Preplanned Studies

Association Between Combinations of 24-Hour Movement Behaviors and Depression Among Adolescents — Inner Mongolia Autonomous Region, China, 2019–2021

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Summary

What is already known about this topic?

In recent years, there has been growing concern regarding the escalating rates of depression among adolescents. While certain individual behaviors have been suggested as potential protective factors for mental health, there is a scarcity of research examining the collective influence of 24-hour movement behaviors.

What is added by this report?

This research documented the prevalence of adolescent depression, along with the rates of adherence to 24-hour movement behavior guidelines encompassing moderate to vigorous physical activity, screen time, and sleep time, in the years 2019, 2020, and 2021. A significant correlation was observed between levels of depression and combined health behaviors. Of particular note was the finding that adherence to the "screen+sleep time" recommendation was linked with the lowest risk of depression.

What are the implications for public health practice?

A comprehensive intervention that targets three 24-hour movement behaviors should be accentuated, with the combination of "sleep and screen time" potentially offering the most effective approach to managing depression.

Depression is a prevalent mental disorder on a global scale. However, limited knowledge exists regarding the correlations between combinations of 24-hour movement behaviors and depression. The aim of this study was to investigate the association between combinations of moderate to vigorous physical activity (MVPA), screen time, and sleep duration with depression in adolescents. The data was obtained from the monitoring of prevalent diseases and contributing factors to health in student populations within Inner Mongolia from 2019 to 2021. The sample consisted of a total of 238,440 adolescents ranging between 13–18 years of age. The findings indicated a dose-response correlation between the number of attained movement guidelines and the risk of depression. Furthermore, in relation to adolescents who met all three guidelines, the "sleep+screen time" combination demonstrated the lowest associated risk with depression. These results propose that limited screen time coupled with ample sleep duration may effectively mitigate the risk of depression among adolescents.

Depression prevalence among adolescents has significantly escalated over the past decade, raising concern due to the critical developmental and transitional occurrences during this stage of life (1). Previous studies indicated specific behaviors, such as promoting physical activity and limiting sedentary times, could potentially contribute to improved mental health among adolescents (2). However, there is a growing consensus that an amalgamation of 24-hour movement behaviors could have a more profound impact on health than isolated behaviors. This is particularly pertinent during adolescence as it is foundational for establishing lifelong behavioral patterns (3). Therefore, this study aims to investigate the correlation between patterns of 24-hour movement behaviors, including MVPA, screen time, and sleep duration, and their associations with depression in adolescents.

Annual health surveillance was conducted on common diseases among students in the Inner Mongolia Autonomous Region, spanning all 12 cities (103 counties) of the region. A stratified cluster random sampling technique was utilized for this purpose. Initially, junior and senior high schools within each county were chosen at random, determined by geographic classification (rural or urban). Thereafter, stratification by grade was carried out, with students participating in the study in class units to meet the minimum quota of 80 students per

grade. In this study, three cross-sectional data sets from the years 2019, 2020, and 2021 were leveraged, encompassing 83,866 adolescents (49.3% boys) in 2019, 67,998 adolescents (49.4% boys) in 2020, and 86,576 adolescents (49.5% boys) in 2021, aged 13–18 years, all with complete data records.

Depression was quantified using the Center for Epidemiological Studies Depression Scale (CES-D). This scale encompasses 20 symptom-related items, which were evaluated based on their frequency of occurrence over the preceding week, utilizing a 4-point grading system ranging from 0 to 3. A cumulative score of ≥16 was delineated as indicative of a depressive mood (4).

Information regarding MVPA, screen time, and sleep duration was obtained through a questionnaire derived from the national program for monitoring and intervention of common diseases and health influencing factors among students. This questionnaire was designed in alignment with the Canadian 24-hour movement guidelines for children and youth (5).

Participants meeting the behavioral recommendations were defined as those engaged in at least one hour of MVPA daily, less than or equal to two hours of daily screen time, and daily sleep duration of at least nine hours for junior high school students or eight hours for senior high school students. These

guidelines consider both Canadian and Chinese standards (6).

Covariates, including gender and school level, were gathered through the questionnaire, while geographical location was designated by administrative divisions.

Statistical analyses were performed utilizing SPSS 26.0 (web version 26.0; IBM, New York, USA) and R 4.2.3 (R Core, TeamVienna, Austria). Categorical variables were described using numbers and percentages, while the chi-square test was utilized to examine group differences. A multivariate logistic regression model was used to analyze the associations between depression and 24-hour movement behaviors, inclusive of subgroups and different combinations. All analyses were two-sided, with a P-value of less than 0.05 indicative of statistical significance. Visualizations were created using R.

Figure 1 illustrates the pattern and group variances in rates of depression. On the whole, the prevalence of depression was 29.1%, 32.2%, and 30.9% in the years 2019, 2020, and 2021, respectively, with significant differences observed in the distribution by sex, stage of schooling, and geographical location across the three years (all $P<0.05$). In particular, girls and senior high school students demonstrated significantly higher rates of depression compared to boys and juniors (2019: $\chi^2=254.16$, 298.28; 2020: $\chi^2=491.94$, 938.81;
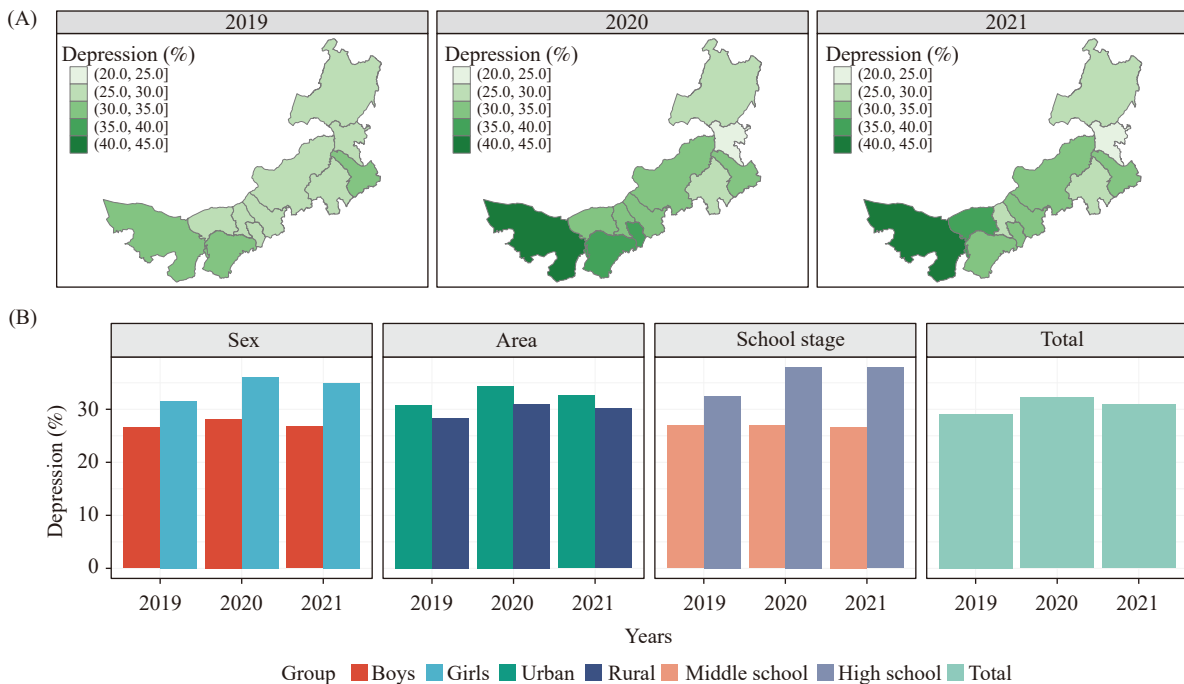

FIGURE 1. Trends and group differences in depression among adolescents aged 13–18 years in Inner Mongolia Autonomous Region, 2019–2021. (A) depression proportions of adolescents from 2019 to 2021; (B) sex, area, and school stage difference of adolescents' depression proportions.

2021: χ^2=676.89, 1197.56; all P<0.001). Regarding the geographical variation, rates of depression across 12 league cities in the Inner Mongolia Autonomous Region showed discrepancies, with a higher proportion of depressive symptoms found in the southwest. Furthermore, only 1.2%, 1.2%, and 2.3% of adolescents across the three years met all three recommended guidelines. Detailed characteristics of depression are presented in Supplementary Table S1 (available in https://weekly.chinacdc.cn/). Additionally, trends and group differences in 24-hour movement behaviors are depicted in Supplementary Figures S1 and S2 (available in https://weekly. chinacdc.cn/).

Figure 2 illustrates the differing distribution of depressive symptoms in adolescents in correlation with assorted 24-hour movement behaviors from 2019 to 2021. Generally, a higher adherence to guidelines saw a lower rate of depression (χ^2=2,735.56, P<0.001). Analyzing the data from a behavioral combination viewpoint, adolescents who adhered to the "screen+sleep" combination displayed the least rate of depression, while those who adhered to the "MVPA only" combination exhibited the highest. The proportion of depressive symptoms increased from 2019 to 2021 among adolescents adhering to the "MVPA only" and "screen only" combinations. Conversely, it decreased among adolescents adhering to the "screen+sleep" combination (χ^2=26.62, 44.60, 51.20, all P<0.05).

Figure 3 illustrates the correlations between depression and 24-hour movement behaviors from 2019 to 2021. There exists a dose-response relationship between the adherence to 24-hour movement guidelines and the prevalence of depression. When examining various combinations of the three behaviors, all combinations — with the exception of the "screen+sleep time" combination — were significantly correlated with an increased risk of depression. Notably, abiding by the "MVPA only" guidelines was associated with the highest risk. Correlations in subgroups defined by sex, school stage, and geographic location are detailed in Supplementary Table S2 (available in https://weekly.chinacdc.cn/). On the
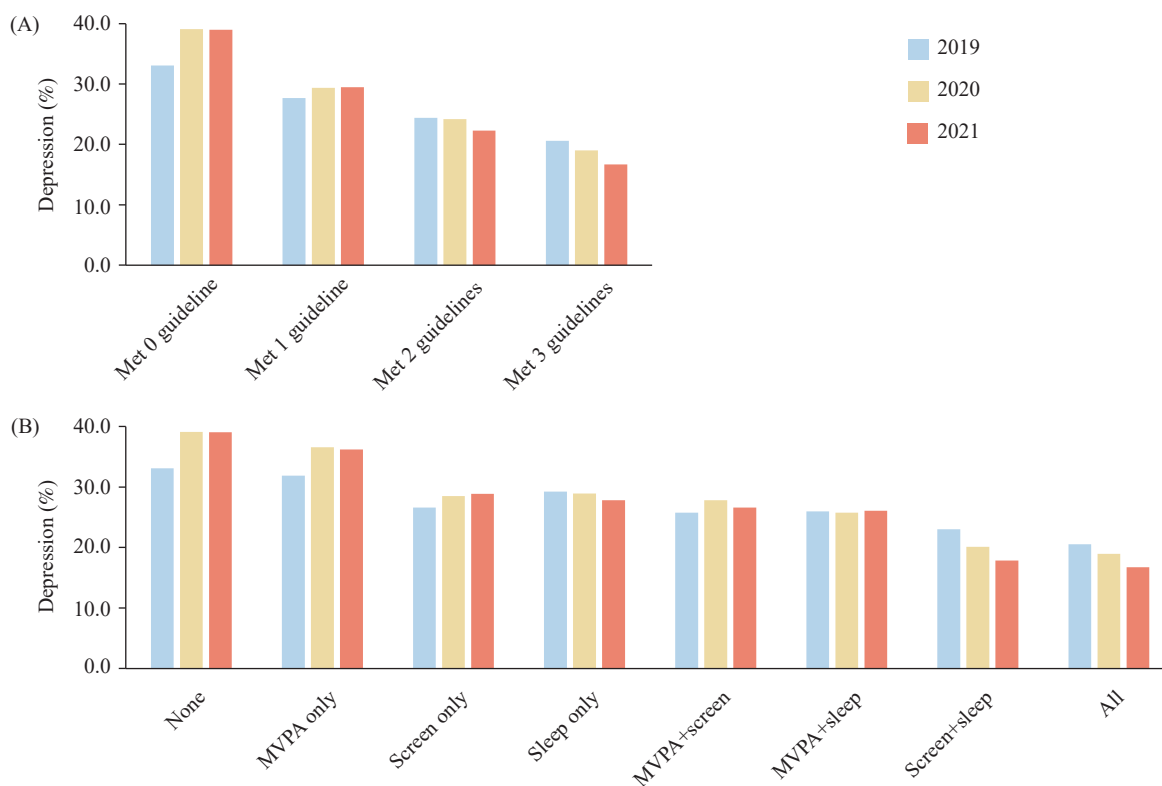

FIGURE 2. Distribution of depression among adolescents aged 13–18 years in Inner Mongolia Autonomous Region in relation to different 24-hour movement behaviors, 2019 to 2021. (A) adolescents' depression proportions with met different numbers of 24-hour movement behaviors guidelines; (B) adolescents' depression proportions with different combinations of 24-hour movement behaviors.
Abbreviation: MVPA=moderate to vigorous physical activity.

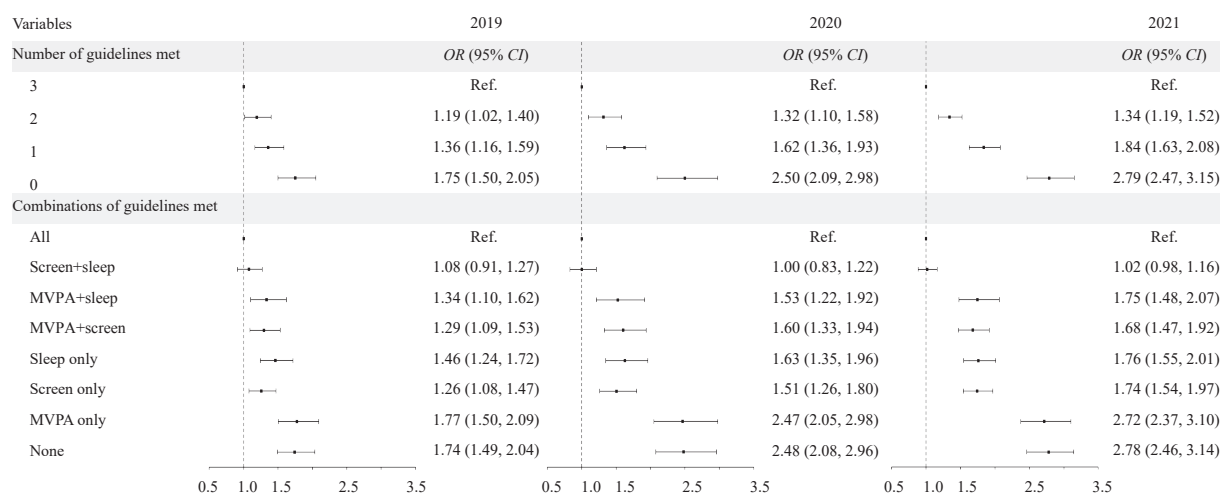| Variables	2019		2020		2021	
Number of guidelines met		OR (95% CI)		OR (95% CI)		OR (95% CI)
3		Ref.		Ref.		Ref.
2		1.19 (1.02, 1.40)		1.32 (1.10, 1.58)		1.34 (1.19, 1.52)
1		1.36 (1.16, 1.59)		1.62 (1.36, 1.93)		1.84 (1.63, 2.08)
0		1.75 (1.50, 2.05)		2.50 (2.09, 2.98)		2.79 (2.47, 3.15)
Combinations of guidelines met						
All		Ref.		Ref.		Ref.
Screen+sleep		1.08 (0.91, 1.27)		1.00 (0.83, 1.22)		1.02 (0.98, 1.16)
MVPA+sleep		1.34 (1.10, 1.62)		1.53 (1.22, 1.92)		1.75 (1.48, 2.07)
MVPA+screen		1.29 (1.09, 1.53)		1.60 (1.33, 1.94)		1.68 (1.47, 1.92)
Sleep only		1.46 (1.24, 1.72)		1.63 (1.35, 1.96)		1.76 (1.55, 2.01)
Screen only		1.26 (1.08, 1.47)		1.51 (1.26, 1.80)		1.74 (1.54, 1.97)
MVPA only		1.77 (1.50, 2.09)		2.47 (2.05, 2.98)		2.72 (2.37, 3.10)
None		1.74 (1.49, 2.04)		2.48 (2.08, 2.96)		2.78 (2.46, 3.14)

FIGURE 3. Association between combinations of 24-hour movement behaviors and depression among adolescents aged 13–18 years in Inner Mongolia Autonomous Region, 2019–2021.
Note: Adjusted for age, sex, school stage, and area.
Abbreviation: MVPA=moderate to vigorous physical activity; OR=odds ratio; CI=confidence interval.

whole, stronger associations were found between the quantity and combinations of 24-hour movement behaviors and depression among male and urban students.

DISCUSSION

In this study, we explored the cross-sectional associations among adolescents in Inner Mongolia from 2019 to 2021. The results indicated that: 1) the prevalence of depression was consistently high among school students throughout the three-year period, with an increase in 2020 followed by a decline in 2021; noteworthy disparities were observed between genders and across different school stages. 2) The current disposition of 24-hour movement behaviors among adolescents was relatively unsatisfactory. 3) The adherence to guidelines exhibited a dose-response relationship with the depression rates, with the conjunction of "sleep+screen time" in particular displaying the lowest risk associated with depression.

Our data revealed that approximately 30% of surveyed adolescents exhibited symptoms of depression, alongside an alarmingly low adherence rate to all three recommendations under examination in this study. These changes in depression rates align with the findings from a previous systematic review and meta-analysis of the impact of the COVID-19 pandemic on the mental health of children and adolescents. The study noted a significant escalation of anxiety and depressive symptoms in 2020, with a

subsequent decline, followed by a mild uptick during the second wave of the pandemic (7). Disturbingly, adherence levels to the 24-hour movement behavior recommendation were markedly lower than previous results (8). Compounded by pandemic-related restrictions, achieving the recommended minimum of one hour of MVPA daily proved to be the most challenging guideline for individuals to comply with. Our study also underlines gender and school-stage disparities in depression rates, confirming the vulnerability of these particular demographics. Girls typically exhibit higher rates of suicidal thoughts and behaviors (9), while senior school students confront greater academic pressures. Depression negatively affects academic performance, a repercussion that potentially extends into college; thus, there's an urgent necessity for heightened attention to the mental health of girls and students in advanced grades (10).

Our research uncovered correlations between failing to meet a greater number of behavioral recommendations and an increased risk of depression, underscoring the importance of holistic interventions for daily movement behaviors. In terms of specific combinations, our findings align with previous research (11), indicating that meeting recommendations for both screen time and sleep duration possesses more mental health benefits than solely adhering to the MVPA recommendations. This suggests that failure to meet either screen or sleep time recommendations may negate the benefits of exercise. Given the close links between social media use, sleep

disruption, and depression (*12*), our research recommends adherence to both screen time and sleep duration guidelines as a more effective approach to enhance adolescents' mental health, as opposed to solely focusing on physical activity interventions.

This study does present several limitations. First, our participant pool was sourced from surveillance data exclusive to the Inner Mongolia province in China. This could potentially confine the extent to which our findings can be generalized across the country. Second, the cross-sectional nature of the study prohibits us from establishing causality. Lastly, we gathered information on 24-hour movement behaviors via questionnaires as opposed to objective instruments, which likely led to some degrees of bias, particularly in relation to physical activity and screen time.

In conclusion, the prevalence of depression and adherence to the 24-hour movement guidelines was suboptimal among adolescents aged 13–18 years in Inner Mongolia from 2019 to 2021, highlighting the urgent need for attention and intervention. A dose-response relationship was observed between the number of guidelines met and the rate of depression. Furthermore, it was found that adhering to the "sleep+screen" combination could provide additional mental health benefits. Nevertheless, it remains critical to maintain all three healthy movement behaviors. Beyond the known benefits of physical activity, achieving recommended screen-viewing and sleep durations is also paramount in reducing depressive symptoms.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Characteristics and distribution of depression among adolescents aged 13–18 years in Inner Mongolia, 2019–2021 (*N*=238,440).

Characteristics	2019 (*N*=83,866)		2020 (*N*=67,998)		2021 (*N*=86,576)		x^2	*P* value[†]
	Total, *N* (%)	Depression, *n* (%)	Total, *N* (%)	Depression, *n* (%)	Total, *N* (%)	Depression, *n* (%)		
Sex							24.635	<0.001
Boy	41,309 (49.3)	10,984 (26.6)	33,575 (49.4)	9,447 (28.1)	42,887 (49.5)	11,473 (26.8)		
Girl	42,557 (50.7)	13,445 (31.6)	34,423 (50.6)	12,421 (36.1)	43,689 (50.5)	15,257 (34.9)		
School stage							756.29	<0.001
Junior high school	51,127 (61.0)	13,784 (27.0)	35,896 (52.8)	9,681 (27.0)	54,104 (62.5)	14,427 (26.7)		
Senior high school	32,739 (39.0)	10,645 (32.5)	32,102 (47.2)	12,187 (38.0)	32,472 (37.5)	12,303 (37.9)		
Area							124.31	<0.001
Urban	25,980 (31.0)	8,019 (30.9)	22,575 (33.2)	7,769 (34.4)	25,229 (29.1)	8,220 (32.6)		
Rural	57,886 (69.0)	16,410 (28.3)	45,423 (66.8)	14,099 (31.0)	61,347 (70.9)	18,510 (30.2)		
24-hour movement behaviors								
MVPA time ≥1 hour	11,136 (13.3)	3,100 (27.8)	9,382 (13.8)	2,843 (30.3)	13,977 (16.1)	3,968 (28.4)	16.455	<0.001
Screen time ≤2 hours	39,228 (46.8)	10,141 (25.9)	34,260 (50.4)	9,352 (27.3)	47,886 (50.9)	12,679 (26.5)	19.655	<0.001
Enough sleep time*	16,382 (19.5)	4,320 (26.4)	9,927 (14.6)	2,431 (24.5)	16,966 (19.6)	3,771 (22.2)	77.973	<0.001

* No less than 9 h for junior high school students and 8 h for senior high school students.
[†] Chi-square test results of the distribution of depression in different characteristics and three years.
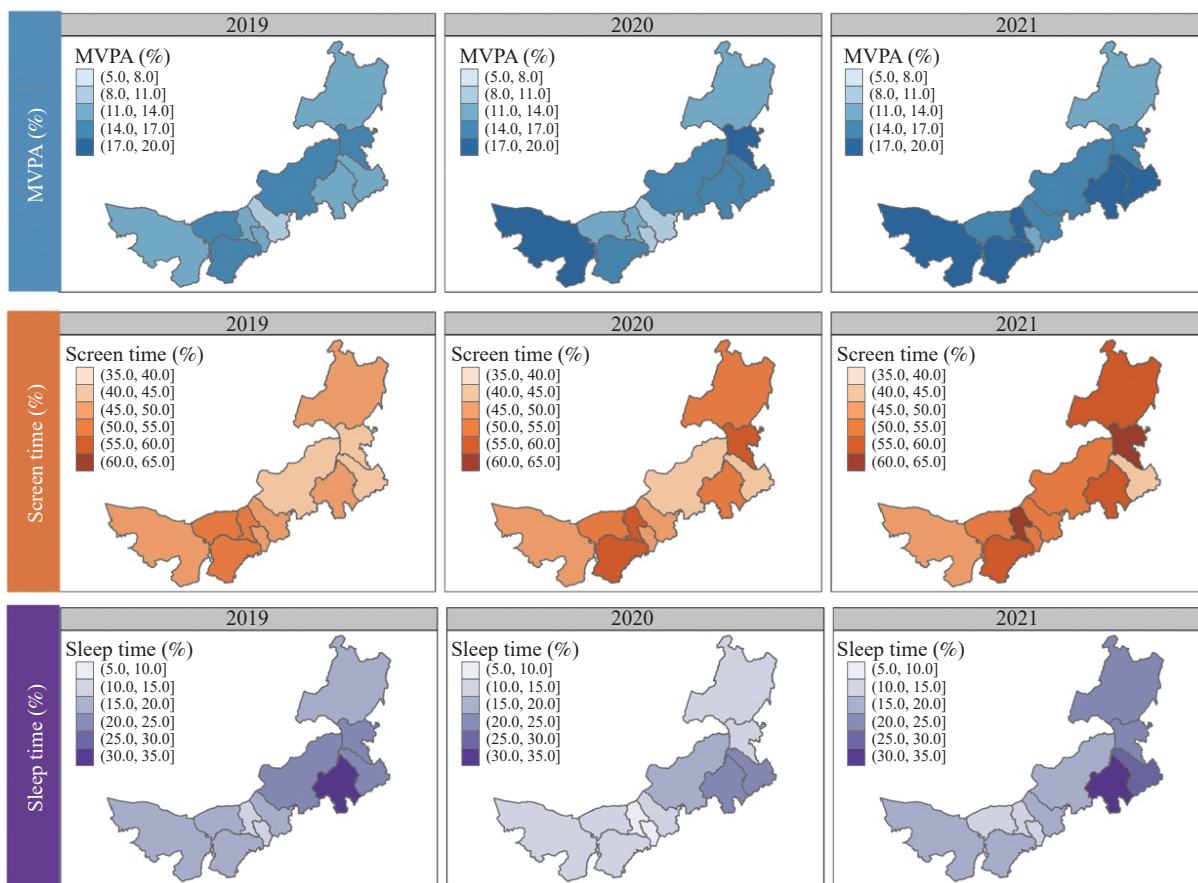Abbreviation: MVPA=moderate to vigorous physical activity.

SUPPLEMENTARY TABLE S2. Associations between combinations of 24-hour movement behaviors and depression in different subgroups of sex, area and gender among adolescents aged 13–18 years in Inner Mongolia, 2021 (N=86,576).

| Variables	Sex				Area				School stage			
	Boy		Girl		Urban		Rural		Middle school		High school	
	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)
Number of guidelines met												
3	Ref		Ref		Ref		Ref		Ref		Ref	
2	0.000	1.42 (1.20, 1.67)	0.019	1.26 (1.04, 1.53)	0.000	1.70 (1.29, 2.25)	0.001	1.26 (1.10, 1.45)	0.030	1.26 (1.02, 1.55)	0.000	1.40 (1.20, 1.64)
1	0.000	1.93 (1.65, 2.27)	0.000	1.81 (1.50, 2.18)	0.000	2.39 (1.82, 3.14)	0.000	1.75 (1.53, 2.00)	0.000	1.92 (1.57, 2.35)	0.000	1.83 (1.57, 2.13)
0	0.000	2.86 (2.44, 3.36)	0.000	2.84 (2.35, 3.44)	0.000	3.52 (2.68, 4.63)	0.000	2.73 (2.38, 3.13)	0.000	2.72 (2.22, 3.33)	0.000	2.98 (2.56, 3.47)
Combinations of guidelines met												
All	Ref		Ref		Ref		Ref		Ref		Ref	
Screen+sleep	0.655	1.04 (0.87, 1.25)	0.691	0.96 (0.78, 1.18)	0.099	1.28 (0.95, 1.73)	0.378	0.93 (0.80, 1.09)	0.373	1.08 (0.91, 1.28)	0.318	0.89 (0.72, 1.11)
MVPA+sleep	0.000	1.81 (1.47, 2.24)	0.001	1.60 (1.22, 2.10)	0.000	2.31 (1.63, 3.27)	0.000	1.60 (1.32, 1.94)	0.000	2.04 (1.65, 2.51)	0.043	1.33 (1.01, 1.76)
MVPA+screen	0.000	1.76 (1.48, 2.10)	0.000	1.67 (1.36, 2.05)	0.000	1.99 (1.49, 2.66)	0.000	1.68 (1.44, 1.95)	0.000	1.66 (1.40, 1.96)	0.000	1.81 (1.45, 2.26)
Sleep only	0.000	1.79 (1.51, 2.14)	0.000	1.69 (1.38, 2.07)	0.000	1.90 (1.42, 2.54)	0.000	1.73 (1.50, 2.01)	0.000	1.94 (1.65, 2.30)	0.000	1.53 (1.23, 1.90)
Screen only	0.000	1.80 (1.53, 2.12)	0.000	1.75 (1.45, 2.12)	0.000	2.35 (1.79, 3.10)	0.000	1.63 (1.42, 1.87)	0.000	1.64 (1.41, 1.91)	0.000	1.96 (1.60, 2.40)
MVPA only	0.000	2.84 (2.39, 3.38)	0.000	2.77 (2.24, 3.42)	0.000	3.41 (2.54, 4.56)	0.000	2.67 (2.30, 3.11)	0.000	3.09 (2.61, 3.65)	0.000	2.35 (1.88, 2.94)
None	0.000	2.86 (2.44, 3.36)	0.000	2.84 (2.35, 3.44)	0.000	3.51 (2.66, 4.61)	0.000	2.71 (2.37, 3.11)	0.000	2.96 (2.54, 3.45)	0.000	2.72 (2.22, 3.33)

Note: Adjust for age, sex, school stage and area.
Abbreviation: MVPA=moderate to vigorous physical activity.

SUPPLEMENTARY FIGURE S1. Distribution of MVPA, screen time, and sleep time in different cities among adolescents aged 13–18 years in Inner Mongolia, 2019–2021.
Abbreviation: MVPA=moderate to vigorous physical activity.
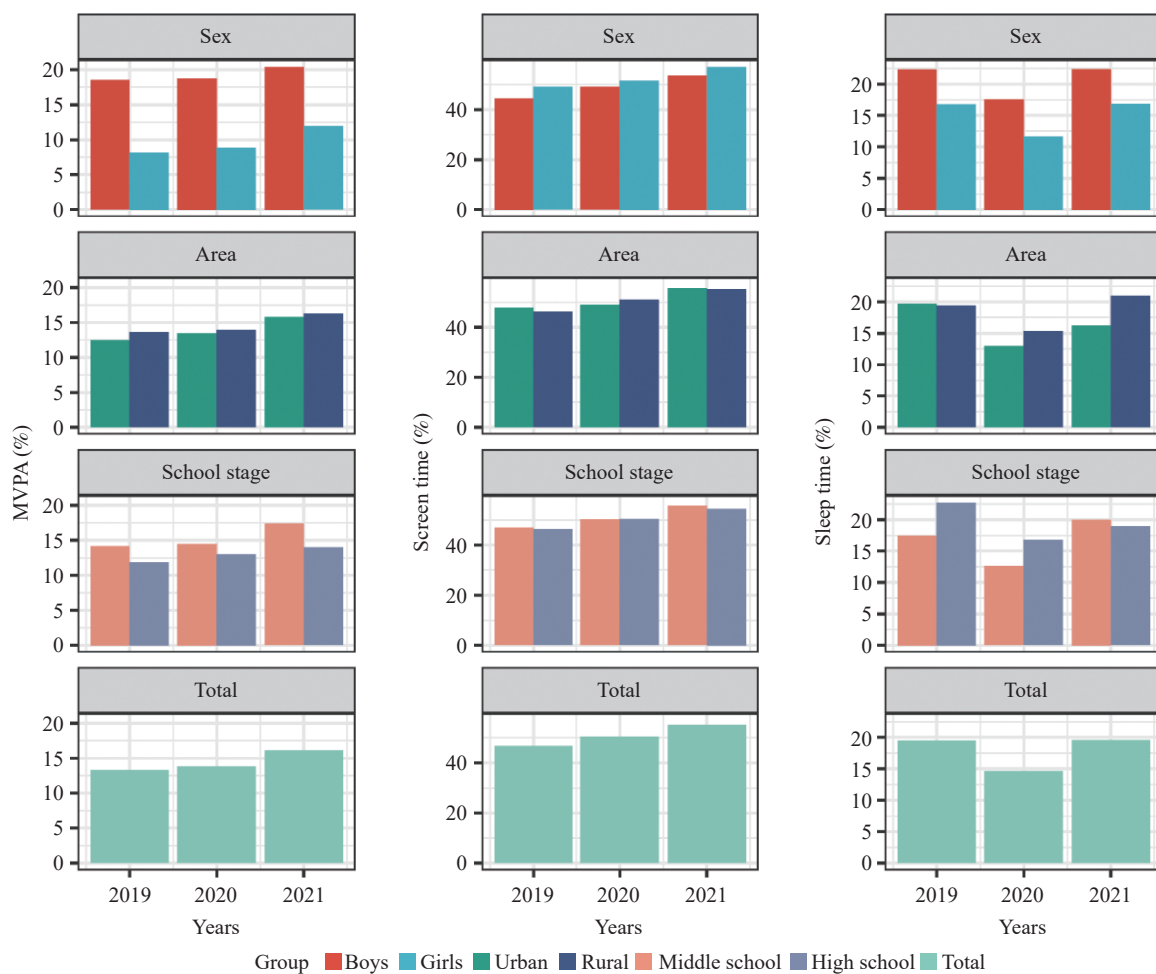
SUPPLEMENTARY FIGURE S2. Distribution of MVPA, screen time, and sleep time in different groups among adolescents aged 13–18 years in Inner Mongolia, 2019–2021.
Abbreviation: MVPA=moderate to vigorous physical activity.