.032	4.049	0.074–0.198	0.000	0.191
Ind2: Overweight/obesity→IA→Anxiety	0.074	0.023	3.229	0.033–0.121	0.001	0.108
Ind3: Overweight/obesity→AB→IA→Anxiety	0.030	0.010	2.959	0.014–0.051	0.003	0.044
Total effects	0.683	0.089	7.660	0.501–0.857	0.000	1.000
Direct effects	0.449	0.082	5.482	0.282–0.614	0.000	0.657
Total indirect effects	0.234	0.045	5.213	0.154–0.154	0.000	0.343
Diff1 = Ind1 - Ind2	0.057	0.040	1.437	−0.015–0.136	0.151	—
Diff2 = Ind1 - Ind3	0.101	0.031	3.225	0.046–0.164	0.001	—
Diff3 = Ind2 - Ind3	0.044	0.021	2.117	0.006–0.087	0.034	—
Model Fit	χ^2/df	CFI	TLI	RMSEA	SRMR	
	1.127	0.999	0.996	0.014	0.013	

Table 3. Indirect effects of overweight/obesity and anxiety through different mediators. Note: CI = confidence interval; AB = academic burnout; IA = internet addiction. Total effects = ind1 + ind2 + ind3 + c2; Direct effect = c2; c2: overweight/obesity directly affects anxiety; Total indirect effects = ind1 + ind2 + ind 3.

	b	SE	Z	Boot (95 CI)	P	Proportion
Reference: normal weight						
Indirect effect						
Ind1: Overweight/obesity→AB→Stress	0.100	0.030	3.321	0.047–0.164	0.001	0.142
Ind2: Overweight/obesity→IA→Stress	0.098	0.027	3.643	0.051–0.153	0.000	0.140
Ind3: Overweight/obesity→AB→IA→Stress	0.040	0.012	3.447	0.021–0.064	0.001	0.057
Total effects	0.704	0.085	8.293	0.545–0.876	0.000	1.000
Direct effects	0.466	0.079	5.917	0.314–0.618	0.000	0.661
Total indirect effects	0.238	0.047	5.097	0.153–0.337	0.000	0.339
Diff1 = Ind1 - Ind2	0.002	0.040	0.045	−0.075–0.085	0.964	—
Diff2 = Ind1 - Ind3	0.060	0.029	2.092	0.009–0.122	0.036	—
Diff3 = Ind2 - Ind3	0.058	0.026	2.217	0.008–0.114	0.027	—
Model Fit	χ^2/df	CFI	TLI	RMSEA	RMR	
	1.127	0.999	0.996	0.014	0.013	

Table 4. Indirect effects of overweight/obesity and stress through different mediators. Note: CI = confidence interval; AB = academic burnout; IA = internet addiction total effects = ind1 + ind2 + ind3 + c3; Direct effect = c3; c3: overweight/obesity directly affects stress; Total indirect effects = ind1 + ind2 + ind3.

for the largest proportion. These data indicate academic burnout and internet addiction played a mediating role between overweight/obesity and anxiety.

Using the normal weight group as the reference group, we detected six statistically significant pathways. The results of the experiment are shown in Table 4. Sex was entered into the models as a covariate. AB (indirect effect 1 = 0.100, 95% bootstrap interval [CI] = 0.047–0.164) and IA (indirect effect 2 = 0.098, 95% bootstrap interval [CI] = 0.051–0.153) played a mediating role in the association between overweight/obesity and stress and were positively correlated. In addition, AB-AI (indirect effect 3 = 0.040, 95% bootstrap interval [CI] = 0.021–0.064) together played a mediating role between overweight/obesity and stress, revealing a positive correlation. The 95% confidence intervals (CIs) of all indirect effects did not contain 0 and were statistically significant ($p < 0.01$), indicating that the mediating effect was significant. Moreover, we found that the mediating effect of indirect effect 1 was greater than that of indirect effect 3, indicating statistical significance ($p = 0.036$), and the mediating effect of indirect effect 2 was greater than that of indirect effect 3 ($p = 0.027$). Therefore, the mediating effect of academic burnout and internet addiction separately on the relationship between overweight/obesity and anxiety were greater than those of the mediating effects of academic burnout and internet addiction. As a mediator, academic burnout accounted for 14.2% of the total effect, the mediating effects accounted for the largest proportion of the effects. These data indicate academic burnout and internet addiction played a mediating role between overweight/obesity and stress.

Discussion

In the present study, we aimed to explore the serial mediating effects of academic burnout and internet addiction on the associations between depression/anxiety/stress symptoms and overweight/obesity among medical

students. Our mediation model revealed that academic burnout and internet addiction were mediating variables between depression/anxiety/stress symptoms and overweight/obesity. Symptoms of depression, anxiety, and stress may be directly or indirectly related to overweight/obesity. Specifically, compared with medical students with a normal weight, medical students with overweight/obesity are more likely to experience academic burnout and internet addiction, which increase the risk of depression/anxiety/stress.

The detection rates of depression, anxiety and stress in medical students were 30.00%, 49.84% and 33.93%, respectively, which are slightly lower than the detection rate of depression (37.80%) and higher than the detection rates of anxiety (38.5%) and stress (21.20%) in Malaysian medical students⁴⁷. These findings are also higher than the detection rates of depression (26.4%), anxiety (25.7%) and stress (12.5%) among medical students in other parts of China⁴⁸. This may explain why the mental health status of Chinese medical students has declined. Differences in geographic regions may also lead to differences in medical students' levels of depression, anxiety and stress; however, the specific reasons for these differences remain to be explored. Moreover, our study revealed that medical students with overweight/obesity status were more likely to suffer from depression (48.22%), anxiety (65.61%) and stress (52.96%) and were at greater risk of depression, anxiety, and stress. This may be due to academic pressure, large amounts of information and high demands of medical courses, fatigue, workload, financial problems, and lack of sleep that medical students face⁴⁹.

The mental health of medical students has declined. Medical students' academic pressure, large amount of information and high demands for medical courses, fatigue, workload, financial problems, and lack of sleep⁴⁹ cause medical students to eat fast food. Studies have shown that, in the nursing profession, stressful situations can contribute to changes in eating habits, including increased food intake, which significantly predisposes individuals to overweight and obesity⁵⁰. Moreover, their consumption of snacks, fruit, milk, dairy products, vegetables, beans and meat is very low, and their diet is unbalanced and poor^{51,52}. Studies have shown that up to 76.7% of medical students do not participate in sports due to a lack of time and academic pressure⁵¹. These poor eating habits and lack of exercise further lead to weight gain over time and eventually cause overweight/obesity⁵³. Overweight/obese people often have mental health problems⁵⁴ that can further lead to depression, anxiety, and stress⁷.

Our sequential mediation model revealed that compared with normal weight, overweight/obesity status had a direct effect on and a positive association with depression, anxiety, and stress risk. Therefore, overweight/obesity status in medical students could lead to symptoms of depression, anxiety, and stress. However, no relevant studies in China have reported the psychological impact of overweight/obesity status on medical students. Further study is needed.

The sequential mediation model revealed that academic burnout and internet addiction acted as mediators between overweight/obesity and symptoms of depression/anxiety/stress in medical students. Compared with medical students with normal weight, overweight/obese medical students are more likely to experience academic burnout and internet addiction, which increase the risk of depression/anxiety/stress.

Many studies have shown that academic burnout and internet addiction are closely related^{55,56}. An online survey in China showed that 4.8% of participants had internet addiction, which is related to academic burnout²⁵. Research by Gu et al.⁵⁷ showed that internet addiction has a significant direct impact on academic burnout. Medical students also feel burned out for professional reasons. Given their high-stress environment, competition, excessive workload, lack of sleep, and peer pressure, medical students experience a high degree of academic burnout⁵⁸. However, various online activities, such as gaming, shopping and social networking, can bring happiness. Therefore, medical students may be particularly susceptible to the influence of internet addiction⁵⁹. Studies have shown that nursing students become more addicted to the internet, their ability to perceive, manage, and utilize emotions effectively diminishes, an important aspect of managing burnout and stress⁶⁰. The survey revealed reciprocal cross-lagged paths between excessive internet use and school burnout among adolescents; specifically, school burnout predicted further excessive internet use, and excessive internet use predicted further school burnout⁶¹. Interestingly, academic burnout was exacerbated during the interaction process, which indicates that intervention or two-way intervention in the development of internet addiction or academic burnout is a possible approach for college students. This study revealed that academic burnout can directly lead to internet addiction and is positively correlated with it, and both of these factors are mediators of the association between overweight/obesity status and depressive/anxiety/stress symptoms.

Compared with those on medical students of normal weight, academic burnout and internet addiction had significant effects on medical students with both overweight/obesity and depressive/anxiety/stress symptoms. Approximately 35.70%, 34.30% and 33.90% (indirect effect/total effect) of the correlations between overweight/obesity and depression, anxiety and stress symptoms, respectively, were mediated by factors including academic burnout and internet addiction.

First, academic burnout mediated the relationship between overweight/obesity and symptoms of depression/anxiety/stress in medical students. Studies have shown that students with academic burnout have decreased interest and motivation in learning and increased levels of negative emotions such as anxiety, depression, and stress^{62–64}. Academic burnout has a considerable effect on the mental health of medical students¹⁵. Several studies have shown that there are significant positive correlations between medical students' fatigue and anxiety, depression and stress^{14,65}. This may be related to the long learning process and academic environment⁶⁵. Among doctors and nurses in some European countries, burnout is positively correlated with higher fast-food consumption and negatively correlated with exercise frequency⁶⁶. Overweight/obesity among medical students is also associated with poor eating habits and a lack of exercise⁴⁶. Therefore, overweight/obesity among medical students may lead to academic burnout through poor diet and lack of exercise, although this finding requires further confirmation. Our results showed that overweight/obesity medical students were directly related to academic burnout and the further development of depression/anxiety/stress. This finding has not been reported in previous studies.

Second, internet addiction mediated the relationship between overweight/obesity status and symptoms of depression/anxiety/stress in medical students. Many psychological factors are associated with IA. College students are particularly prone to internet addiction because of their heavy reliance on the internet for academic purposes, social interaction, and entertainment. One study revealed that students with severe anxiety and depression scores were more likely to be addicted to the internet⁶⁷. IA has also been identified as an important predictor of depression and anxiety⁶⁸. Some studies suggest that internet addiction is significantly correlated with stress but not with depression or anxiety. This study was conducted with college students, who understandably experience considerable stress in their academic pursuits⁶⁹. In addition, due to their age, interest in science and the need for social networking, medical students are particularly prone to developing internet addiction⁷⁰. For medical students, internet addiction is strongly correlated with depression, anxiety, and stress⁷¹. Several studies have shown that there is a significant relationship between college students' internet addiction and obesity⁷². People with internet addiction may be more susceptible to the influence of obesity risk factors, such as unhealthy food consumption, lack of physical exercise and obesity as well as sleep pattern disorders⁷³. Similarly, our study showed that overweight/obese status is directly related to internet addiction and the further development of depression/anxiety/stress.

Finally, our study revealed that academic burnout and internet addiction simultaneously mediated the relationship between overweight/obesity and depression/anxiety/stress in medical students. The indirect effect showed that overweight and obese medical students can experience academic burnout and internet addiction and develop symptoms of depression, anxiety, and stress. Therefore, in this study, all three indirect mediating pathways were significant. (1) Academic burnout mediates the relationship between overweight/obesity and depression/anxiety/stress among medical students; (2) internet addiction mediates the relationship between overweight/obesity and depression/anxiety/stress among medical students; and (3) academic burnout and internet addiction also mediate the relationship between overweight/obesity and depression/anxiety/stress among medical students. A comparison of the three pathways revealed that the mediating effect of academic burnout on the relationship between overweight/obesity and depression/anxiety/stress was greater than that of the other factors. Therefore, academic burnout and internet addiction are key points when designing interventions to reduce depression/anxiety/stress in overweight/obesity medical students.

This study has several limitations. First, the main limitation to generalizing these results is that the four majors represented were pharmaceutical preparations, medical laboratory technology, medical imaging technology and preventive medicine. Therefore, the results may not be representative of medical students in other specialties. Second, all the data were recorded at the same time in this cross-sectional study. MacKinnon et al.⁷⁴ suggested that longitudinal research would provide richer information about mediation and would help to identify cause-and-effect relationships in mediating effects analysis. More longitudinal studies should be conducted to facilitate the identification of pathways and cause-and-effect relationships. Future research should consider longitudinal designs to examine changes in burnout, internet addiction, and weight over time. Given that internet addiction and mental health risks may vary by cultural context, a discussion of how cultural factors might affect the findings would improve generalizability.

Conclusion

Depression/anxiety/stress symptoms in overweight/obesity medical students should be detected early. Our study confirmed that academic burnout and internet addiction are mediating variables between depression/anxiety/stress symptoms and overweight/obesity in medical students. Therefore, the further development of symptoms of depression, anxiety, and stress in overweight/obese medical students can be alleviated by preventing academic burnout and providing early intervention for individuals with internet addiction. In future, more studies should be carried out to better understand depression/anxiety/stress. From one perspective, longitudinal study is necessary to verify the relationship between overweight/obesity, academic burnout, internet addiction and depression/anxiety/stress over time.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

HYZ, MJL, YW, YW, CHdata curation and investigation of this study and take full responsibility for the paper. HYZ took the lead in writing – original draft and formal analysis. HYZ, HLZ revised the paper and participated in the study design, methodology and software. HLZ and JBZ took the supervision and writing – review & editing. JBZ and BW final approval of the version to be submitted and resources.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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