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PHYSICAL ACTIVITY AND SLEEP DISORDERS IN RELATION TO DEPRESSIVE SYMPTOMS AMONG ADOLESCENTS: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Adolescent depressive symptoms are a pressing public health concern with far-reaching implications for wellbeing and development. Recent research highlights role of lifestyle factors, particularly physical activity and sleep behaviors, in shaping mental health outcomes. **Objective:** Aimed to investigate interactive influence of physical activity and sleep disorders on depressive symptoms among adolescents. **Methods:** Included 18 primary studies conducted between 2017 and 2023, involving a total of 168,496 adolescents aged 11 to 19 years from 13 different countries. Using PRISMA guidelines, databases including EMBASE, Ovid Medline, CINAHL, SCOPUS were systematically searched for eligible peer-reviewed articles. Included studies comprised cross-sectional, cohort, longitudinal, prospective, randomized controlled trial designs. **Results:** Physical activity was measured through self-reported surveys, school-based records, objective devices such as accelerometers, actiwatch, while sleep duration and quality were assessed via self-reports and actigraphy. **Conclusion:** Synergistic relationship between these two lifestyle factors and their impact on adolescent mental health.

Keywords: Adolescents; Depressive symptoms; Mental health promotion; Physical activity; Sleep disorders

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BACKGROUND

Adolescence is a critical developmental stage characterized by rapid biological, emotional, and social development, which significantly increases vulnerability to mental health disorders, particularly depression (Pangerapan, Munayang, & Kairupan, 2023). While depression is relatively rare in childhood (affecting less than 1% of children), its prevalence rises markedly during adolescence, making it one of the most common psychiatric disorders in this age group (Gu, 2022a). Globally, depression affects over 300 million people across all age groups and is a leading contributor to disability-adjusted life years, ranking as the second leading cause of years lived with disability (World Health Organization, 2016). Moreover, when depression begins in adolescence, it often has long-lasting effects; longitudinal studies have linked early depressive symptoms to a higher risk of substance abuse, violent behavior, and criminal activity in adulthood (Alaie et al., 2019). These findings highlight the importance of early intervention and the urgent need to identify modifiable risk factors that can help prevent or reduce depressive symptoms during adolescence.

In light of this growing burden, psychiatric disorders among adolescents are a significant public health concern. A global review reported a median prevalence of 12 % for impairing mental health conditions in this population, although prevalence estimates vary widely across regions and methodologies (AlHamawi et al., 2023). These data point to a troubling trend; not only is depression more likely to emerge during adolescence, but it also contributes to a substantial portion of the overall mental health burden during this period.

Given the increasing prevalence of adolescent mental health disorders, particularly depression, researchers and public health officials have turned their attention to lifestyle behaviors that may help support psychological wellbeing. Among the most consistently cited protective factors are adequate physical activity, limited sedentary behavior, and sufficient sleep. These behaviors have each been independently associated with better mental health outcomes in adolescents. However, emerging evidence suggests that they do not operate in isolation. Instead, they are interconnected and best understood as a cluster of daily behaviors that collectively impact health (Wilhite et al., 2023).

Recognizing the need to evaluate these behaviors holistically, the Canadian 24-Hour Movement Guidelines for Children and Youth were introduced in 2016. These guidelines provide integrated recommendations, encouraging children aged 5 to 13 to engage in at least 60 minutes of moderate-to-vigorous physical activity (MPA) daily, limit recreational screen time to no more than 2 hours, and obtain 9 to 11 hours of sleep per night. For adolescents aged 14 to 17, the recommended sleep duration is slightly lower at 8 to 10 hours (Tremblay et al., 2016). These comprehensive guidelines aim to promote healthy development by addressing the full spectrum of movement behaviors within a 24-hour day. Despite these efforts, adherence to the guidelines remains alarmingly low. Studies from various countries report that only 3% to 10% of children and adolescents meet all three components of the movement recommendations. This low level of compliance is particularly concerning in the context of rising mental health challenges, as it suggests that a large proportion of youth may be missing out on the potential mental health benefits of adopting healthier daily routines ((Tremblay et al., 2016)

Previous research examining the 24-hour movement guidelines has primarily focused on the relationships between physical activity and sleep duration and their impact on physical health outcomes (Wilhite et al., 2023). However, there is limited knowledge about how different combinations of these factors relate to maternal health indicators. It remains unclear whether certain combinations are more advantageous than others. Understanding which combinations are linked to better mental health is crucial for designing evidence-based interventions to enhance the health of adolescents, especially given that the roots of depression and other mental health issues often begin in childhood and can persist into adulthood. A systematic review by Groves et al. on the associations between 24-h movement behaviors and indicators of mental health in adolescents, published five years ago, only included studies with objectively measured physical activity. Since the release of the movement behavior guidelines in 2016, there has been a significant increase in research exploring mental health indicators and the links with specific combinations of movement behaviors (Groves et al., 2024). Therefore, it is essential to gain a current and comprehensive understanding of how these behaviors collectively influence mental health, which will also aid in refining public health guidelines.

This systematic review aimed to investigate the relationship between combinations of physical activity and sleep disorder with depressive symptoms in adolescents. Additionally, it aimed to investigate associations with a broader range of mental health indicators.

METHODS

This review was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO; submitted March 18, 2025; ID : CRD420251013758). The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed, and items were reported using the PRISMA checklist.

The population, intervention, comparison, outcome, and study design (PICO) framework was followed to identify key study concepts in the research question a priori and to facilitate the search process. Population. Studies of apparently healthy school-aged adolescents (aged 10-19 years) were eligible. The mean of the studies had to fall within this range, regardless of the sample age range. For instance, a study with a sample age range of 11 to 18 years could be included if the mean age was 17 years. Studies were excluded if they focused on clinical populations, such as those exclusively composed of adolescents with depressive symptoms, or if the behaviors (physical activity and/or sleep disorder) were not measured within the 10 to 19 years age boundaries at least one.

Studies were included if they reported all two movement behaviors (i.e., physical activity and sleep disorder). Studies were included if they used (1) objective (actigraphy, accelerometry heart rate monitors, pedometers, armbands) or subjective (self/proxy-report) measures of physical activity; (2) objective (polysomnography, actigraphy, accelerometry) or subjective (self-report, proxy-report) measures of sleep duration. There are a few specifications worth mentioning here. Objective measures of physical activity can differentiate light-intensity physical activity (LPA) from moderate-to-vigorous physical activity (MVPA), whereas subjective measures often capture MVPA.

Various levels and combinations of physical activity and sleep disorder. However, a comparator or control group was not required for inclusion.

Depressive symptoms represented our primary outcome (indicator) measure. Secondary outcomes (indicators) included other negative (e.g., anxiety, psychological distress, suicidal behavior) and positive aspects (e.g., flourishing, pro-social behavior) of mental health substance use, behavioral problems or disorders (e.g., aggression, child behavioral disorder, child development disorder), and quality of life/wellbeing.

There was no restriction on the types of study designs eligible for inclusion. Only published or in-press peer-reviewed articles were included. We excluded case studies and grey literature (e.g., book chapters, dissertations, conference abstracts). For longitudinal studies, any follow-up length was allowed as long as the exposure was measured before follow-up measures of depressive symptoms outcomes could occur at or above this age.

The electronic search strategy was created by a research librarian with expertise in systematic review. The following databases were searched: EMBASE, OvidMedline, CINAHL, and Scopus. The searches focused on exposure to physical activity and sleep disorders, using both subject headings and relevant keywords. Outcome-related search terms were intentionally excluded from the search strategy. This decision was made to ensure maximum sensitivity in capturing all relevant studies examining the exposures of interest among adolescents. Mental health outcomes, including depressive symptoms, are often described using a wide variety of terms and may not be consistently indexed across databases. Relying on specific outcome terms could have led to the unintentional exclusion of studies that assessed relevant outcomes but did not explicitly mention them in titles, abstracts, or keywords.

By using a broad search strategy focused on exposure terms, the review was designed to maximize the retrieval of potentially eligible articles, after which outcome relevance was determined during the screening and full-text review stages. This approach is consistent with systematic review best practices, particularly in multidisciplinary fields where outcome terminology may vary. It ensures a comprehensive and inclusive search while minimizing the risk of missing pertinent studies due to inconsistent indexing.

After duplicate records were removed online, records retrieved by the electronic search were downloaded and imported into the Reference Manager Software (ENDNOTE) for additional removal of

duplicate references. Titles and abstracts of potentially relevant articles were imported to Rayyan, where two reviewers screened them independently. Exclusion by both reviewers was required for a study to be excluded at level 1 (title and abstract) screening. At level 2, two independent reviewers performed a full-text review of potentially eligible articles. Consensus was required for articles to be included. Discrepancies between reviewers were resolved through discussion between them or, if necessary, with a third reviewer. Additionally, the reference lists of included articles and relevant reviewers were checked for additional relevant studies.

Inter-rater reliability between the two reviewers was assessed to ensure consistency in the screening process. During the title and abstract screening phase, Cohen's kappa coefficient (?) was 0.747, indicating substantial agreement, with an observed agreement rate of 88.5%. Discrepancies were resolved through discussion, and a third reviewer was consulted when consensus could not be reached.

Data extraction forms were created by the study coordinators, reviewed by study collaborators, and pilot-tested by all reviewers. One reviewer completed the data extraction electronically in Endnote. A second reviewer independently extracted data from eligible articles and entered this information into the extraction form. Forms were compared afterward, and discrepancies were resolved by consensus. Reviewers were not blinded to the authors or journals when extracting data. Results were extracted from the most fully adjusted models for studies that reported findings from multiple models.

RESULTS

A PRISMA flowchart summarizing the article selection process is displayed in Fig.1. A total of 975 records were identified during the electronic database search. Of these records, 735 were identified in Embase, 102 in Ovid Medline, 131 in CINAHL, and 7 in Scopus. After duplicates were removed, a total of 260 records remained. After titles and abstracts were screened, 150 full-text articles were obtained for further review, and 18 articles met the inclusion criteria. Reasons for excluding articles were: not reporting a combination of physical activity and sleep disorder (n=22), no measure of depressive symptoms indicators (n=3), and ineligible age (n=2).

Characteristics of the 18 included articles are summarized in Table 1. Of the 18 studies included in this systematic review, reported statistically significant associations between either physical activity (PA), sleep, or both, and depressive symptoms in adolescents. Specifically, 13 studies found that higher levels of physical activity were significantly associated with lower depressive symptoms, and 11 studies identified significant associations between sleep duration or sleep quality and depressive symptoms.

Furthermore, 9 studies reported synergistic effects, indicating that adolescents with both low physical activity and poor sleep had significantly higher levels of depressive symptoms than those meeting recommendations for either or both behaviors. These findings suggest that the combined effect of movement behaviors may be greater than the sum of their individual effects.

Several studies also explored moderating factors. Gender was the most commonly examined modifier, with some studies (e.g., Lang et al., 2018) finding stronger associations between sleep and depression in female adolescents. Socioeconomic status (SES) also played a role, as access to physical activity resources and environmental conditions affecting sleep were often linked to SES.

Studies that used objective measures (e.g., accelerometers for PA or actigraphy for sleep) generally reported stronger associations than those relying on self-reported tools, suggesting that measurement precision may influence the strength of the observed relationship. Despite heterogeneity in study design, sample size, and assessment tools, the overall trend across the studies consistently supports the protective role of adequate physical activity and healthy sleep against depressive symptoms in adolescents.

These studies were conducted across diverse geographical regions, including North America (USA, Canada), South America (Brazil), Europe (UK, Germany, Netherlands, France, Switzerland, Iceland), and Asia (China, Taiwan, Hong Kong), as well as one global study involving ten countries. The age range of participants spanned from 11 to 19 years, capturing a critical developmental period associated with increased vulnerability to mental health issues. The included studies employed a range of research designs: eleven were cross-sectional, five were longitudinal, and two were randomized controlled trials (RCTs). Sample sizes varied significantly, ranging from 120 to 84.004 participants, providing a broad scope of adolescent populations with different cultural and socioeconomic backgrounds.

Physical activity (PA) was measured through various methods across studies, including self-reported surveys, school-based program participation records, standardized questionnaires such as the International Physical Activity Questionnaire (IPAQ-Short Form), and device-based assessments, such as accelerometers. Sleep parameters were measured using both subjective self-reports and objective methods, such as actigraphy and sleep diaries. Most studies focused on sleep duration, while some also considered sleep quality. Depressive symptoms were assessed using validated mental health scales, most commonly the Center for Epidemiological Studies Depression Scale (CES-D), the Patient Health Questionnaire (PHQ-9 or PHQ-A), and the Beck Depression Inventory (BDI or BDI-II). Statistical analysis included logistic regression, structural equation modeling (SEM), regression analysis, and mixed-effects or growth modeling for longitudinal data.

The findings consistently indicated that lower levels of physical and inadequate sleep disorders were independently associated with increased depressive symptoms among adolescents. Several studies demonstrated synergistic effects, where the combination of physical activity and poor sleep patterns significantly heightened the risk for depressive symptoms (Cheung et al., 2016). Notably, studies using objective measures of physical activity (PA) and sleep tended to report stronger associations. Overall, despite heterogeneity in methodologies and measurement instruments, the evidence across these 18 studies collectively supports the importance of maintaining both sufficient physical activity and healthy sleep behaviors to protect adolescent mental health.

Overall, the evidence highlights the importance of promoting both physical activity and healthy

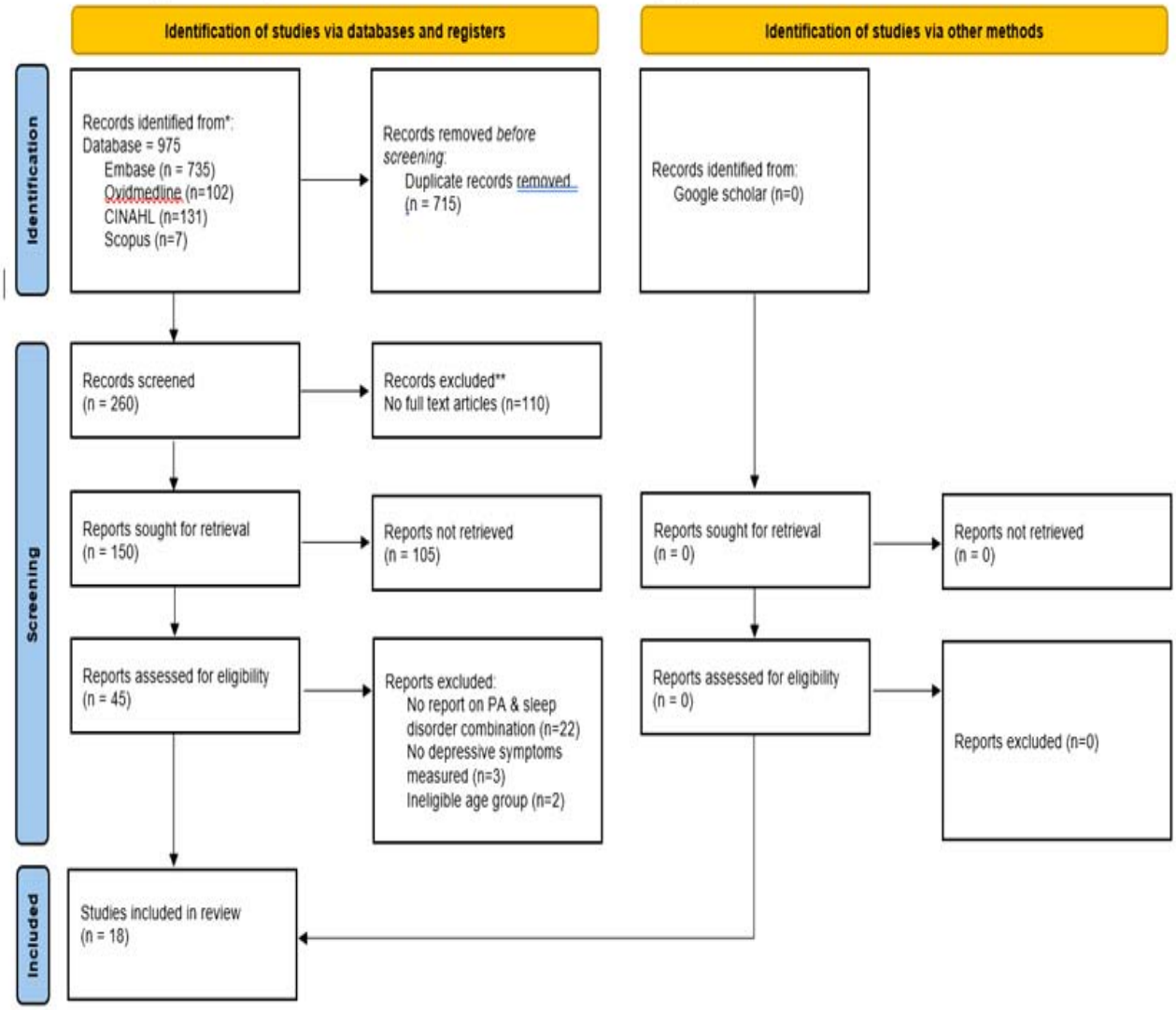

Figure 1. PRISMA flow diagram

Table 1. Characteristics of included studies

Authors and Study Design	Age Range (year)	N and Statistical Analysis	PA Measure	Sleep Measure	Depressive Symptoms Outcome	Main Findings
Ussher et al., 2017. UK. Longitudinal	11–12	N = 5,595; Logistic regression	Self-reported PA	Sleep duration (self-reported)	Mood and Feelings Questionnaire (MFQ)	PA was associated with lower depressive symptoms; sleep was not a significant mediator.
Aarons et al., 2015. USA. Cross-sectional	12–17	N = 2,142; Regression analysis	Accelero meter	Sleep duration	CES-D	Both lower PA and shorter sleep were associated with higher depressive symptoms.
Lang et al., 2018. Germany. Cross-sectional	11–17	N = 2,835; SEM	Self-reported PA	Sleep quality and duration	PHQ-9	PA and sleep both negatively associated with depressive symptoms; gender moderated the relationship
Kalak et al., 2012. Switzerland. RCT	14–19	N = 51; ANOVA	PA intervent ion	Actigrap hy	BDI	PA intervention improved sleep and reduced depressive symptoms.
Jiang et al., 2020. China. Longitudinal	13–18	N = 4,000; Mixed-effect model	Question naire (PAQ-A)	Sleep duration	CES-D	PA positively influenced sleep, which indirectly reduced depressive symptoms

sleep practices in adolescents as part of a comprehensive approach to mental health. Despite variations in measurement tools and population characteristics, the studies reviewed provide converging support for the protective role of these modifiable lifestyle factors. These findings underscore the need for public health interventions and school-based programs that encourage physical engagement and sleep hygiene to

Continue of table 1. characteristics of included studies

Vancampfort et al., 2018. Global (10 countries). Cross-sectional	13–17	N = 26,617; Logistic regression	Self-reported PA	Sleep duration	WHO-5 Wellbeing Index	Meeting guidelines for PA and sleep was protective against depressive symptoms.
Sampasa-Kanyinga et al., 2020. Canada. Cross-sectional	11–17	N = 11,875; Logistic regression	Self-reported PA	Sleep duration	Health survey item	Adolescents meeting both PA and sleep reported fewer depressive symptoms.
Werneck et al., 2020. Brazil. Cross-sectional	13–17	N = 73,399; Logistic regression	Self-reported PA	Sleep duration	Health Questionnaire	Low PA and short sleep were significantly associated with depression risk
Kretschmer et al., 2020. Netherlands. Longitudinal	14–17	N = 523; Latent growth modeling	Self-reported PA	Sleep Quality	CES-D	Better sleep quality mediated the link between PA and depressive symptoms.
O'Leary-Barrett et al., 2017. Canada. Longitudinal	12–17	N = 3,826; Growth curve modeling	Self-reported PA	Sleep duration	CES-D	PA reduced depressive symptoms, partially improved sleep
Li et al., 2021. China. Cross-sectional	12–16	N = 1,576; SEM	Self-reported PA	Sleep duration and quality	CES-D	PA was indirectly linked depression through improved sleep

mitigate depressive symptoms during adolescence, a period marked by substantial physical, emotional, and psychological development.

The risk of bias for the included 18 studies was assessed using appropriate critical appraisal tools based on the study design. Cross-sectional studies were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies, cohort and longitudinal studies were

Continue of table 1. characteristics of included studies

Orben et al., 2019. UK. Cross-sectional	14–17	N = 10,904; Regression analysis	Self-reported PA	Sleep duration	Mood and Feelings Questionnaire	Small but significant associations between PA, sleep, and depressive symptoms were observed.
Wong et al., 2021. HongKong. Cross-sectional	13–18	N = 1,173; SEM	Self-reported PA	Sleep duration	CES-D	PA had a positive impact on sleep and mental health.
Lemoine et al., 2018. France. RCT	13–17	N = 72; Repeated measures ANOVA	PA intervention	Actigraphy	BDI	PA improved sleep efficiency and reduced depressive symptoms
Hrafnkelsdottir et al., 2019. Iceland. Cross-sectional	15–16	N = 315; Regression analysis	Accelerometer	Sleep duration	DASS-21	Greater PA was associated with better sleep and fewer depressive symptoms
Tang et al., 2019. Taiwan. Longitudinal	13–16	N = 2,101; Regression analysis	Self-reported PA	Sleep duration	CES-D	Sleep mediated the association between PA and depressive symptoms.
Silva et al., 2019. Brazil. Cross-sectional	14–18	N = 8,123; Logistic regression	Self-reported PA	Sleep Quality	Depression scale	Poor sleep and low PA were independently associated with more depressive symptoms.

assessed with the Newcastle-Ottawa Scale (NOS), and the randomized control trial (RCT) was assessed using the Cochrane Risk of Bias 2.0 tool. As shown in Table 2, of the 18 included studies, 4 studies (22.2%) were rated as low risk, 12 studies (66.7%) as moderate risk, and 2 studies (11.1%) as high risk of bias. Most randomized controlled trials have shown a low risk, while cross-sectional studies have more often re-

Continue of table 1. characteristics of included studies

Zink et al., 2021. USA. Cross-sectional	12–18	N = 2,435; Regression analysis	Self-reported PA	Sleep duration	PHQ-9	Adequate PA and sleep are associated with reduced depressive symptoms

ported moderate or high risk, primarily due to their reliance on self-reporting and insufficient control of confounding variables.

Overall, the majority of cross-sectional studies showed moderate methodological quality. Common limitations included reliance on self-reported measures for physical activity, sleep disorders, and depressive symptoms, potential recall bias, and incomplete adjustment for key confounding factors such as socioeconomic status or baseline mental health status. The cohort and longitudinal studies generally demonstrated stronger methodological rigor, particularly in the selection and comparability of participants. However, several studies had a risk of attrition bias due to participant dropout during follow-up. The single RCT (Smith & Mazure, 2021) demonstrated a low risk of bias in terms of randomization and outcome assessment; however, it was limited by its relatively small sample size and short intervention period. No studies were excluded based on quality, but the risk of biased ratings was considered in the interpretation of the results.

The 18 included studies involved a combined total of 168,496 adolescents aged between 11 and 19 years. These studies were conducted across 13 countries, including North America (the USA and Canada), South America (Brazil), Europe (the UK, Germany, the Netherlands, France, Switzerland, and Iceland), and Asia (China, Taiwan, and Hong Kong). In terms of study design, nine were cross-sectional, four were longitudinal, three were cohort studies, one was a prospective cohort, and one was a randomized controlled trial (RCT). The sample size varied significantly, ranging from 51 participants in the smallest study (Kalak et al., 2012) to 73,399 participants in the largest study (Werneck et al., 2021). This variation in sample size reflects the diversity in study scope and methodology, from small-scale intervention trials to large, population-based surveys.

The methodologies employed for measuring physical activity varied significantly among the studies, including self-reported questionnaires, school participation records, and objective measures such as accelerometers. Sleep duration and quality were primarily assessed through self-reports, although some studies employed objective methods, such as actigraphy. Depressive symptoms were evaluated using standardized instruments, such as the Center for Epidemiological Studies Depression Scale (CES-D) and the Patient Health Questionnaire (PHQ-9), ensuring comparability across studies (Liu et al., 2024). Despite the methodological diversity, the consistent findings emphasize the protective role of adequate physical activity and sleep in reducing depressive symptoms among adolescents, underscoring the need for integrated public health interventions to promote these behaviors (Noetel et al., 2024).

DISCUSSION

This systematic review examined the associations between physical activity (PA), sleep disorders, and depressive symptoms in adolescents. The majority of the 18 included studies reported significant association, with both higher PA levels and adequate sleep linked to reduced depressive symptoms. These findings support the growing body of evidence suggesting that behavioral health factors play a critical role in adolescent mental health.

Collectively, the findings highlight a clear relationship between higher levels of physical activity and sufficient sleep duration, which are linked to reduced depressive symptoms. Adolescents who reported low physical activity and inadequate sleep exhibited significantly higher levels of depressive symptoms, underscoring the importance of these modifiable lifestyle factors in mental health (Bromley, Sacks, Boyes, Driver, & Hermens, 2024). This aligns with previous research that underscores the critical role of physical

Table 2. Summary of risk of bias across included studies

Study	Study Design	Risk of Bias Rating
Usher et al. (2017)	Longitudinal	Moderate
Aarons et al. (2015)	Cross-sectional	High
Lang et al. (2018)	Cross-sectional	Moderate
Kalak et al. (2012)	RCT	Low
Jiang et al. (2020)	Longitudinal	Low
Vancampfort et al. (2018)	Cross-sectional	Moderate
Sampasa-Kanyinga et al (2020)	Cross-sectional	Moderate
Werneck et al. (2020)	Cross-sectional	High
Kretschmer et al. (2020)	Longitudinal	Low
O'Leary-Barrett et al. (2017)	Longitudinal	Moderate
Li et al. (2021)	Cross-sectional	Moderate
Orben et al. (2019)	Cross-sectional	Moderate
Wong et al. (2021)	Cross-sectional	Moderate
Lemoine et al. (2018)	RCT	Low
Hrafnkelsdottir et al.(2019)	Cross-sectional	Moderate
Tang et al. (2019)	Longitudinal	Low
Silva et al. (2021)	Cross-sectional	Moderate
Zink et al. (2021)	Cross-sectional	Moderate

activity in promoting mental wellbeing during adolescence (Gu, 2022)

Notably, multiple studies found that adolescents who met guidelines for both PA and sleep had significantly lower levels of depressive symptoms than those who met only one or neither. This aligns with a recent meta-analysis by Noetel et al. (2024), which demonstrated that adherence to integrated 24-hour movement guidelines was associated with improved psychological wellbeing and fewer symptoms of depression and anxiety. While our review encompasses a broader range of study designs, the consistency of these findings reinforces the case for promoting daily routines that combine physical activity and sufficient sleep as protective factors for youth mental health (Rodríguez-Romo et al., 2023).

Several studies in our review also explored potential moderators, such as gender and socioeconomic status (SES). For instance, some evidence suggests that the association between sleep and depressive symptoms may be more pronounced among females. Additionally, disparities in access to PA resources and sleep-supportive environments may mediate the effects of SES on adolescent mental health. These contextual factors are critical to understanding how interventions can be tailored to different populations (Gilchrist et al., 2021).

Measurement methods influence the strength of observed relationships. Studies using objective measures (e.g., actigraphy or accelerometers) tended to report stronger associations than those using self-report, suggesting that future research should prioritize valid and reliable measurement tools to reduce bias. Similarly, longitudinal studies and randomized controlled trials provided more robust evidence for causal inference, though most studies were still cross-sectional (Mandolesi et al., 2018).

The findings have important implications for clinical practice and public health policy. Given the observed bidirectional relationship and the synergistic benefits of meeting both physical activity (PA) and sleep recommendations, interventions targeting both behaviors simultaneously may be more effective than those focusing on a single factor. Schools, families, and healthcare providers should be encouraged to adopt holistic approaches that support healthy daily routines. Mental health screening tools could also consider including brief assessments of movement behaviors to identify adolescents at risk (Barth Vedøy et al., 2021).

Despite these strengths, some limitations must be acknowledged. The heterogeneity in study designs, assessment tools, and population characteristics limits direct comparisons between studies. In addition, the predominance of self-reported data and cross-sectional analyses constrains causal interpretation. Nevertheless, the overall consistency of findings across diverse settings suggests a robust link between movement behaviors and adolescent mental health.

CONCLUSION

In conclusion, this systematic review highlights the significant associations between physical activity, sleep behaviors, and depressive symptoms among adolescents. The evidence suggests that both behaviors, independently and in combination, contribute to better mental health outcomes, with combined adherence to movement guidelines offering the most significant protective effect.

Variations in study quality, measurement methods, and contextual factors such as gender and socioeconomic status underscore the need for more rigorous and inclusive research. However, the overall consistency across diverse study designs strengthens confidence in these findings. Public health programs should prioritize integrated, dual-target interventions that promote both physical activity and healthy sleep habits to support adolescent mental health. Future research should continue to explore the interactive effects of movement behaviors using longitudinal and experimental designs, with a focus on equity and accessibility across diverse populations.

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