

EVALUATING THE ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND DEPRESSIVE SYMPTOMS AMONG ADOLESCENTS IN XIAMEN, PEOPLE'S REPUBLIC OF CHINA

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Abstract. Physical activity has been reported to be an effective method to reduce risk for developing depression. In this cross-sectional observational study, we aimed to determine if there is a significant association between physical activity levels and the presence of depression symptoms among middle school students in Xiamen, People's Republic of China in order to inform efforts to reduce depression in the study population. Study subjects were randomly chosen from grades 7-9 at the study school. Inclusion criteria for study subjects were being a student aged 12-16 years, attending the study school, completing the study questionnaire and the subjects and their parents/guardians were giving informed consent to participate in the study. Exclusion criteria for subjects were being diagnosed with a mental health condition, having a physical disability that prevents exercising and not completing the study questionnaire. The minimum number of subjects calculated to be needed for the study was 1,225. The presence of depressive symptoms was determined using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10). Heights and weights were measured for each subject and the body mass index (BMI) was calculated and subjects were categorized into underweight (BMI <18.5 kg/m²), normal weight (18.5-22.9 kg/m²), overweight (23.0-24.9 kg/m²) and obese (≥25.0 kg/m²). Physical activity level was assessed using a standardized questionnaire asking about the subject's activity level during the previous 7 days, expressed as metabolic equivalents of task in hours (MET-hours) per week. Study subjects were then divided

into 4 equal groups based on their total weekly MET-hours as follows: sedentary activity level (Group Q1: ≤ 28.2 MET-hours/week, $n = 361$), low physical activity (Group Q2: 28.7-33.8 MET-hours/week, $n = 361$), medium physical activity (Group Q3: 33.8-41.7 MET-hours/week, $n = 360$) and high physical activity (Group Q4: >41.7 MET-hours/week, $n = 361$). We used logistic regression analysis and restricted cubic splines to identify significant associations between activity levels and having a CES-D-10 score ≥ 10 . A total of 1,443 subjects were included in the study: 52.1% ($n = 752$) females. The mean (\pm standard deviation (SD)) age of study subjects was 14 (± 1.0); range: 11-17 years. The mean (\pm SD) body mass index of subjects was 20.63 (± 3.67); range 14.05-40.45 kg/m². The mean (\pm SD) CES-D-10 scores were 8.05 (± 6.51) for Group Q1, 8.59 (± 5.47) for Group Q2, 8.40 (± 5.48) for Group Q3 and 6.72 (± 5.28) for Group Q4. 452 subjects (31.4%) were underweight; 810 (56.1%) had a normal weight; 146 (10.1%) were overweight; and 35 (2.4%) were obese. After adjusting for age, gender, grade, and BMI, subjects in Group Q4 had significantly lower (aOR = 0.59; 95% CI: 0.42-0.82, p -value < 0.001) odds of having a CES-D-10 score ≥ 10 than subjects in Group Q1. Underweight subjects in Group Q4 had significantly lower odds (aOR = 0.32, 95% CI: 0.17-0.57, p -value < 0.001) of having a CES-D-10 score ≥ 10 than underweight subjects in Group Q1. In summary, subjects with high levels of physical activity (Group Q4) had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects who were sedentary (Group Q1) and underweight subjects in Group Q4 had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects in Group Q4 who were normal weight, overweight or obese. We conclude subjects with a high level of physical activity and underweight subjects are less likely to have depressive symptoms. Further studies are needed to determine if counselling to increase physical activity and control weight are able to prevent major depression in this study population.

Keywords: depression, adolescents, physical activity, sedentary behavior

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INTRODUCTION

Depression is a common mental health disorder among adolescents worldwide (Thapar *et al*, 2012). A meta-analysis of studies conducted during 2001-2020 reported 34% of subjects worldwide aged 10-19 years had depressive symptoms and this increased from 24% during 2001-2010 to 37% during 2011-2020 (Shorey *et al*, 2022). This suggests millions of young people worldwide may have depression (Shorey *et al*, 2022).

Multiple factors have been reported to be associated with depressive symptoms among adolescents. Academic stress has been reported to be associated with up to 3 times the likelihood of having depressive symptoms (Beiter *et al*, 2015). Accessing the internet for more than 4 hours a day is associated with a 1.75-fold higher likelihood of having elevated depressive symptom scores and accessing social media more than 2 hours per day is associated with a 46% higher likelihood of having

depressive symptom scores through a variety of mechanisms, such as comparing themselves socially with others and experiencing cyberbullying (McAllister *et al*, 2021). Some studies have reported an association between excessive social media use and experiencing feelings of loneliness, anxiety and low self-esteem, feelings associated with higher depressive symptom scores (Shah *et al*, 2019; Zhou *et al*, 2023).

These studies highlight the need for developing healthy methods to reduce the risk of developing depressive symptoms. It has been reported that subjects who have regular physical activity have 20-30% lower depressive symptom scores than those who do not (Recchia *et al*, 2023).

The metabolic equivalent of task (MET) method is used to quantify intensity of physical activity (Matthews *et al*, 2020; Mendes *et al*, 2018; Tian *et al*, 2024). MET-hours per week is the METs multiplied by the number of hours

that intensity is sustained per week. MET-hours may be used to study the association between physical activity and health outcomes. A systematic review and meta-analysis of prospective cohort studies reported that adults who sustain 8.8 MET-hours per week had a 25% lower risk of depression (95% CI: 16%-35%) than those reporting no physical activity, demonstrating a significant inverse association between physical activity and depression risk (Pearce *et al*, 2022).

One study reported an association between using a computer/playing video games and depressive symptoms among girls (95% CI: 0.04-0.18, *p*-value = 0.002) but not boys (Zink *et al*, 2020). Several studies have explored associations between physical activity and depressive symptoms (He *et al*, 2022; Liang *et al*, 2023; Philippot *et al*, 2022) but most have been among adults. Few studies have evaluated the effect of different levels of physical activity on depressive symptoms among adolescents (Velazquez *et al*, 2022;

Wang *et al*, 2023) highlighting a need for this type of study.

In this study, we aim to investigate potential associations between levels of physical activity and depressive symptom scores among Chinese middle school students in order to inform efforts to reduce depressive symptoms in this population.

MATERIALS AND METHODS

Study design and subject selection

We randomly selected study subjects from middle school students attending grades 7-9 during 2024 at Xiamen Cailin Middle School, Xiamen, People's Republic of China. Subjects were asked to complete a standardized questionnaire asking about their levels of physical activity and presence of depressive symptoms. The questionnaire was pilot tested among 50 middle school students at the same school. To minimize selection bias, we employed a cluster sampling approach in which entire classes were randomly

selected from each grade level.

Inclusion criteria for study subjects were being a student aged 12-16 years, attending the study school, completing the study questionnaire and the subjects and their parents/guardians being willing to give informed consent to participate in the study.

Exclusion criteria for subjects were being diagnosed with a mental health condition, having a physical disability that prevents exercising and not completing the study questionnaire.

Sample size calculation

The minimum number of study subjects needed for the study to reach statistical significance was calculated using the following formula: $n = (Z^2 \times p \times (1-p)) / d^2$, where $Z = 1.96$ (95% confidence level), $p = 0.15$ (expected prevalence of depression symptoms among subjects based on previous studies) and $d = 0.02$ (margin of error) (Althubaiti, 2022). This number was calculated to be 1,225 subjects. To account for potential dropouts

and missing data an additional 20% was added to the minimum number, so we aimed to recruit 1,530 subjects.

Depressive symptom assessment

The presence of depressive symptoms was assessed using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10) (Singh *et al*, 2020). The CES-D-10 is a screening instrument previously validated in the Chinese population and found to have good reliability (Cronbach's $\alpha = 0.85$) among children and adolescents (Yu *et al*, 2015; Zhou *et al*, 2021). The scale consists of 10 self-rated items that assessed depressive symptoms experienced during the previous week. Each question is answered using a 4-point Likert scale of 0-3 giving a total potential score 0-32 points. A total score of ≥ 10 points was classified as an elevated depressive symptom score. The CES-D-10 is a screening tool that assesses depressive symptoms but does not diagnose major depressive disorder, which must be done by a

mental health professional.

Physical activity assessment

Subjects were asked how many minutes they engaged in physical activity and to what intensity level were they active during the previous 7 days using a standardized questionnaire (Singh *et al*, 2020). These 4 intensity levels were defined by standardized metabolic equivalents of tasks (MET), which estimate energy expenditure compared to a calculated basal metabolic rate. These intensities are defined as 1 MET-watching TV or using a computer, 3.3 METs-commuting to school or shopping, 4.0 METs-cycling or Tai Chi and 8.0 METs-playing basketball or football. The number of minutes the subject was active at that intensity level was used to calculate the MET-hours/week as follows: (total minutes engaged at that intensity level during the previous 7 days × the level of METs for that activity) ÷ 60 (Ainsworth *et al*, 2011). For example, if a subject was active at an intensity level of 4.0 METs for

150 minutes during the previous 7 days, the calculation would be $150 \times 4.0 \div 60 = 10$ MET-hours per week.

Subjects were divided into 4 groups (quartiles), each with equal numbers of subjects, based on their MET-hours/week as follows: Quartile Group 1 (Group Q1) subjects ($n = 361$) had ≤ 28.2 MET-hours/week, defined as a sedentary level of physical activity; Group Q2 subjects ($n = 361$) had 28.2-33.8 MET-hours/week, defined as a low level of physical activity; Group Q3 subjects ($n = 360$) had 33.8-41.7 MET-hours/week, defined as a medium level of physical activity; Group Q4 subjects ($n = 361$) had > 41.7 MET-hours/week, defined as a high level of physical activity.

Statistical analysis

Continuous variables and frequencies (percentages) are presented as means (\pm standard deviations). Comparison between those with and without a CES-D-10 ≥ 10 was made for continuous variables with an independent

sample *t*-test and for categorical variables with a Chi-square test.

Associations between physical activity levels and a CES-D-10 ≥ 10 was determined using hierarchical logistic regression models. Three logistic regression models were used: Model 1 (unadjusted univariate analysis), Model 2 (adjusted for age and gender, bivariate) and Model 3 (adjusted for age, gender and body mass index (BMI), multivariate). The BMI was classified using Asian standards as: underweight (< 18.5 kg/m²), normal weight (18.5-22.9 kg/m²), overweight (23.0-24.9 kg/m²) and obese (≥ 25.0 kg/m²).

Nonlinear relationships were explored using restricted cubic spline (RCS) modeling with three knots at the 10th, 50th and 90th percentiles. Statistical significance was set at *p*-value < 0.05 (two-sided). All analyses were performed using R software version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical approval and consent to participate

This study protocol was approved by the Ethics Review Committee of Xiamen Cailin Middle School (Approval No. clllsc-24-01). Informed consent was obtained from all study subjects and their parents/legal guardians prior to participation in the study. All data were collected anonymously.

RESULTS

Table 1 describe the selected demographic characteristics of study subjects. A total of 1,443 subjects were included in the study, 52.1% ($n = 752$) females. The mean (\pm SD) age of study subjects was 14 (± 1.0); range 11-17 years. 36.7% of subjects ($n = 530$) were in grade 7, 31.5% ($n = 454$) were in grade 8, and 31.8% ($n = 459$) were in grade 9. The mean (\pm SD) subject BMI was 20.63 (± 3.67); range 14.05-40.45) kg/m². 31.4% of subjects ($n = 452$) were underweight, 56.1% ($n = 810$) had a normal weight, 10.1% ($n = 146$) were overweight and 2.4% ($n = 35$)

were obese.

The mean (\pm SD) overall activity level was 44.3 (\pm 34.3) MET-hours/week. The mean (\pm SD) activity levels for Groups Q1, Q2, Q3 and Q4 were 23.9 (\pm 3.5), 31.0 (\pm 1.6), 37.3 (\pm 2.3) and 85.3 (\pm 48.7) MET-hours/week, respectively (p -value <0.001) (Table 1).

33.9% of subjects ($n = 489$) had a CES-D-10 score ≥ 10 (Table 1).

On univariate, bivariate and multivariate logistic regression analysis, subjects in Group Q4 had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects in Group Q1 (cOR = 0.52, 95% CI: 0.38-0.71, p -value <0.001 ; aOR = 0.59, 95% CI: 0.42-0.82, p -value <0.001 ; aOR = 0.59, 95% CI: 0.42-0.82, p -value <0.001 , respectively) (Table 2). No significant differences were seen between Groups Q1 and Groups Q2 and Q3 for odds of having a CES-D-10 score ≥ 10 (Fig 1).

Also in Table 2, on bivariate logistic regression analysis, males in Group Q4 had significantly lower

odds than males in Group Q1 of having a CES-D-10 score ≥ 10 (aOR = 0.55, 95% CI: 0.34-0.89, p -value = 0.015) but on multivariate logistic regression analysis there was no significant difference. On none of the comparisons was there a difference among female subjects.

On multivariate logistic regression analysis, we found no significant association between having a CES-D-10 score ≥ 10 and subject grade level. Underweight subjects in Group Q4 had significantly lower odds of having a CES-D-10 score ≥ 10 than normal weight, overweight and obese subjects in Group Q4 (OR = 0.32, 95% CI: 0.17-0.57, p -value <0.001) but this difference was not seen for other quartile groups or in other weight categories (Table 2).

Restricted cubic spline analysis revealed a significant overall association between total physical activity and elevated depressive symptoms (p -value = 0.011), with a U-shaped relationship (Fig 2).

Table 1
Demographic and selected characteristics of study subjects (N = 1,443)

Variables	Results				p-value	
	Overall	Group Q1	Group Q2	Group Q3		Group Q4
Numbers of subjects	1443	361	361	360	361	
Mean (\pm SD) subject age in years	14.00 \pm 0.95	14.06 \pm 0.90	14.08 \pm 0.97	14.28 \pm 0.91	13.58 \pm 0.90	<0.001
Mean (\pm SD) subject BMI in kg/m ²	20.63 \pm 3.67	20.71 \pm 3.75	20.47 \pm 3.49	21.03 \pm 3.70	20.33 \pm 3.71	0.030
Mean (\pm SD) subject MET-hours/week	44.3 \pm 34.3	23.9 \pm 3.5	31.0 \pm 1.6	37.3 \pm 2.3	85.3 \pm 48.7	<0.001
Subject gender, n (%)						0.996
Male	691 (47.9)	173 (47.9)	174 (48.2)	173 (48.1)	171 (47.4)	
Female	752 (52.1)	188 (52.1)	187 (51.8)	187 (51.9)	190 (52.6)	
Subject grade levels, n (%)						<0.001
7	530 (36.7)	109 (30.2)	103 (28.5)	81 (22.5)	237 (65.7)	
8	454 (31.5)	133 (36.8)	132 (36.6)	125 (34.7)	64 (17.7)	
9	459 (31.8)	119 (33.0)	126 (34.9)	154 (42.8)	60 (16.6)	

Table 1 (cont)

Variables	Results				<i>p</i> -value
	Overall	Group Q1	Group Q2	Group Q3	
Subject BMI categories, <i>n</i> (%)					0.049
Underweight (<18.5 kg/m ²)	452 (31.4)	113 (31.3)	105 (29.1)	96 (26.7)	138 (38.2)
Normal (18.5-24.9 kg/m ²)	810 (56.1)	199 (55.1)	220 (60.9)	212 (58.9)	179 (49.6)
Overweight (25.0-29.9 kg/m ²)	146 (10.1)	39 (10.8)	30 (8.3)	41 (11.4)	36 (10.0)
Obese (≥30.0 kg/m ²)	35 (2.4)	10 (2.8)	6 (1.7)	11 (3.1)	8 (2.2)
CES-D-10 scores, <i>n</i> (%)					<0.001
<10	954 (66.1)	224 (62.0)	224 (62.0)	232 (64.4)	274 (75.9)
≥10	489 (33.9)	137 (38.0)	137 (38.0)	128 (35.6)	87 (24.1)

Note: Group Q1 is sedentary physical activity level; Group Q2 is low physical activity level; Group Q3 is moderate physical activity level; Group Q4 is high physical activity level.

BMI: body mass index; CES-D-10: 10-item Center for Epidemiologic Studies Depression Scale; kg/m²: kilograms per square meter; MET-hours/week: metabolic equivalent hours/week; SD: standard deviation

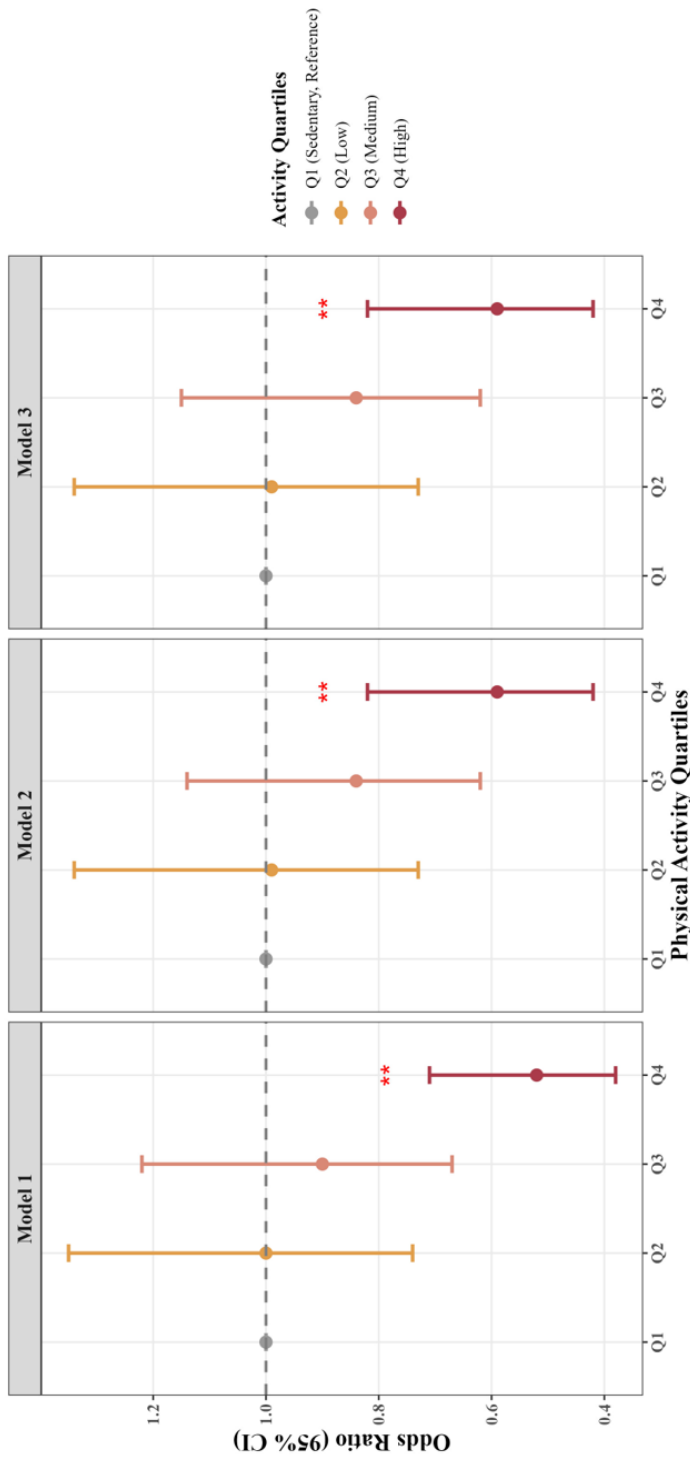


Fig 1 - Associations between different intensities of physical activity and odds of having depressive symptoms using univariate, bivariate and multivariate logistic regression analysis
 Model 1: not adjusting for factors; Model 2: adjusting for age and gender; Model 3: adjusting for age, gender and body mass index.

Table 2

Stratified analysis of associations between physical activity quartiles and depressive symptoms by gender, grade, and BMI category

Characteristic	Physical activity, aOR (95% CI)						p for interaction
	Group Q1 (Reference)	Group Q2	p-value	Group Q3	p-value	Group Q4	
Gender							0.648
Female	1	0.93 (0.60-1.43)	0.732	0.89 (0.57-1.38)	0.606	0.63 (0.40-1.00)	0.052
Male	1	1.06 (0.69-1.63)	0.795	0.80 (0.51-1.25)	0.332	0.55 (0.34-0.89)	0.015
Grade							0.364
7	1	0.97 (0.52-1.79)	0.915	0.96 (0.50-1.83)	0.900	0.64 (0.38-1.09)	0.101
8	1	1.29 (0.77-2.14)	0.331	0.82 (0.48-1.40)	0.465	0.75 (0.38-1.44)	0.397
9	1	0.80 (0.48-1.34)	0.400	0.81 (0.50-1.32)	0.399	0.53 (0.27-1.00)	0.053
BMI							0.174
Underweight	1	0.82 (0.47-1.43)	0.488	0.67 (0.38-1.20)	0.182	0.32 (0.17-0.57)	< 0.001
Normal	1	1.34 (0.89-2.02)	0.158	1.12 (0.74-1.70)	0.578	0.93 (0.59-1.46)	0.743
Overweight	1	0.46 (0.15-1.32)	0.158	0.60 (0.23-1.55)	0.296	0.57 (0.20-1.58)	0.285
Obese	1	0.32 (0.03-2.71)	0.310	0.23 (0.03-1.56)	0.144	0.21 (0.02-1.73)	0.165

Note: (1) Group Q1 is sedentary physical activity level; Group Q2 is low physical activity level; Group Q3 is moderate physical activity level; Group Q4 is high physical activity level. (2) All models were adjusted for age, gender, grade and BMI. (3) BMI was classified using Asian standards as: underweight (<18.5 kg/m²), normal weight (18.5-22.9 kg/m²), overweight (23.0-24.9 kg/m²) and obese (≥25.0 kg/m²).

aOR: adjusted odds ratio; BMI: body mass index; CI: confidence interval

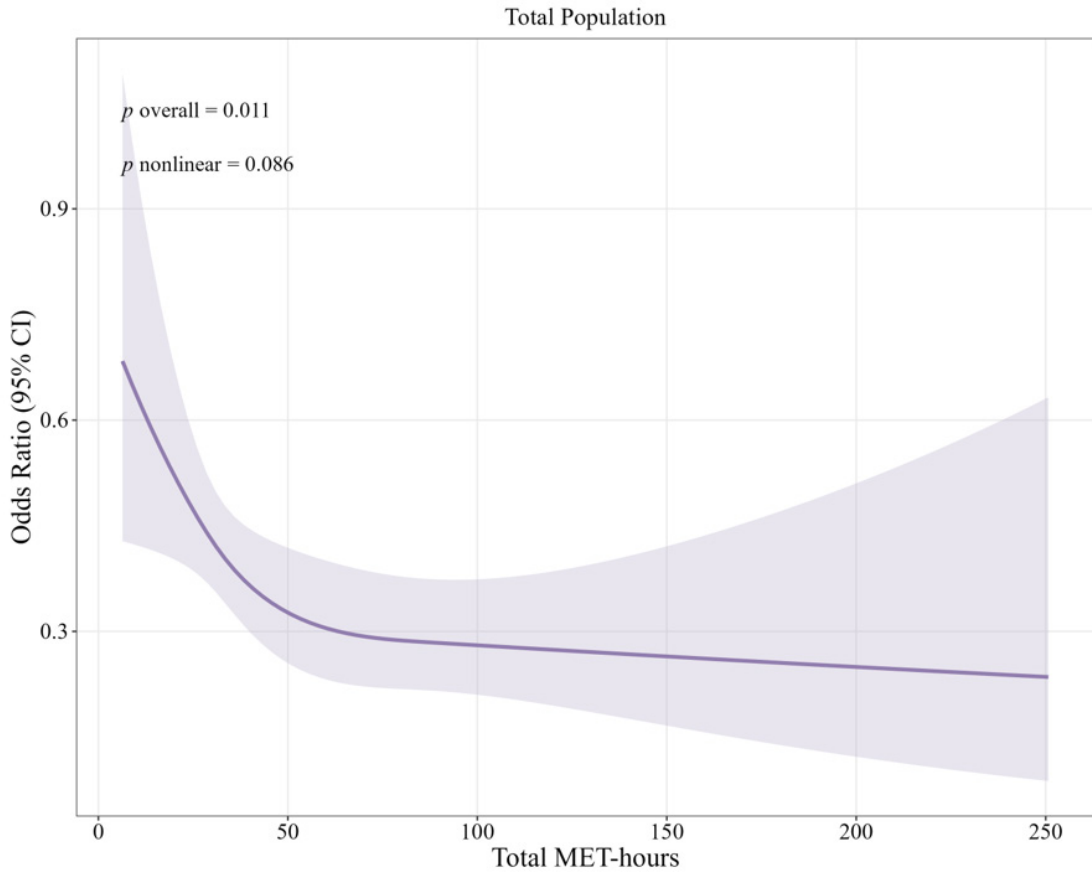


Fig 2 - Nonlinear relationships between different levels of physical activity and depressive symptoms

BMI: body mass index; CI: confidence interval; MET-hours: metabolic equivalent in hours per week

DISCUSSION

In our study, we found subjects with high levels of physical activity had significantly lower odds of having a CES-D-10 score ≥ 10 ,

similar to the findings of another study that reported a high level of physical activity was significantly associated with lower odds of having depressive symptoms (Tonorezos *et al*, 2019). A 13-year longitudinal

study reported finding subjects who exercised >300 minutes per week had significantly lower odds of having depressive symptoms but those who exercised 150 minutes per week did not have significantly lower odds of having depressive symptoms (Hallgren *et al*, 2019).

Previous studies have reported subjects with sedentary behavior, are at greater risk of having depressive symptoms (Penninx *et al*, 2013), especially among adolescents (Zhai *et al*, 2015). A previous study from South Korea found adolescents who were sedentary had a higher risk of developing depressive symptoms (Kim *et al*, 2022). Prolonged sitting in class by middle school students is sedentary behavior combined with academic pressure may increase the risk for developing depressive symptoms.

In our study, subjects in Group Q4 had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects in Group Q1, but we found no significant association between physical activity and

having a CES-D-10 score ≥ 10 among subjects in Groups Q2 and Q3, similar to the findings of a previous study (Bewernick *et al*, 2017). This suggests, higher physical activity levels among adolescents may prevent depressive symptoms but prospective studies are needed to confirm this.

A strength of our study was its large study population size allowing for subgroup analyses. Another strength of our study was our use of restricted cubic spline modeling allowed examination of nonlinear relationships between physical activity and depressive symptoms, revealing dose-response patterns. A limitation of our study was its cross-sectional design prevents assessment of cause-and-effect relationships; we were only able to determine associations. Another limitation of the study was that it was confined to subjects from only one city, limiting its generalizability to other similar populations. Another limitation was physical activity and depressive

symptoms were assessed using self-reporting, which may be subject to recall bias and social desirability bias. Another limitation was that we did not account for other possible confounding variables, such as academic performance, family socioeconomic status, or other lifestyle factors that might influence physical activity and mental health. Finally, in this study we used an RCS model to analyze nonlinear effects but the nonlinear relationships between different activity types and mental health may vary by individual.

In summary, subjects with high levels of physical activity (Group Q4) had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects who were sedentary (Group Q1) and underweight subjects in Group Q4 had significantly lower odds of having a CES-D-10 score ≥ 10 than subjects in Group Q4 who were normal weight, overweight or obese. We conclude subjects with a high level of physical activity and underweight subjects are less likely

to have depressive symptoms. Further studies are needed to determine if counselling to increase physical activity and control weight are able to prevent major depression in this study population.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare they have no conflicts of interest in the conduction of this study or interpretation of the results.

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