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Associations between physical activity and mental well-being among adolescents in the Danish health behaviour in school-aged children study

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Abstract

Objectives: There has been increasing global attention on the rise of negative mental health among adolescents. Much research has examined the relationship between negative mental health states and physical activity (PA) among adolescents. However, the association between positive mental health states (e.g. mental well-being), and PA has not been as extensively investigated. This study aimed to investigate the association between PA and mental well-being in adolescents and whether sex moderated the association.

Methods: Data stem from a Danish nationally representative sample of 3,732 adolescents aged 13 and 15 from the 2022 cross-sectional Health Behaviour in School-aged Children study. PA was assessed using two measures: meeting the guidelines of 60-min daily moderate-to-vigorous PA (MVPA) and time spent on leisure time vigorous PA (VPA). Mental well-being was assessed using the SWEMWBS scale. Logistic regression analyses were conducted.

Results: Our findings show significant positive associations between different measures for PA and mental well-being. The strongest association was found for meeting the MVPA guidelines. Adolescents who met the MVPA guidelines were more likely to report high mental well-being (OR=2.01, 95% CI: 1.61–2.52). There was also a positive association between the other PA measures, however the positive association was lower with more VPA included in the exposure. The relationship between PA and mental well-being was not moderated by sex.

Conclusions: The results indicate that PA may be beneficial for mental well-being among adolescents. Further research

is needed to understand the causal relation and mechanisms involved in the association.

Keywords: mental health; exercise; teenager; HBSC; SWEMWBS

Introduction

The mental health among adolescents in western countries has deteriorated in recent years and is an increasing public health concern [1]. Several factors have been proposed to contribute to this trend, including increasing schoolwork pressure, increased social media use, sleep problems, and broader societal uncertainties that may place additional stress on young people [2–4]. Furthermore, mental well-being and life satisfaction are lower among older adolescents compared to younger adolescents, and girls' mental health is generally worse than boys' mental health at this developmental stage [1]. An early onset of mental health problems is associated with poor mental and physical health in adulthood [5–7]. Thus, improving the mental health and well-being of adolescents and young people is a priority in the WHO European Framework for action on mental health 2021–2025 [8]. To strengthen prevention efforts, it is essential to identify modifiable factors that can protect adolescents' mental health and support the development of effective interventions. Physical activity (PA) is one such modifiable behavior and plays an important role.

Physical activity (PA) plays an important role in promoting mental health across the lifespan, extending beyond the prevention of mental health disorders. Mental health encompasses more than the absence of illness, as illustrated by findings from Santini et al. [9], who show that symptoms of depression explain only 25% of the variation in mental well-being in the general Danish population. This highlights the need to focus on positive dimensions of mental health when designing public health strategies. In this regard, PA is positively associated with a range of indicators of positive mental health, including self-esteem [10, 11], psychological well-being [12, 13], socioemotional outcomes [14], and quality of life [15, 16]. In addition to these broader benefits, PA also protects against the development of depressive symptoms

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among adolescents [13, 16–18] and contributes to the prevention of depression in early adulthood [19]. Molcho et al. [12] find a positive association between PA and mental health among adolescents in a cross-sectional study based on data from the Irish Health Behaviour in School-aged Children (HBSC) survey. Mental health is measured through the Mental Health Inventory (MHI-5), a well-being index that measures positive mental health, and the study shows a positive association between mental well-being and PA for both moderate to vigorous PA (MVPA) and vigorous PA (VPA) outside of school, with the strongest association observed for VPA outside of school. Evidence regarding sex differences in the association between physical activity (PA) and mental health is mixed. Some studies report stronger associations for girls than for boys, suggesting that girls may experience greater mental health benefits from PA [12]. In contrast, other studies find no significant sex differences, indicating that PA may be similarly beneficial for mental health among both girls and boys [11, 20]. Overall, these inconsistent findings highlight the lack of consensus in the literature and underscore the importance of further research to clarify whether sex moderates the relationship between PA and mental health. Alshallal et al. [21] find a small positive association between PA and mental health among English adolescents in a school-based study. In the study PA was measured using accelerometers, and mental health was assessed as mental well-being through the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) [22]. A further challenge lies in how mental well-being is conceptualized and measured. Studies vary widely in the instruments they use, and relatively few employ comprehensive measures that capture both hedonic (emotional, pleasure-related) and eudaimonic (meaning- and purpose-related) components. Most research on positive mental health emphasizes the hedonic dimension focusing on positive emotions and life satisfaction while the eudaimonic dimension, which encompasses meaning, purpose, and personal growth, is often less examined despite evidence that it provides an important stabilizing foundation for overall mental well-being [23]. When studying positive mental health among adolescents it is important to use measures for general mental well-being to ensure that positive mental health is adequately measured and represented [23].

A limited number of studies have investigated the association between PA and mental well-being among adolescents through validated general mental well-being instruments such as WEMWBS [22] or the WHO-5 Well-Being index [24]. Furthermore, only a few studies have investigated the association between PA and mental well-being among Danish adolescents [25]. Understanding how PA relates to mental wellbeing during adolescence is essential, as

this developmental period is marked by increasing mental health challenges and shifting lifestyle behaviors. A clearer understanding of this relationship may help inform strategies to promote PA not only for physical health but also as a potential lever to enhance psychological well-being among young people. Existing research suggests that the benefits of PA for mental health may depend on both the amount and intensity of activity, yet evidence among adolescents, particularly in a Danish context, remains limited. Examining this relationship can therefore contribute to addressing an important research gap and support public health efforts aimed at improving youth mental health. Thus, the aim of this study is to investigate the associations between PA and mental well-being in a large sample of Danish adolescents. Furthermore, the study examines whether these associations differ according to PA intensity and whether patterns vary between boys and girls.

Methods

Data collection

The current study applies data from the Danish part [26] of the international cross-sectional Health Behaviour in School-aged Children (HBSC) study from 2022 [27]. The HBSC study collects data from a nationally representative sample of 11, 13 and 15-year-olds (corresponding to students in the fifth, seventh and ninth grade in Denmark) every four years. Data are collected through school-based surveys following an internationally standardized research protocol [27]. The validity of the questions from the survey is continuously ensured by both the international and national organizations involved in the survey [26]. Schools were selected through cluster sampling from a complete list of private and public schools in Denmark. In 2022, a total of 588 schools were invited to participate, and 94 accepted (participation rate for schools: 16 %). Because the sampling strategy intentionally oversampled schools to reduce the risk of resampling in the event of low participation, the low participation rate should be interpreted in light of this oversampling rather than as an indication of poor recruitment success. The participation rate for students was 70 %, resulting in a sample of 5,823 participants [26]. Students in fifth grade were excluded from this study, as the outcome measure was not assessed in this grade. After exclusion, the sample for this study consists of 3,467 participants. The characteristics of the study sample is shown in Table 1.

Table 1: Characteristics of the study sample. (Total n=3,467).

Characteristic	n (%)
Grade	
7th grade	1,934 (55.8)
9th grade	1,533 (44.2)
Total	3,467 (100)
Sex	
Boys	1,730 (49.9)
Girls	1,737 (50.1)
Total	3,467 (100)
SEP	
High	1,620 (47.1)
Middle	1,123 (32.7)
Low	261 (7.6)
Unclassifiable	435 (12.7)
Total	3,439 (100)
Migration status	
Danish origin	3,140 (90.9)
Descendants	194 (5.6)
Immigrants	119 (3.5)
Total	3,453 (100)
Self-rated health	
Excellent	1,035 (30.1)
Good	1,828 (53.2)
Fair	508 (14.8)
Poor	67 (2.0)
Total	3,438 (100)
Meet the guidelines for MVPA	
Yes	575 (16.6)
No	2,886 (83.4)
Total	3,461 (100)
VPA outside school	
≥7 h/week	636 (18.5)

Table 1: (continued)

Characteristic	n (%)
Grade	
<7 h/week	2,794 (81.5)
Total	3,430 (100)
Combination of meeting the guidelines for MVPA & VPA outside school	
Meet the guidelines for MVPA & VPA ≥4 h/week outside school	401 (11.7)
Does not meet the guidelines for MVPA and/or VPA <4 h/week outside school	3,025 (88.3)
Total	3,426 (100)
Mental well-being (SWEMWBS)	
Low	2,879 (83)
High	588 (17)
Total	3,467 (100)

Measures

Outcome: mental well-being

The outcome of interest was mental well-being, assessed in seventh and ninth grade using The Short Warwick-Edinburgh Mental Well-being Scale (SWEMWBS) [28]. SWEMWBS is a seven-item measure which focuses exclusively on positive dimensions of mental health unlike many other mental health scales. It is used to monitor mental well-being in the general population and encompasses both hedonic and eudemonic aspects of the concept of mental well-being [28]. The Danish translation of the scale has been validated in Denmark [29] and has shown good psychometric properties and construct validity in a Danish sample of schoolchildren aged 10–16 years [30]. In the Danish HBSC study, the questions in SWEMWBS have been adapted through translation and testing in focus groups to be applicable for children in the 7th grade and above. SWEMWBS consists of seven positively worded questions, such as “how often do you feel optimistic about the future?” (for all questions see supplementary file 1). Response options were: 1 “None of the time”; 2 “Rarely”; 3 “Some of the time”, 4 “Often”, 5 “All of the time”. One of the modifications from the original scale is that the survey does not inquire about the previous two weeks but instead asks “how often”. SWEMWBS is scored as a continuous variable where the lowest sum score is seven and the highest is 35. SWEMWBS

can be used as a continuous outcome variable in statistical analysis if the data fits a normal distribution in either raw or converted form. The respondents SWEMWBS scores did not fit a normal distribution in either form. Therefore, mental well-being was categorized into two groups. These are: 'low and moderate mental well-being' (sum scores between 7 and 30) and 'high mental well-being' (sum scores between 31 and 35). These cut points align with the ones used in the Danish HBSC study [26]. (See Supplementary File 1 for an overview of outcomes, items and categorization of the variables).

Exposure: physical activity

Meeting the guidelines for moderate to vigorous physical activity (MVPA)

PA level was assessed based on two measures, meeting MVPA recommendations and VPA in leisure time. MVPA was measured by asking the participants how many days during the last 7 days they exercised for at least 1 h. The survey item defined MVPA as 'any type of movement, that makes your heartbeat faster or causes you to get out of breath some of the time'. It further specified that the respondent should consider PA in multiple arenas e.g. in school playing with friends, at sports and during transportation. The question also included examples such as running, brisk walking and roller skating. The question was categorized according to the Danish guidelines for MVPA among 5–17-year-olds. The guideline states that children and adolescence should be physically active at moderate intensity for at least 1 h every day [31]. Thus, MVPA is dichotomised according to whether the respondent reported at least 1 h of MVPA 7 days a week or not, which corresponds to meeting the guidelines for PA. This cut point aligns with what is reported in the international HBSC study [32].

Vigorous physical activity (VPA) outside school

VPA outside school was measured by asking participants how many hours per week they engaged in exercise outside of school that made them out of breath or sweat. The VPA measure was dichotomized into VPA 7 h or more per week and less than 7 h of VPA per week. Although this cut point may seem relatively high, it corresponds to the categorization used in the Danish HBSC study [26]. Using this threshold likely captures a smaller subgroup of adolescents with particularly high levels of VPA, which may influence the exposure's distribution. However, it enables us to examine whether high levels of VPA are associated with mental well-being while ensuring comparability with national monitoring data.

Combination of meeting the guidelines for MVPA & VPA outside of school

A combined measure of VPA and MVPA was created to approximate whether the participants adhered to WHO's recommendations for physical activity. WHO recommends that children and adolescence should be physically active at moderate intensity on average 1 h every day across the week and that vigorous intensity activities as well as those that strengthen muscles are incorporated at least 3 times a week [33]. Since it was not possible to operationalize WHO's recommendations directly, we have identified a group of highly active students, who meet the Danish MVPA guidelines and engaged in 4 h or more of VPA per week outside of school to approximate WHO's recommendations.

Covariates

Grade, sex, migration status, Socioeconomical Position (SEP) and self-rated health were included as covariates (An overview of the variables is presented in Supplementary File 1). Information about grade and sex stem from the students UNI-login. UNI-login is the individual login the students use to access all digital material in Danish schools. The students use their UNI-login to access the HBSC questionnaire [26]. To measure the students' SEP, the students answered questions about their parents' occupation. Based on their answers they were categorized into the social class that corresponded with the social class for the highest placed parent, this categorization is based on the Danish Occupational Social Class (DOCS), for further details see [34]. Social class I is the highest and V is the lowest along with an additional category of transfer income. The social classes are further grouped into "High SEP" which corresponds to social class I and II, "Middle SEP" which corresponds to social class III and IV, and "Low SEP" which corresponds to social class V and transfer income. Those who were non-classifiable were kept as non-classifiable. This categorisation of social class aligns with the categorisation used in the Danish HBSC study from 2018 [35].

Migration status is based on questions about the students' and the students' parents' country of birth. A student is categorized as being of Danish origin if the student and at least one parent were born in Denmark. A student is categorized as a descendant if the student was born in Denmark, but both parents were born in another country. A student is categorized as an immigrant if the student and both parents were born in another country [26].

Furthermore the students self-rated health was assessed with the question "Would you say your health is.?" with the options: "Excellent", "Good", "Fair" or "Poor". This variable was not further categorised.

Statistical analysis

STATA (version 18.0) was used to perform all analysis. First, a descriptive analysis was conducted to show the characteristics of the sample. Second, logistic regression models were made to assess associations between mental well-being and PA. Mental well-being was used as outcome and PA was used as the exposure. We performed three logistic regression models for each of the three variables of PA. Model 1: regressions were unadjusted. Model 2: Regressions were adjusted for grade, sex, socioeconomic position (SEP) and migration status. Model 3: Regressions were adjusted for the aforementioned variables as well as self-rated health. Additionally, an interaction analysis was performed to assess whether the association between mental well-being and PA was moderated by sex. The interaction analysis was adjusted for grade, SEP, migration status and self-rated health. Lastly a sensitivity analysis was conducted using different cut points in the three PA measures.

In the sensitivity analysis, meeting the MVPA guideline was dichotomized based on whether respondents reported at least 1 h of MVPA on four days per week. VPA was similarly dichotomized into at least 4 h per week vs. less than 4 h per week. For the combined measure, students were categorized as either meeting the Danish MVPA guideline and engaging in at least 2 h of VPA per week outside school or not meeting the MVPA guideline and/or engaging in less than 2 h of VPA per week. This sensitivity analysis was conducted to assess whether the results remain robust when using alternative thresholds for PA.

Results

Table 1 presents the characteristics of the study sample. Overall, 49.8 % of the participants were girls, 56.0 % were in the 7th grade, 90.6 % were of Danish origin, and 46.6 % had a high socioeconomic position (SEP). The table also details the distribution of mental well-being, with 17 % of the students having a high mental well-being. More students reported engaging in VPA for more than 7 h per week outside of school (18.5 %) compared to those adhering to the MVPA guidelines (16.6 %). Combining the measures for MVPA and VPA, a total of 11.7 % of the students were classified as highly active (adheres to the MVPA guidelines and engage in VPA for more than 4 h/week outside of school). The number of missing observations varied from 19 to 265 with no missing data for mental well-being, grade and sex. The missing data did not vary systematically from the other observations.

Table 2 shows the logistic regression models estimating associations between PA and mental well-being. Meeting the guidelines for MVPA was positively associated with mental well-being. Those who meet the guidelines have 101 % higher odds (OR=2.01, CI: [1.61; 2.52]) for high mental well-being, compared to those who do not meet the guidelines after adjusting for grade, sex, SEP, migration status and self-rated health. Those who reported at least 7 h of VPA outside school per week had 30 % higher odds (OR=1.30, CI: [1.03; 1.63]) for high mental well-being compared to those reporting less than 7 h of VPA outside school per week. Those who meet the MVPA guidelines and report at least 4 h of VPA outside school per week have 65 % higher odds (OR=1.65, CI: [1.27; 2.13]) for high mental well-being compared to those who either do not meet the MVPA guidelines and/or report less than 4 h of VPA outside school per week (Table 2).

Table 3 shows the results from the interaction analysis, indicating that the associations between PA and mental well-being do not differ by sex. Although the stratified results show different odds ratios for boys and girls, the differences are not statistically significant.

The sensitivity analysis shows the same pattern with a positive association between PA and mental well-being. However, the association between VPA outside school and mental well-being is no longer significant when the cut point

Table 2: Associations between high mental well-being and physical activity.

	Model 1 ^a OR [95 % CI]	Model 2 ^b OR [95 % CI]	Model 3 ^c OR [95 % CI]
Meet the guidelines for MVPA			
No	1	1	1
Yes	2.88 [2.34; 3.53] ^e	2.36 [1.90; 2.91] ^e	2.01 [1.61; 2.52] ^e
VPA outside school			
<7 h/week	1	1	1
≥7 h/week	2.17 [1.77; 2.67] ^e	1.76 [1.42; 2.17] ^e	1.30 [1.03; 1.63] ^d
Combination of meeting the guidelines for MVPA & VPA outside school			
Does not meet the guidelines for MVPA and/or VPA <4 h/week outside school	1	1	1
Meet the guidelines for MVPA & VPA ≥4 h/week outside school	2.65 [2.10; 3.35] ^e	2.11 [1.65; 2.69] ^e	1.65 [1.27; 2.13] ^e

^aUnadjusted. ^bAdjusted for grade, sex, SEP, and migration status. ^cAdjusted for grade, sex, SEP, and migration status and self-rated health. ^dp<0.05 ^ep<0.001.

Table 3: Association between high mental well-being and physical activity, sex stratified and interaction analysis.

	Boys OR [95 % CI]	Girls OR [95 % CI]	Boys vs. girls OR [95 % CI]
Meet the guidelines for MVPA			
Yes	1.97 [1.52; 2.55] ^b	2.14 [1.39; 3.31] ^a	1,0.09 [0.66; 1.81]
VPA outside school			
≥7 h/week	1.32 [1.02; 1.72] ^a	1.21 [0.77; 1.92]	0.92 [0.54; 1.55]
Combination of meeting the guidelines for MVPA & VPA outside school			
Meet the guidelines for MVPA & VPA ≥4 h/week outside school	1.58 [1.18; 2.11] ^a	1.90 [1.13; 3.19] ^a	1.20 [0.66; 2.18]

The analysis is adjusted for grade, SEP, migration status and self-rated health ^a $p < 0.05$ ^b $p < 0.001$.

is 4 h instead of 7 h. As in the primary analysis, no statistically significant interaction was found in the sensitivity analysis (See Supplementary File Table S2 & S3).

Discussion

The aim of this study was to investigate the associations between PA and mental well-being among adolescents, and to explore if these associations differed by sex. Our findings show significant positive associations between three measures for PA and mental well-being: Meeting the MVPA guidelines, VPA outside school, and a combined measure of MVPA and VPA. The strongest association was found for meeting the MVPA guidelines and having high mental well-being (OR: 2.01, CI 95 % [1.61; 2.52]).

Our findings are consistent with a substantial body of cross-sectional research that finds that PA is positively associated with various indicators of mental health in adolescents, including self-esteem [11, 36], life satisfaction [36, 37] and mental well-being [12, 21]. This consistency suggests that the beneficial association between mental health is relatively consistent across populations and measurement approaches. Importantly, our study contributes to this evidence by showing similar positive associations in a large, nationally representative sample of Danish adolescents and by using a validated measure of general mental well-being, which strengthens confidence in our findings.

Our results are further consistent with conclusions from broader reviews on PA and mental health [13] and quality of

life [16]. Rodriguez-Ayllon et al. [13] reported that PA is positively associated with satisfaction of life and total psychological well-being, which is consistent with the pattern observed in our study. Similarly, Poitras et al. [16] identified associations between objectively measured PA (e.g. accelerometers) and quality of life/well-being among school-aged children and youth from both cross-sectional and intervention studies. However, Poitras et al. [16] also emphasized that the quality of the cross-sectional studies was deemed to be very low, due to problems with attrition bias and using measures of quality of life which were not validated. Our study expands on the current knowledge by using a validated measure of mental well-being in a nationally representative study sample.

Our findings contrast those from a cross-sectional study in British private schools in Dubai that finds no association between MVPA and mental health, however the study finds a positive association between attitudes toward exercise and mental health [38]. Contextual differences, including sample size and cultural environment may explain these discrepancies, and direct comparisons should be made with caution. Likewise, Molcho et al. [12] observed a stronger association between VPA and mental well-being than between meeting MVPA guidelines and mental well-being. This difference may be partly attributable to different measures for both VPA and mental well-being [12]. Molcho et al. [12] created an indicator of VPA by multiplying two different items, which measures how often and how many hours the adolescents engaged in VPA. Furthermore, the study used WHO-5 as the indicator of mental well-being [12] which primarily captures the hedonic dimensions of subjective well-being [39]. Moreover, Molcho et al. [12] reported a stronger association between PA and mental well-being for girls than for boys, suggesting potential gender differences in how PA relates to well-being.

In our study, we investigated whether the associations between PA and mental well-being differed by boys and girls. We found no interaction by sex, indicating that the relationship between PA and mental well-being is consistent across gender. These findings are consistent with results from a Canadian cross-sectional study examining the association between movement guidelines and self-esteem and life stress in adolescents [11]. Sampasa-Kanyinga et al. [11] similarly reported no interaction by sex. This aligns with a recent review of mediators and moderators that impact the association between PA and mental health in all population groups, which concludes that the evidence regarding sex as a moderator is conflicting [20].

Two studies find cross-sectional, but not longitudinal associations between MVPA measured with accelerometers and quality of life [37] and mental well-being [21] respectively. Both studies comment that a causal relationship

between PA and mental health cannot be ruled out based on their study. Causality cannot be inferred based on our study due to the cross-sectional design. Studies examining the causal relationship between PA and positive mental health has conflicting findings.

Evidence on the relationship between PA and mental well-being in young people is mixed. A systematic review suggests PA can improve mental well-being [13], whereas another found no clear effects of PA interventions on quality of life [16]. Longitudinal studies indicate that the association may be complex: one Danish study showed a bidirectional relationship in adults [40], and a U.S. study found that adolescent sport participation predicted better well-being in adulthood, though not causally [41]. Overall, these findings highlight the need for further research to clarify whether PA causally influences mental well-being in adolescents.

Several studies indicate that the domain in which PA takes place could mediate the relationship between PA and mental well-being [36, 42–46]. Participating in team sports [43–45] and organized leisure activities [43] rather than individual PA is associated with better mental health outcomes. The only specific domain that our study investigates is leisure time PA. In our study we do not find that leisure time PA (VPA) had higher OR's than PA across all domains (meeting the guidelines/MVPA). However, this might be due to the different intensities of the two measures. A Canadian study found that adolescents who were more frequently physically active with their parents were more likely to adhere to PA recommendations and have higher life satisfaction [47]. These above-mentioned studies indicate that especially PA with others, can have a positive impact on mental health among adolescents. A systematic review finds that social connection mediates the relationship between PA and mental health [20]. The literature suggests that a social aspect of PA may play a significant role in the relationship between PA and mental well-being, which needs further investigation. Other important possible mediators of the association include self-efficacy, body image, emotional regulation or emotional intelligence and resilience [20]. These mediators should be explored further. However, it has not been possible to investigate the underlying mechanisms in the current study.

Strengths and limitations

The study has some notable strengths. The main strengths are the standardized and validated data collection procedures, based on the international HBSC study [27], and the use of a large nationally representative sample of Danish adolescents [26] to investigate the association between PA and

mental well-being. Our results concern the general population of Danish 13–15-year-old adolescents. By using a comprehensive mental well-being instrument that includes both hedonic and eudemonic indicators we provide a better representation of general mental well-being [23]. This is important, when studying general populations, as these measures do not experience ceiling effects the same way that measures that focus on the presence of mental health problems do [22]. According to Rose [48] smaller benefits for the entire population will have a bigger impact, than large benefits for an at-risk population. As this study finds a positive association between PA and mental well-being among Danish adolescents by using a measure where we are confident that there are no ceiling effects [29], we believe that PA would be beneficial for the mental well-being of the entire population of Danish adolescents. Further, we had the opportunity to investigate the association across different measures of PA. Finally, the sensitivity analyses examine the sensitivity of the dichotomized exposures and therefore contributes to the reliability of the results.

However, some limitations should be considered. First, due to the cross-sectional nature of the study, causality cannot be inferred by from our findings. Second, the self-reported measures used in the study can be subject to information bias (e.g. recall bias) [49]. The PA measures cover different time perspectives. Specifically, one measure assesses MVPA over the past seven days, while the other inquires about VPA over a typical week.

This led to some participants reporting seven hours of VPA per week while indicating no MVPA in the past seven days (data not shown), suggesting inconsistencies in how activities were reported. Therefore, comparisons between the PA measures should be interpreted with caution. Third, some residual confounding may remain, as we were unable to adjust for social support. Finally, although some studies examine PA, sleep, and sedentary time as combined exposures for mental health, assessing the total effect of these movement behaviors was beyond the scope of the present study, which focused specifically on the relationship between PA and mental well-being.

In 2022, the HBSC data collection took place during the COVID-19 pandemic, which may help explain the low school response rate. Many schools were still managing the after-effects of lockdowns, catching up on missed curriculum, and dealing with higher student absenteeism, which further limited their ability to engage in research activities. Finally, only 13- and 15-year-olds (7th and 9th graders) were included in the data, as the 11-year-olds (5th graders) did not report mental well-being, which may limit generalizability to younger adolescents.

Conclusions

Using a representative sample of Danish adolescents, this study found that PA is positively associated with general mental well-being, and that these associations do not differ by sex. By applying a validated general well-being measure and addressing methodological limitations found in earlier research, the study provides new evidence supporting the role of PA in promoting population-level mental well-being among adolescents. While more longitudinal research is needed to clarify causation, these findings strengthen existing arguments for promoting PA to support adolescent mental health.

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Research ethics: The HBSC study complied with national guidelines and regulation regarding data protection, and ethics approval. The Danish HBSC survey from 2022 was registered (Case 10.622, University of Southern Denmark). The research group had no access to information that can identify participants. According to section 14 in the Danish Scientific Ethical Committees Act, there is no request for ethical approval of population-based questionnaire surveys (<https://www.retsinformation.dk/eli/lt/2017/1083>).

Informed consent: The study complied with national legislation about consent to participate. The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee at the University of Southern Denmark, Case No. 10.622. We received approval from the school principal, the school board representing the parents, and the board of schoolchildren representing the schoolchildren in every participating school. We informed the participants orally and in writing about the purpose of the study, that data collection was pseudonymised and voluntary, that publication of data would be in a pseudonymised format, and that data could be used for research with similar purposes by approval of University of Southern Denmark. We also provided written information to the parents about the study. The parents also received an electronic link to a short video with information about the study and that participation was voluntary and confidential as well as an electronic link by which they could reject their child's participation in the study.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Use of Large Language Models, AI and Machine Learning

Tools: AI was used to improve language.

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability: Applications to access the dataset should be sent to the Primary Investigator of the Danish HBSC Study, Dr. Katrine Rich Madsen, krma@sdu.dk.

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