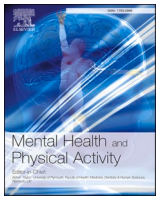
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Physical activity and adolescent mental health across 45 countries: Exploring the role of country-level perceived health☆☆

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ABSTRACT

Purpose: Physical activity (PA) has been linked to better adolescent mental health, yet most evidence comes from single-country studies. Although a recent meta-analysis established that this association varies significantly by country, the specific country-level factors underlying this variability remain untested. This study examined whether cross-national variability in the PA–mental health association is related to country-level differences in adolescents' perceived health. We examined the PA–mental health association in a large cross-national sample and tested country-level perceived health as a moderator to provide a more holistic perspective on the interplay between physical activity, its context and outcomes.

Methods: This cross-sectional study used data from the 2018 Health Behaviour in School-aged Children survey of adolescents aged 11, 13, and 15 from 45 countries (N = 217,384). Mental health was measured using self-reported life satisfaction and psychological health complaints. PA was assessed as the number of days per week with at least 60 min of moderate-to-vigorous activity. Multilevel linear regression models were estimated, with adolescents nested within countries. Random intercepts and slopes were included to capture cross-national variability, and cross-level interactions were tested to assess moderation by country-level perceived health.

Results: Higher PA was consistently associated with better mental health across all outcomes (all ps < 0.001). Marginal R^2 ranged from 0.012 to 0.051, and conditional R^2 from 0.040 to 0.095, indicating meaningful country-level variance. A non-significant trend toward moderation by country-level perceived health was observed for life satisfaction ($b = 0.15$, $p = .076$) and sleep difficulty ($b = 0.08$, $p = .092$), though neither reached the pre-specified significance threshold ($p < .05$).

Conclusions: Findings suggest that country-level context may play a role in the PA–mental health association, though this requires confirmation in future research. Programs promoting mental health through PA should encompass the role of the broad context, considering cross-national differences and adapting strategies to local health perceptions.

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1. Introduction

Physical activity (PA) is associated with better mental health in youth. The body of literature indicates that, on average, more active adolescents report higher life satisfaction, better moods, and fewer mental health issues than their less active peers (Nie et al., 2025; Rodriguez-Ayllon et al., 2019), a between-person association observed primarily in observational, cross-sectional evidence. Experimental and longitudinal work has further proposed several within-person mechanisms that could plausibly underlie increases in PA improving an individual's mental health over time, operating at neurobiological, psychosocial, and behavioral levels (Lubans et al., 2016; Stillman et al., 2020). For example, PA may induce neuroplasticity through the expression of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), and lead to increased self-esteem and perceived social support through participation in sport (Nguyen Ho et al., 2023; Noetel et al., 2024; White et al., 2024; Wu et al., 2023). However, these within-person mechanisms are not directly tested by the present study's cross-sectional, between-person design. Promoting PA is nonetheless often advocated to support adolescent mental health on the basis of this broader body of evidence, though the present study itself speaks only to between-person patterns.

The mechanisms underlying the association between PA and adolescent mental health can be understood across three complementary domains. First, neurobiological mechanisms are primarily quantity-driven, reflecting the physiological effects of regular activity such as endorphin release and increases in brain-derived neurotrophic factor (BDNF), both of which support brain plasticity, mood regulation, and stress recovery (Azevedo et al., 2020; Jemni et al., 2023; Phillips, 2017). Second, psychosocial mechanisms emphasize the social and emotional context of PA, including enhanced self-esteem, peer support, and a sense of mastery or achievement (Eather et al., 2023; Haugen et al., 2013; Martín-Rodríguez et al., 2024). Third, behavioral mechanisms relate to improvements in health-promoting routines such as sleep regulation, daily structure, and reductions in sedentary behavior (Lubans et al., 2016). Importantly, these mechanisms do not operate in isolation but are influenced by the qualitative characteristics of PA, its goals, delivery, and cultural framing. For example, PA motives are unlikely to be uniform even within a single cultural region: a large-scale Danish study found that psychological condition, physical condition, and enjoyment, not performance or appearance, were the most prevalent motives for PA participation among adults (Elmose-Østerlund et al., 2023), suggesting substantial within-country heterogeneity in PA motives that likely also exists across Western European contexts. Nonetheless, some evidence suggests that performance- or physique-oriented framing of PA, where present, may attenuate its association with mental health (McMahon et al., 2017), while a diversity of motives, including enjoyment and social connection, may be more consistently associated with positive outcomes. By contrast, when PA is embedded in supportive environments that emphasize enjoyment, inclusion, or coping, psychosocial and behavioral pathways are likely to amplify its benefits (Lubans et al., 2016; Ntoumanis et al., 2021).

However, most of the evidence supporting the link between PA and adolescents' mental health comes from single-country or population-specific studies, with findings varying considerably across these individual studies (Pascoe et al., 2020). Direct cross-national comparisons of the strength of the PA–mental health association itself, however, remain scarce (Fu et al., 2025). Cultural and environmental contexts differ substantially between countries, which may influence both the average level of mental health and the extent to which PA influences mental health (Bann et al., 2019; Weinberg et al., 2019). For example, the way adolescents live, their support, and opportunities for PA vary by country due to factors such as school schedules, urban form, climate, and cultural attitudes toward sport (European Union, 2020; Kolovelonis et al., 2024). Likewise, adolescent mental health outcomes (e.g., the prevalence of depressive symptoms or stress) are highly variable across countries (European Union, 2020).

A recent meta-analysis of intervention studies confirmed that country is a significant moderator of the PA–mental health association (Fu et al., 2025), indicating that cross-national variability itself is not in question even in experimental contexts. However, whether, and through what country-level factor, this variability is moderated, in observational, population-representative data remains untested. However, the specific contextual factors underlying this variability remain largely unexamined; in particular, to our knowledge, no study has tested whether a country-level health indicator, such as the aggregate perceived health of the adolescent population, explains it.

Examining the cross-national pattern of the PA–mental health relationship is of relevance to public health. If it is more robust in some countries and weaker in others, then moderating factors at the country level may explain this cross-national pattern. Identifying such factors could inform population-level public health priorities, though translating country-level moderation into individual-level intervention targets would require additional, individual-level evidence that this study's aggregate, cross-national design cannot provide. One such country-level factor is the general health status of the adolescent population, often operationalized by perceived health, which is the proportion of youth who rate their health as good or excellent (Kim & Shim, 2025; White et al., 2024). Perceived health is a broad indicator of how healthy adolescents perceive themselves to be and reflects both their objective health status and cultural expectations of health (Idler & Benyamini, 1997; Roberts et al., 2007). Countries vary in the prevalence of youth reporting good health, which could be associated with the extent to which PA is linked to better mental health (Patton et al., 2016). For example, the average PA–mental health association may be more pronounced in countries where most adolescents already report good health, consistent with an amplification pattern. Alternatively, in countries where adolescents report poorer average health, the association may be stronger due to greater 'room for improvement' at the population level, consistent with a buffering pattern. These are hypotheses about between-country patterns in the strength of association, not claims about how PA affects any individual adolescent. This dual possibility, amplifying in healthier contexts versus buffering in less healthy contexts, has been suggested in related fields and highlights the importance of examining both directions of moderation (Liu et al., 2025; Moon & Han, 2022). Crucially, country-level perceived health is conceptually distinct from individual-level mental health outcomes used in this study (i.e., life satisfaction and emotional symptom frequency) (Diez-Roux, 1998). While individual perceived health reflects personal self-assessment, the country-level aggregate captures a structural characteristic of the national health environment, the broader cultural and systemic context in which adolescents develop (Idler & Benyamini, 1997). This distinction justifies its role as a contextual moderator rather than an overlapping construct. We selected aggregate perceived health, rather than macroeconomic (e.g., GDP) or policy-based indicators (e.g., PA infrastructure investment), because it directly reflects how adolescents themselves experience the national health context in which they live, integrating both objective health conditions and culturally shaped expectations of health (Idler & Benyamini, 1997). While macro-structural indicators capture resources and policy, they do not necessarily reflect how these translate into adolescents' lived health experience, which we argue is more proximally relevant to the psychosocial mechanisms linking PA to mental health.

To address these gaps, the present study leverages data from the Health Behaviour in School-aged Children (HBSC) study, which provides representative data from 45 countries to examine the association between PA and adolescent mental health in a cross-national context. These countries are primarily located in Europe and North America; this regional composition reflects a range of economic development, cultural norms, and public health infrastructure, providing a meaningful basis for cross-national comparison. We had four aims: (1) to examine the overall association between PA and mental health across this large,

diverse sample of countries; (2) to assess the extent of between-country variability in the PA–mental health link by estimating country-specific associations; and (3) to examine country-level moderation, testing whether the average perceived health of adolescents in each country moderates the strength of the PA–mental health relationship. Given prior evidence that the strength of the PA–mental health association may differ by sex (Lee et al., 2023), social context (Li & Hao, 2025), and mental health trajectories (McMahon et al., 2017), we additionally explore sex as a potential moderator of the PA–wellbeing relationship. This focus on country-level differences aligns with a broader recognition that contextual influences are associated with variation in the PA–mental health association. Vella et al. (2023) proposed a model of PA-level contextual factors, activity type, physical and social environment, delivery, and domain that operate at the level of the individual PA experience. The present study addresses a conceptually distinct, more distal form of context: the aggregate national health environment in which PA occurs, rather than the activity's proximal characteristics. Specifically, we consider whether perceived health amplifies the PA-mental health association in healthier contexts or buffers the relationship in less healthy contexts.

Examining contextual influences aligns with calls for a more holistic perspective on the relationship between PA and mental health (Vella et al., 2023), one that considers PA not as a decontextualized individual behavior but as embedded within broader environments (Bronfenbrenner, 1979; Diez-Roux, 1998). Piggin (2020) similarly argues for a broader conceptualization of PA as socially and culturally embedded behavior, rather than a narrowly quantified metric of exertion. In the present study, this perspective is operationalized narrowly by combining an individual-level behavioral measure (PA frequency), which reflects the dominant, narrower conceptualization that Piggin critiques, with a single country-level contextual indicator (aggregate perceived health) within a multilevel framework. This study does not claim to capture the full range of contextual factors that a fully holistic model would require. In particular, this study does not address the activity-level contextual factors central to Vella et al.'s (2023) framework (e.g., PA type, social environment, delivery); rather, it examines a single macro-level contextual dimension, country-level perceived health, that operates upstream of, and is conceptually distinct from, those proximal factors. This represents an initial step toward integrating one contextual dimension into the analysis of the PA–mental health association, not a comprehensive test of contextual influence. This is consistent with recent evidence that the modifiable determinants of adolescent PA and sedentary behavior are highly setting-specific, operating across individual, interpersonal, and broader contextual domains in school, home, and mixed settings (Ciaccioni et al., 2026); a single country-level indicator, such as the one examined here, cannot be expected to capture this full range of proximal and distal influences.

2. Methods

2.1. Study design and sample

This study used a cross-sectional design. Data from the 2017/2018 wave of HBSC were used for the current study. Forty-five countries (primarily European and Canada) participated in the 2017/18 wave (World Health Organization, 2020b). However, Greenland is reported separately, bringing the total number of analytic units in our Supplementary Tables 1–46. For the random-slope models, two units

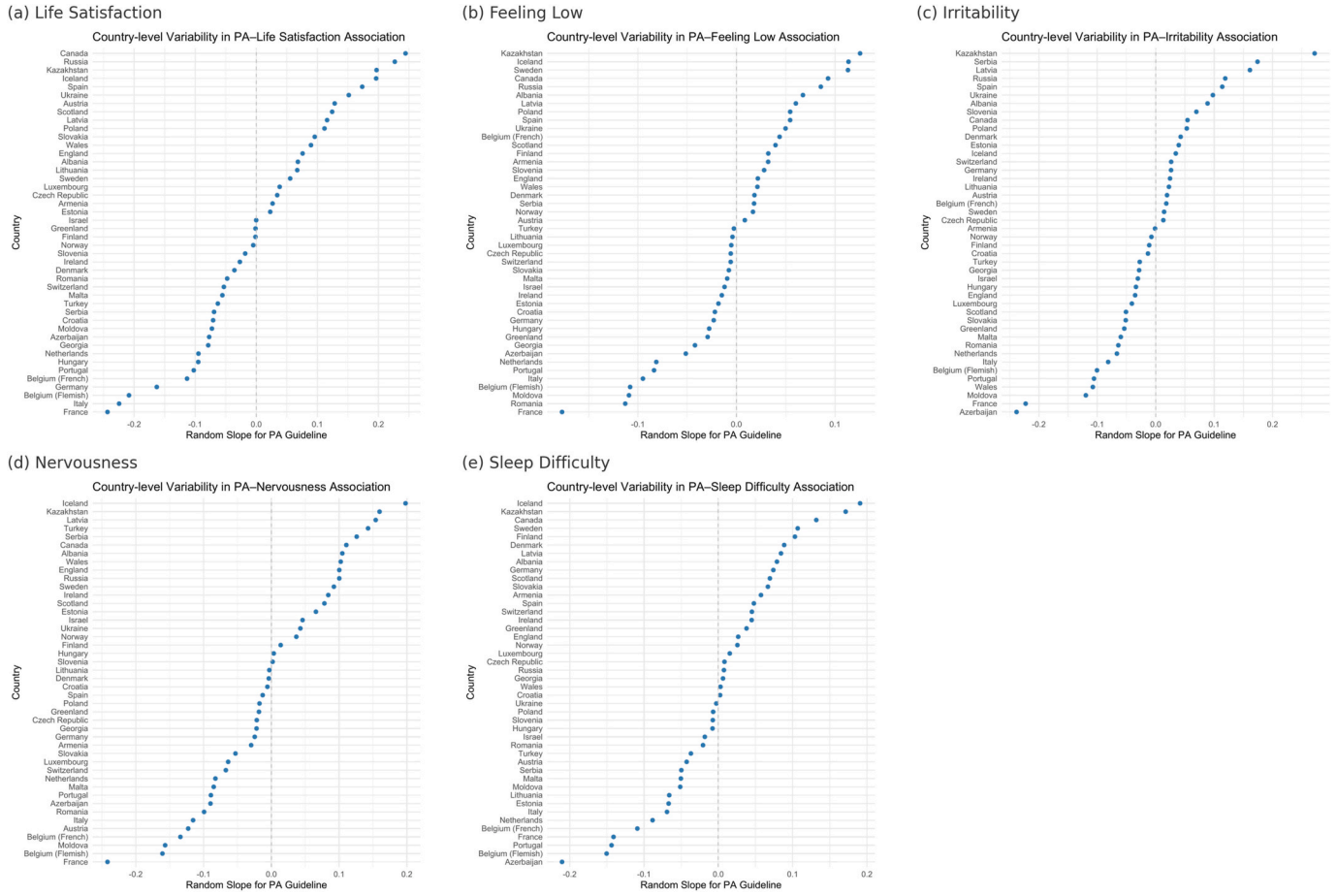


Fig. 1. Country-level variability in the association between physical activity and adolescent mental health outcomes. *Country-specific random slope estimates for the association between physical activity and adolescent mental health outcomes. Higher values indicate stronger positive associations.*

(Greece and Bulgaria) were excluded due to insufficient variance, so Fig. 1 presents 44 units. Sampling and data collection in each country followed standardized protocols. Students were sampled from schools, and classes were sampled within schools to ensure the national representativeness of students aged 11, 13, and 15 years. Surveys were completed anonymously in classroom settings. Ethical approval was obtained in each country in accordance with national regulations and HBSC international protocols prior to data collection (World Health Organization, 2020a). Passive or active parental consent and student assent procedures were followed as required by each country's institutional review board. All data were collected anonymously in school settings, and participation was voluntary. As this study uses pre-existing, de-identified secondary data from the HBSC Data Management Centre, no additional ethics approval was required for the current analysis. The final analytic sample size was N = 217,384 adolescents. Sample sizes across countries varied from a few thousand to just over 10,000, depending on the population size and design of each country survey. The analytic sample consisted only of respondents who had complete data on the variables of interest (physical activity, mental health outcomes, and perceived health). The analytic sample consisted of respondents with complete data on the variables of interest (physical activity, mental health outcomes, and perceived health), yielding a final N of 217,384. Given the low proportion of missingness, we assumed data were missing at random (MAR) with respect to the observed covariates; however, we did not formally test this assumption, and multiple imputation was not implemented. This is noted as a limitation.

2.2. Measures

2.2.1. Physical activity

Students' PA was assessed using the HBSC standard item: "On how many days in the past week were you physically active for a total of at least 60 min per day?" (response options: 0-7 days). This measure assessed the overall frequency of moderate-to-vigorous physical activity (MVPA) during the past week. The question was introduced by text defining MVPA as any activity that increases the heart rate and makes the person get out of breath some of the time, with examples provided. For the primary dose-response analyses (Table 2), the 0–7 day response was recoded into a four-level categorical variable (physact60_C2) based on active days per week: Level 1 = Inactive (0 days); Level 2 = Low (1–2 days); Level 3 = Moderate (3–4 days); Level 4 = High/Meets guideline (5–7 days), with Level 1 (Inactive) serving as the reference category. A separate dichotomous indicator (physact60_C) of meeting the daily PA guideline (1 = active 7 days/week vs. 0 = all other frequencies) was used in the sex- and age-interaction models (Table 3). Categorizing PA in this way retains information about partial adherence to the recommendation and allows for a dose-response interpretation, rather than relying solely on a strict guideline cutoff (Chaput et al., 2020; Gammon et al., 2022). The HBSC PA item has demonstrated acceptable test-retest reliability across countries and age groups (Booth et al., 2001), although it is subject to recall bias common to self-report measures.

Table 1
Descriptive characteristics of the analytic sample (N = 217,384).

Variable	M (SD) or %	Range
Demographic characteristics		
Age, years	13.53 (1.63)	10.0–16.5
Sex, % female	51.1	—
Physical activity		
Days physically active ≥ 60 min (past 7 days)	4.07 (2.08)	0–7
PA category, %		
Inactive (0 days/week)	5.1	
Low (1–2 days/week)	19.6	
Moderate (3–4 days/week)	31.9	
High/Meets guideline (5–7 days/week)	43.4	
Vigorous PA frequency	3.03 (1.63)	1–7
Mental health indicators		
Perceived health	1.81 (0.71)	1–4
Life satisfaction (Cantril ladder)	7.72 (1.91)	0–10
Feeling low[a]	3.88 (1.33)	1–5
Irritability/bad temper[a]	3.49 (1.35)	1–5
Feeling nervous[a]	3.54 (1.38)	1–5
Difficulty sleeping[a]	3.77 (1.47)	1–5

Note. All statistics are weighted using HBSC international sampling weights, based on non-missing observations for each variable (N ≤ 217,384). Sex is coded 1 = male, 2 = female. Physical activity category) is the four-level variable used in the primary multilevel models. a Symptom frequency items (feeling low, irritability, nervousness, difficulty sleeping) were reverse-coded such that higher scores indicate fewer symptoms, for conceptual comparability with life satisfaction.

2.2.2. Mental health

Adolescents' mental health was assessed using two complementary self-report indices, consistent with a dual-continua perspective in which positive and negative dimensions of mental health are conceptually and empirically distinct (Keyes, 2005): (a) life satisfaction, reflecting a positive, evaluative dimension of well-being, and (b) a psychological symptom index, reflecting the frequency of negative emotional and psychosomatic complaints. These two constructs were selected because they are the core, cross-nationally validated mental health indicators included in the HBSC survey, enabling comparability across the 45 countries examined. Life satisfaction was assessed with the validated Cantril ladder measure, which asks participants to rate their life on a scale from 0 ("worst possible life") to 10 ("best possible life") (Moor et al., 2020). Higher scores indicate higher subjective well-being and life satisfaction. Emotional symptoms were assessed using four items from the HBSC Symptom Checklist: frequency of (1) feeling low, (2) irritability or bad temper, (3) nervousness, and (4) difficulty falling asleep (Moor et al., 2020). Participants indicated how often they had experienced each symptom in the past six months using a 5-point scale from 1 = "rarely or never" to 5 = "about every day." All four symptom variables were reverse-coded so that higher scores reflect fewer psychological complaints and better mental health (e.g., a score of 5 after recoding indicates "rarely or never") (Moor et al., 2020). These reverse-coded variables were examined individually and combined as indicators of a psychological symptom index (reverse-scored, such that higher values indicate fewer complaints). This coding direction was selected to maintain conceptual comparability with the life satisfaction measure, such that higher scores across all outcomes indicate better mental health (World Health Organization, 2020a). Formal measurement invariance testing across the 45/46 countries was not conducted in the present study. However, prior psychometric work using the same 2018 HBSC wave supports configural and metric invariance of the HBSC Symptom Checklist across countries, though not full scalar invariance, with non-invariance concentrated in the irritability, nervousness, and feeling low items (Heinz et al., 2022). This suggests that cross-country comparisons of mean levels on these items should be interpreted with some caution, though the overall factor structure and item discrimination appear broadly comparable across countries. Critically, metric invariance, equivalence of factor loadings across countries, was supported; this is the condition required for the within-country strength of the PA–mental health association (i.e., regression slopes) to be validly compared across countries, which is the primary analytic target of this study. Scalar invariance, the equivalence of item intercepts, is required specifically for comparing latent mean levels across countries (e.g., whether adolescents in one country report systematically higher or lower symptom levels than in another), a comparison that this study's central models do not rely on.

2.2.3. Perceived health

The primary contextual variable was country-level perceived health, or the percentage (%) of adolescents in each country who indicated their health as “excellent” or “good” (vs. fair or poor) on a standard HBSC item. Each student provided an assessment of their health (“Would you

Table 2
Summary of multilevel models predicting mental health outcomes by physical activity level.

Predictor	Life Satisfaction	Feeling Low	Irritability	Nervousness	Sleep Difficulty
PA Level 2 (Low, 1–2 days/week, vs. Inactive)	0.396 [0.358, 0.434] p < .001	0.182 [0.155, 0.208] p < .001	0.222 [0.195, 0.250] p < .001	0.200 [0.172, 0.228] p < .001	0.169 [0.139, 0.199] p < .001
PA Level 3 (Moderate, 3–4 days/week, vs. Inactive)	0.628 [0.591, 0.666] p < .001	0.331 [0.305, 0.356] p < .001	0.334 [0.308, 0.361] p < .001	0.310 [0.283, 0.337] p < .001	0.279 [0.250, 0.308] p < .001
PA Level 4 (High/Meets guideline, 5–7 days/week, vs. Inactive)	0.919 [0.883, 0.956] p < .001	0.415 [0.390, 0.441] p < .001	0.406 [0.380, 0.432] p < .001	0.372 [0.345, 0.398] p < .001	0.351 [0.322, 0.379] p < .001
Age	−0.192 [−0.197, −0.187] p < .001	−0.100 [−0.104, −0.097] p < .001	−0.115 [−0.118, −0.111] p < .001	−0.107 [−0.110, −0.103] p < .001	−0.025 [−0.029, −0.021] p < .001
Sex (Female)	−0.217 [−0.233, −0.202] p < .001	−0.407 [−0.418, −0.396] p < .001	−0.301 [−0.312, −0.290] p < .001	−0.337 [−0.348, −0.325] p < .001	−0.233 [−0.245, −0.220] p < .001
R^2 (Marginal)	0.051	0.051	0.041	0.038	0.012
R^2 (Conditional)	0.086	0.095	0.083	0.088	0.040

Note. Results are from five separate multilevel linear models predicting mental health outcomes using physical activity level (physact60_C2), controlling for age and sex. Values are unstandardized coefficients with 95% confidence intervals in brackets and p-values below each estimate. PA Level 1 (Inactive, 0 days/week) is the reference group. Sex is coded 1 = male, 2 = female.

Table 3
Fixed effects from multilevel models with PA × sex and age interactions.

Predictor	Life Satisfaction	Feeling Low	Irritability	Nervousness	Sleep Difficulty
PA Guideline (male, mean age)	0.408 [0.381, 0.435] p < .001	0.087 [0.069, 0.106] p < .001	0.073 [0.054, 0.092] p < .001	0.081 [0.061, 0.100] p < .001	0.069 [0.048, 0.090] p < .001
PA × Sex	−0.004 [−0.045, 0.036] p = .833	0.053 [0.025, 0.081] p < .001	0.068 [0.039, 0.096] p < .001	0.049 [0.020, 0.078] p < .001	0.016 [−0.016, 0.048] p = .323
Sex (Female)	−0.239 [−0.256, −0.222] p < .001	−0.430 [−0.442, −0.418] p < .001	−0.324 [−0.336, −0.312] p < .001	−0.354 [−0.367, −0.342] p < .001	−0.247 [−0.261, −0.234] p < .001
Age (centered)	−0.201 [−0.207, −0.196] p < .001	−0.112 [−0.116, −0.108] p < .001	−0.123 [−0.126, −0.119] p < .001	−0.116 [−0.120, −0.113] p < .001	−0.031 [−0.035, −0.027] p < .001
PA × Age	−0.003 [−0.015, 0.009] p = .626	0.032 [0.023, 0.040] p < .001	0.016 [0.007, 0.025] p < .001	0.029 [0.020, 0.038] p < .001	0.005 [−0.004, 0.015] p = .274

Note. Results are from five separate multilevel linear models: outcome ~ PA guideline (7 days/week vs. other) × sex + PA guideline × age + (1 | country). Values are unstandardized coefficients with 95% confidence intervals in brackets and p-values below each estimate. Sex is coded 0 = male (reference), 1 = female; the PA main effect is therefore interpretable as the association among male adolescents. Age is grand-mean centered (M = 13.53 years); the PA main effect reflects the association at the sample mean age rather than at the biologically meaningless value of age = 0.

say your health is… excellent/good/fair/poor?"); we then averaged responses at the country level to generate a country-level percentage of youth with positive self-rated health. This country-level measure served as an indicator of the general health status and well-being of adolescents. The country-level perceived health percentage was grand-mean centered for interpretability in analyses (i.e., each country's percentage minus the overall mean percentage across all countries). Grand-mean centering was applied because it (a) improves the interpretability of the intercept, which then represents the expected outcome for a country at the sample average level of perceived health, (b) reduces multicollinearity between the main effect and the cross-level interaction term, and (c) prevents conflation of within- and between-country effects when interpreting the interaction coefficient (Enders & Tofighi, 2007).

2.3. Statistics analysis

Analyses controlled for the multilevel data structure with students nested within countries. Multilevel linear regression models were estimated to assess the associations of PA with each mental health outcome, adjusting for individual-level covariates (age, sex). Age and sex were selected as covariates because both are well-established correlates of adolescent PA and mental health that could otherwise confound the association of interest (Biddle et al., 2019; Rodriguez-Ayllon et al., 2019). We recognize that socioeconomic status (SES) is also a well-documented confounder of the PA–mental health association (Elgar et al., 2015; Stalsberg & Pedersen, 2010), and HBSC includes a validated SES measure, the Family Affluence Scale (FAS). However, FAS was not included in the primary models because it had a substantially higher rate of missingness than age, sex, or the outcome variables across the 45 countries, and including it would have disproportionately reduced the analytic sample, particularly in lower-income countries where non-response to affluence items tends to be higher. To balance model parsimony and cross-national sample retention, we prioritized the two covariates with the most complete data. This omission is acknowledged as a limitation, and we recommend that future analyses of this dataset assess the robustness of the current associations after adjusting for SES. HBSC also includes screen time and self-reported height/weight (from which BMI can be derived), both of which are established correlates of adolescent PA and mental health. These variables were similarly excluded from the primary models for the same reasons of missingness and cross-national data completeness, and their omission is acknowledged as a further source of potential residual confounding. The analyses of life satisfaction were performed using the variable as a continuous outcome. Analyses of the four reverse-coded symptom frequency variables (feeling low, irritability, nervousness, sleep difficulty) were conducted using these variables as quasi-continuous outcomes (higher scores are indicative of better mental health). To evaluate if the association between PA and mental health differed between countries, we employed two-level linear regression models with adolescents (Level 1) nested within countries (Level 2). At Level 1, predictors included individual physical activity, age, and sex (coded as 1 for male and 2 for female). At Level 2, country-level perceived health was included as a contextual moderator. This approach models individual physical activity behavior as nested within, and potentially shaped by, the broader national context, consistent with the narrower scope of contextual embedding described in the Introduction. Intraclass correlation coefficients (ICCs) and likelihood ratio tests were used to evaluate the presence and strength of between-country variation.

Two complementary analytic strategies were subsequently used to assess country-level moderation. We subsequently extracted country-

level slope estimates from the random-slope models to illustrate cross-national variation. This step was undertaken to visualize the pattern of cross-national heterogeneity (Fig. 1) and to verify that the moderation findings described below were not driven by a small number of outlying countries, rather than to independently re-test the moderation hypothesis. In secondary analyses, we examined whether the cross-national average of adolescents' perceived health moderated the relationship between PA and mental health by including a cross-level interaction term. Specifically, both the individual-level PA variable (days/week) and the country-level perceived health percentage were grand-mean centered, and the interaction term was computed as their product $(PAij-\bar{PA})\times(PHj-\bar{PH})$. This cross-level interaction model, estimated on the full individual-level dataset, constitutes the primary confirmatory test of moderation reported in the Abstract and Results. In contrast, the country-level slopes-as-outcomes regression (n = 46) does not propagate the sampling uncertainty of the extracted slopes and has limited statistical power, and is therefore treated as a descriptive/robustness check rather than an independent confirmatory test.

In additional models, interaction terms with dummy variables (e.g., sex coded as 1 = male, 2 = female) were created by multiplying the dummy variable with PA to test whether associations differed across subgroups. We also calculated bivariate correlations between country-level PA slopes and percentages of perceived health as a robustness check. All models were estimated with international sampling weights provided by HBSC to obtain nationally representative estimates. Statistical significance was evaluated at $p < .05$. Analyses were performed with R version 4.5.1. Multilevel models were fitted using the lmer() function from the lme4 package (Bates et al., 2015); marginal and conditional R^2 values were computed using the r.squaredGLMM() function from the MuMIn package (Nakagawa & Schielzeth, 2013). Weighted descriptive statistics and cross-tabulations incorporating HBSC sampling weights were computed using the svydesign(), svymean(), and svytable() functions from the survey package (Lumley, 2004).

3. Results

Descriptive statistics for the analytic sample are presented in Table 1. High levels of PA were related to better adolescent mental health in the overall sample from the 45 countries combined. The fixed effects from multilevel models using PA as a categorical predictor (with the **0** days/week group as the reference) showed a dose-response effect for mental health outcomes (Table 2). Adolescents in the highest PA category (Level 4: 5–7 active days/week) had higher life satisfaction scores (0.92 points) compared to the inactive group (0 days/week; all ps < 0.001). Similarly, compared to inactive adolescents, PA Level 2 (1–2 days/week), Level 3 (3–4 days/week), and Level 4 (5–7 days/week) were each significantly associated with better outcomes on the four reverse-coded psychological symptom indicators (feeling low, irritability, nervousness, and sleep difficulty). For instance, the 1.45-point difference on the reverse-coded "feeling low" scale between adolescents meeting the PA guideline and the inactive group reflects fewer depressive symptoms reported by the daily active youth. Negative values for symptom indicators reflect that greater PA is linked with a lower frequency of complaints, as these variables were not reverse coded in the model output. All covariates were in the expected directions: life satisfaction was lower, and symptoms were more prevalent among older adolescents and girls. To explore sex differences in the PA-mental health association, we tested for PA × sex interactions in the individual-level models (Table 3). Interaction effects were minor overall and positive for most outcomes, suggesting marginally stronger associations between PA and better mental health for girls than for boys. For instance, the interaction term was 0.053 for feeling low and 0.068 for irritability. The effect on life satisfaction was negligible (−0.004). We similarly tested PA × age interactions in the same models (Table 3). These interactions were small but statistically significant for three of the four symptom outcomes, indicating a slightly stronger positive association between PA and mental health among older adolescents: feeling low (b = 0.032, 95% CI [0.023, 0.040], p < .001), irritability (b = 0.016, 95% CI [0.007, 0.025], p < .001), and nervousness (b = 0.029, 95% CI [0.020, 0.038], p < .001). The PA × age interactions for life satisfaction (b = −0.003, 95% CI [−0.015, 0.009], p = .626) and sleep difficulty (b = 0.005, 95% CI [−0.004, 0.015], p = .274) were not statistically significant.

Adjusted ICCs, calculated from the covariate-adjusted random-intercept models, indicated that between-country variance accounted for a modest but statistically significant proportion of total variance in each outcome (life satisfaction: 3.4%, $\chi^2(1) = 6794.55$, p < .001; feeling low: 4.6%, $\chi^2(1) = 8840.26$, p < .001; irritability: 4.4%, $\chi^2(1) = 9062.63$, p < .001; nervousness: 5.1%, $\chi^2(1) = 9955.85$, p < .001; sleep difficulty: 3.7%, $\chi^2(1) = 6767.69$, p < .001). This indicates that the vast majority of the variability occurred at the individual level, although country-level clustering remained statistically robust across all outcomes. Throughout, higher (more positive) slope values indicate a stronger positive association between PA and better mental health for that outcome, regardless of whether the outcome itself was reverse-coded. The random-slope models that follow reveal significant between-country variability in the strength of the PA–mental health relationship (Fig. 1, Supplementary Table 1). However, in Fig. 1, only 44 analytic units are represented. Although the HBSC 2017/18 officially included 45 participating countries/regions, our analytic dataset comprised 46 units because Greenland is reported separately. All 46 units were analyzed, and the raw slopes for every country are presented in Supplementary Table 1. However, due to convergence issues and extreme variability in Greece and Bulgaria, these two units were not visualized in Fig. 1, resulting in 44 units being displayed. Slopes are age- and sex-adjusted and represent model-based random slopes, or deviations from the fixed effects, in the multilevel models for each country. For ease of interpretation and to permit secondary analyses, raw country-level slope estimates from which these visualized random slopes were calculated were also extracted and analyzed separately. Slopes visualized in Fig. 1 are model-based random slopes. Slope values reported in the text (e.g., Iceland = 0.47 for life satisfaction) are extracted values used for secondary regression analyses and may not precisely match the visualized slopes. In the case of life satisfaction, slope estimates ranged from 0.08 in Bulgaria to stronger associations in Iceland (0.47), Canada (0.44), and Scotland (0.41). For feelings of low, a negative association between PA and feeling low (i.e., fewer symptoms) was observed in most countries, with slopes ranging from 0.04 to 0.23. The strongest associations were found in Russia (0.23). A similar degree of variability was observed across countries in irritability, nervousness, and sleep difficulty. In the case of irritability, slope estimates ranged from −0.14 to 0.19, with the strongest associations observed in Russia, Spain, Serbia (0.19). Slopes for nervousness ranged from 0.03 to 0.15, with the largest values observed in Scotland (0.15). Slopes for sleep difficulty were also found to similarly range from 0.03 to 0.19, with the strongest (negative) associations in Iceland (0.19), Scotland (0.18) and Canada (0.18). Taken together, Fig. 1 shows that the strength of the PA–mental health association varies substantially across countries for every outcome, raising the question of what explains this cross-national heterogeneity. We next tested one candidate explanation: whether countries differ systematically in this association based on their aggregate level of adolescent-reported health.

Building on the country-level variability shown in Fig. 1, we conducted a secondary analysis to evaluate whether this heterogeneity could be explained by national differences in perceived health, plotting each country's random slope (Fig. 1) against its mean perceived health (Fig. 2) to visualize this candidate explanation directly. To this end, we regressed country-level slope estimates on the national mean of adolescent-reported health (Fig. 2). The extracted slope values had been adjusted for age and sex during the estimation process, but the regressions did not include any further covariates. Results showed a non-significant trend toward moderation for life satisfaction (b = 0.15, p = .076) and sleep difficulty (b = 0.08, p = .092). These exploratory

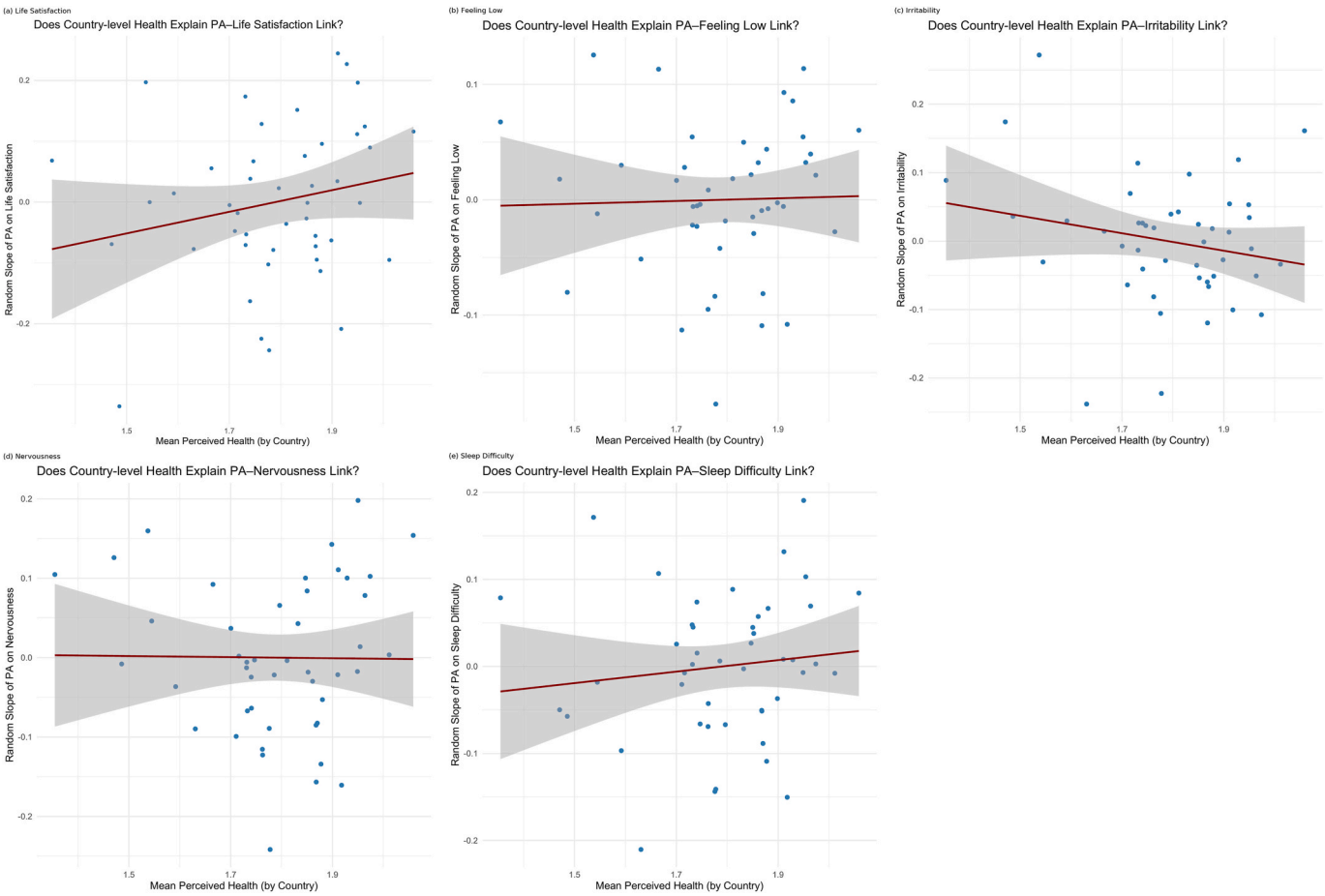


Fig. 2. Cross-level moderation of the physical activity–mental health association by country-level perceived health. *Scatter plots of country-level perceived health and random slopes of PA on adolescent mental health outcomes, with fitted regression lines (95% CI).*

findings tentatively suggest that the PA–mental health association may be somewhat more pronounced in countries where adolescents report better health in general, but should be interpreted with caution given the non-significant test statistics. No significant moderation was observed for feeling low (b = 0.02, p = .621), irritability (b = −0.001, p = .979), or nervousness (b = 0.05, p = .322).

4. Discussion

This study used a large cross-national sample of adolescents from 45 countries to examine whether higher PA was related to better mental health across a variety of indicators. As expected, meeting the daily PA guideline was associated with higher life satisfaction and fewer symptoms of emotional distress (feeling low, irritability, nervousness, sleep difficulty). The effects ranged from modest to substantial (β range: 0.069 [95% CI: 0.048, 0.090] for sleep difficulty to 0.408 [95% CI: 0.381, 0.435] for life satisfaction; Table 3) and were largely consistent across age and sex, with only minimal sex differences. It should be noted that, although statistically significant given the very large sample size, the explained variance attributable to PA at the individual level was modest (marginal R^2 ranged from 0.012 (sleep difficulty) to 0.051 (life satisfaction); conditional $R^2 \approx 0.08$–0.09 across outcomes), indicating that PA accounts for only a small proportion of the total variability in adolescent mental health. These findings should therefore be interpreted in terms of population-level patterns rather than as indicating strong individual-level predictive or clinical significance. Positive associations between PA and mental health were observed across the vast majority of the 45 countries examined, with particularly strong effects in Iceland, Canada, Scotland, Russia, and Ireland. Only minimal or near-zero associations were found in Bulgaria and Georgia, suggesting that the overall positive relationship is robust but not universal. However, the magnitude of these associations varied across countries, indicating that the magnitude of the PA–mental health association is not universal but varies with broader contextual factors. We also observed some indication that country-level perceived health may strengthen the PA–mental health relationship, although moderation effects were marginal and did not reach conventional significance levels. These findings suggest that the PA–mental health association cannot be fully understood without considering the broader environments in which adolescents live. PA operates within complex ecological systems that include cultural norms, institutional supports, and national health environments (Diez-Roux, 1998). By incorporating country-level indicators into the analysis, the present study highlights how contextual conditions are linked to differences in the strength of the PA–mental health relationship (Pesce et al., 2023; Vella et al., 2023).

Significant variability across countries highlighted the role of broader systems. Iceland, Canada, Scotland, Russia, Slovenia, and Ireland showed strong and consistent associations across all mental health indicators. One possible, untested explanation is that these contexts are characterized by investments in public sport infrastructure, daily school PE, and integrated health-promotion policies (Cathro et al., 2024; Pedersen et al., 2022; Rutkauskaite et al., 2021; Warburton et al., 2010). Their education and health systems also emphasize resilience, peer relations, and life skills (Rodger et al., 2014; Whitley & Gooderham, 2015). Russia has recently implemented the GTO fitness campaign (Rubtcova & Pavenkov, 2018; Ryzhkin et al., 2020) and invested in school-based mental health promotion (Slobodskaya et al., 2023), while Slovenia mandates daily PE (Jurak et al., 2014; Sport E. W. G. & Health,

2008) and reports high levels of PA enjoyment and competence (Sember et al., 2016). By contrast, Bulgaria, Georgia, Moldova, Flanders, and the Netherlands displayed weak associations. A similarly speculative interpretation is that, in Eastern European settings, underinvestment in youth-targeted health and leisure services is a major factor (Ignatovitch et al., 2020; Rechel et al., 2009), while structural inequities and psychosocial stressors may overwhelm the association between PA and mental health (Bejenaru et al., 2024; Crismaru, 2020; Way, 2022). In the Netherlands and Flanders, despite high PA participation, ceiling effects and performance/physique-focused cultural framing may reduce mental health returns (McMahon et al., 2017; Ritchie et al., 2024; Vatandoost et al., 2024). Both countries also report some of the highest life satisfaction scores, suggesting a possible ceiling effect (Handa et al., 2023; Levin et al., 2011). We emphasize that these country-specific interpretations are speculative and derived from external literature on national PA policy and culture rather than from variables directly modeled in this study; they should be tested directly in future research using country-level policy or infrastructure indicators.

The moderation coefficients for life satisfaction and sleep difficulty were positive, indicating non-significant trends toward stronger associations with PA in countries reporting higher average perceived health. These patterns did not reach the pre-specified significance threshold and should not be interpreted as evidence of differential effects across national contexts. Nevertheless, they may provide hypotheses for future studies examining more comprehensive country-level health, policy, socioeconomic, and environmental indicators, such as safety, infrastructure, and cultural norms around well-being (Hibbert et al., 2023; Homocianu, 2024; Lau et al., 2025). Sleep, in turn, is strongly tied to stress, regulation, and environmental supports (Billings et al., 2020; Korkutata et al., 2025). By contrast, emotional symptoms such as low mood, irritability, and nervousness are more reactive and psychobiologically complex, associated with personal coping, temperament, and interpersonal stressors (Cassiello-Robbins et al., 2020; Peris-Baquero et al., 2023; Tyra et al., 2021). Cross-cultural differences in how these symptoms are expressed may further reduce comparability (Formella & Ugwuanyi, 2024; He et al., 2021; Hofmann & Hinton, 2014). Thus, macro-level perceived health may differentially moderate well-being versus ill-being outcomes.

Several limitations warrant caution. First, the cross-sectional HBSC design precludes causal inference. Longitudinal or intervention studies are needed. Relatedly, at least three alternative interpretations of the observed PA–mental health association should be considered: (1) consistent with the framing adopted throughout this paper, PA may contribute to better mental health through the neurobiological, psychosocial, and behavioral mechanisms outlined in the Introduction; (2) the relationship may run in the opposite direction: adolescents who already report better mental health may be more likely to initiate and sustain regular PA, for example because they have greater energy, motivation, or social engagement, rather than PA causally improving their mental health; or (3) both PA and mental health may be jointly influenced by unmeasured third variables, such as family socioeconomic status, parental mental health, peer relationships, or underlying temperament, that were not included as covariates in the present models, producing a spurious or partly spurious association even in the absence of any direct causal link between PA and mental health in either direction. The cross-sectional design of this study cannot adjudicate among these three possibilities; longitudinal or experimental designs are needed.

Second, we did not adjust for SES despite its established role as a joint correlate of PA and mental health, due to higher missingness on this measure across countries; sensitivity analyses adjusting for SES in the subsample with complete data would help clarify the robustness of the present findings. We did not conduct this sensitivity analysis in the present study, as FAS data availability varies substantially by country and would have introduced a different, non-overlapping pattern of missingness than the primary analytic sample, complicating direct comparison with the main results; we flag this as a priority for follow-up analysis using this dataset. The same applies to screen time and BMI, both plausible joint correlates of PA and mental health, which were not included as covariates. Third, reliance on self-report may introduce recall bias and cross-cultural differences. Fourth, we included only one national-level moderator (perceived health), whereas school policies, urban design, and family affluence were not. Fifth, we excluded some countries from slope analyses due to statistical instability. Sixth, we did not formally test measurement invariance of the mental health measures across countries. Existing psychometric evidence using the same HBSC wave indicates partial (metric but not scalar) invariance of the Symptom Checklist, with the irritability, nervousness, and feeling low items showing the greatest cross-country non-invariance; this may affect the comparability of absolute mean differences between countries, though it is less likely to substantially bias the within-country PA–mental health associations that are the primary focus of this study, because these associations depend on metric invariance (which was supported) rather than scalar invariance (which was not); scalar non-invariance primarily threatens comparisons of absolute mean levels across countries, such as those presented descriptively in Table 1 and Fig. 1, rather than the relative strength of within-country associations modeled in our primary analyses. Finally, the 2017/2018 data may have limited relevance today, as PA and mental health have since changed alongside COVID-19 (Wang et al., 2023) and technological innovations such as mobile health tools (Lee et al., 2024).

This paper provides cross-national evidence that physical activity is associated with better adolescent mental health, though effect sizes vary by country. Country-level perceived health emerged as a potential moderator, highlighting the importance of macro-level environments in relation to how physical activity relates to youth mental health. Given the cross-sectional design of the present study, longitudinal research should be the first priority for future work, to verify whether these cross-sectional associations hold over time and to help disentangle the direction of the PA–mental health relationship. Building on such longitudinal evidence, future research should also integrate multi-level analyses that link macro-level contexts (e.g., policies, infrastructures) with micro-level mechanisms (psychological, behavioral, biological) to better explain variability. Before such macro-level indicators can inform intervention recommendations, they should be explicitly connected to the more proximal, setting-specific determinants of adolescent PA identified in school, home, and mixed settings (Ciaccioni et al., 2026); country-level context alone is unlikely to translate directly into actionable, individual-level guidance. Overall, this study provides descriptive, population-level evidence that PA is associated with better adolescent mental health across diverse national contexts, though the cross-sectional design precludes conclusions about whether promoting PA would causally improve mental health. Should future longitudinal or intervention research confirm a causal pathway, these findings would suggest that PA-based strategies might also benefit from considering broader contextual environments, rather than treating PA as a stand-alone intervention. This cross-sectional evidence calls for future research to directly evaluate the effectiveness of such context-sensitive strategies.

CRediT authorship contribution statement

Youngjun Lee: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Ciaccioni:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **David Stodden:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Janet Hauck:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Rodrigo A. Lima:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Caterina Pesce:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation,

Data curation, Conceptualization.

Ethics approval

National-level ethics approval was obtained in each country in accordance with HBSC protocols.

Consent to participate/publish

Not applicable (secondary data).

Data availability

HBSC datasets are available upon request from the HBSC Data Management Centre.

Ethics approval and consent to participate

Not applicable. This study analyzed anonymized, publicly available secondary data from the 2017/2018 Health Behaviour in School-aged Children (HBSC) survey. Ethical approval and informed consent were obtained by the original HBSC national research teams at the time of data collection in each participating country; no additional institutional review board approval was required for the present secondary analysis.

Consent for publication

Not applicable.

Data statement

The HBSC 2017/2018 dataset analyzed in this study is available to registered users through the HBSC Data Management Portal at: https://www.hbsc.org/data/

Declaration of generative AI use

During the preparation of this work, the authors did not use AI-assisted tools.

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Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Dr. Caterina Pesce and Dr. David Stodden are Guest Editors of the Special Issue “A Holistic Perspective on Physical Activity and Mental Health.” To avoid any potential conflict of interest, they will not be involved in the editorial handling, reviewer selection, or decision process for this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mhpa.2026.100826.

References

Azevedo, K. P. M.d., de Oliveira, V. H., Medeiros, G. C. B. S.d., Mata, Á. N.d. S., García, D.Á., Martínez, D. G., Leitao, J. C., Knackfuss, M. I., & Piuvezam, G. (2020). The effects of exercise on BDNF levels in adolescents: A systematic review with meta-analysis. *International Journal of Environmental Research and Public Health, 17*(17), 6056.

Bann, D., Scholes, S., Fluharty, M., & Shure, N. (2019). Adolescents' physical activity: Cross-national comparisons of levels, distributions and disparities across 52 countries. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1), 141.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Bejenaru, I., Doga, V., & Ciobanu, M. (2024). Assessing and enhancing children's well-being in Moldova: A methodological framework aligned with EU standards. *Creşterea economică în condiţiile globalizării*.

Biddle, S. J., Ciaccioni, S., Thomas, G., & Vergeer, I. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise, 42*, 146–155.

Billings, M. E., Hale, L., & Johnson, D. A. (2020). Physical and social environment relationship with sleep health and disorders. *Chest, 157*(5), 1304–1312.

Booth, M., Okely, A., Chey, T., & Bauman, A. (2001). The reliability and validity of the physical activity questions in the WHO health behaviour in schoolchildren (HBSC) survey: A population study. *British Journal of Sports Medicine, 35*(4), 263–267.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard university press.

Cassiello-Robbins, C., Anand, D., McMahon, K., Guetta, R., Trumbull, J., Kelley, L., & Rosenthal, M. Z. (2020). The mediating role of emotion regulation within the relationship between neuroticism and misophonia: A preliminary investigation. *Frontiers in Psychiatry, 11*, 847.

Cathro, A., Spence, J. C., Cameron, C., Varela, A. R., Morales, D., Kohn, E. R., Pratt, M., & Hallal, P. C. (2024). Progress in physical activity research, policy, and surveillance in Canada: The global observatory for physical activity–GoPA. *BMC Public Health, 24*(1), 2866.

Chaput, J.-P., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., Jago, R., Ortega, F. B., & Katzmarzyk, P. T. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: Summary of the evidence. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 141.

Ciaccioni, S., Oddi, L., Kolovelonis, A., Syrmpas, I., Marcuzzi, A., Khudair, M., Ng, K., Tempest, G. D., Peric, R., & Bartoš, F. (2026). Modifiable determinants of adolescents' physical activity and sedentary behaviour in school, home and mixed settings: A DE-PASS systematic review and meta-analysis of self-reported data with a holistic analysis. *Mental Health and Physical Activity*, Article 100803.

Crismaru, M. (2020). A critical review of youth-oriented policies in the Republic of Moldova from the perspective of youth transition regime. *Economie şi Sociologie*, (2), 131–139.

Diez-Roux, A. V. (1998). Bringing context back into epidemiology: Variables and fallacies in multilevel analysis. *American journal of public health, 88*(2), 216–222.

Eather, N., Wade, L., Pankowiak, A., & Eime, R. (2023). The impact of sports participation on mental health and social outcomes in adults: A systematic review and the ‘mental health through sport’conceptual model. *Systematic Reviews, 12*(1), 102.

Elgar, F. J., Pförtner, T.-K., Moor, I., De Clercq, B., Stevens, G. W., & Currie, C. (2015). Socioeconomic inequalities in adolescent health 2002–2010: A time-series analysis of 34 countries participating in the health behaviour in School-aged children study. *The Lancet, 385*(9982), 2088–2095.

Elmose-Østerlund, K., Dalgas, B. W., Bredahl, T. V. G., Lenze, L., Høyer-Kruse, J., & Ibsen, B. (2023). Motives for leisure-time physical activity participation: An analysis of their prevalence, consistency and associations with activity type and social background. *BMC Public Health, 23*(1), 2399.

Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel models: A new look at an old issue. *Psychological Methods, 12*(2), 121.

European Union. (2020). *Health at a glance: Europe 2020 state of health in the EU cycle: State of health in the EU cycle*. OECD Publishing.

Formella, Z., & Ugwuanyi, B. C. (2024). *Cross-cultural considerations in the assessment and treatment of depression: A comparative analysis*.

Fu, Q., Li, L., Li, Q., & Wang, J. (2025). The effects of physical activity on the mental health of typically developing children and adolescents: A systematic review and meta-analysis. *BMC Public Health, 25*(1), 1514.

Gammon, C., Atkin, A. J., Corder, K., Ekelund, U., Hansen, B. H., Sherar, L. B., Andersen, L. B., Anderssen, S., Davey, R., & Hallal, P. C. (2022). Influence of guideline operationalization on youth activity prevalence in the international children's accelerometry database. *Medicine & Science in Sports & Exercise, 54*(7), 1114.

Handa, S., Pereira, A., & Holmqvist, G. (2023). The rapid decline of happiness: Exploring life satisfaction among young people across the world. *Applied Research in Quality of Life, 18*(3), 1549–1579.

Haugen, T., Säfvenbom, R., & Ommundsen, Y. (2013). Sport participation and loneliness in adolescents: The mediating role of perceived social competence. *Current Psychology, 32*(2), 203–216.
He, Z., Muhlert, N., & Elliott, R. (2021). Emotion regulation of social exclusion: A cross-cultural study. *Humanities and Social Sciences Communications, 8*(1), 1–7.
Heinz, A., Sischka, P. E., Catunda, C., Cosma, A., García-Moya, I., Lyyra, N., Kaman, A., Ravens-Sieberer, U., & Pickett, W. (2022). Item response theory and differential test functioning analysis of the HBSC-Symptom-Checklist across 46 countries. *BMC Medical Research Methodology, 22*(1), 253.
Hibbert, P. D., Stewart, S., Wiles, L. K., Braithwaite, J., Runciman, W. B., & Thomas, M. J. (2023). Improving patient safety governance and systems through learning from successes and failures: Qualitative surveys and interviews with international experts. *International Journal for Quality in Health Care, 35*(4), 0.
Hofmann, S. G., & Hinton, D. E. (2014). Cross-cultural aspects of anxiety disorders. *Current Psychiatry Reports, 16*(6), 450.
Homocianu, D. (2024). Life satisfaction: Insights from the world values survey. *Societies, 14*(7), 119.
Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: A review of twenty-seven community studies. *Journal of Health and Social Behavior*, 21–37.
Ignatovitch, A., Fras, M., & Basarab, T. (2020). *Youth work in eastern Europe: Realities, perspectives and inspiring initiatives*, 2020.
Jemni, M., Zaman, R., Carrick, F. R., Clarke, N. D., Marina, M., Bottoms, L., Matharoo, J. S., Ramsbottom, R., Hoffman, N., & Groves, S. J. (2023). Exercise improves depression through positive modulation of brain-derived neurotrophic factor (BDNF). A review based on 100 manuscripts over 20 years. *Frontiers in Physiology, 14*, Article 1102526.
Jurak, G., Kovač, M., Starc, G., & Strel, J. (2014). Support of science for political decisions about physical education in Slovenia. *SportLogia, 10*(2).
Keyes, C. L. (2005). Mental illness and/or mental health? Investigating axioms of the complete state model of health. *Journal of Consulting and Clinical Psychology, 73*(3), 539.
Kim, Y., & Shim, J. (2025). Relevance of self-rated health level and mental health in Korean adolescents. *Frontiers in Public Health, 13*, Article 1526127.
Kolovelonis, A., Syrmpas, I., Marcuzzi, A., Khudair, M., Ng, K., Tempest, G. D., Peric, R., Bartoš, F., Maier, M., & Brandes, M. (2024). DE-PASS best evidence statement (BESt): Determinants of adolescents' device-based physical activity and sedentary behaviour in settings: A systematic review and meta-analysis. *BMC Public Health, 24*(1), 1706.
Korkutata, A., Korkutata, M., & Lazarus, M. (2025). The impact of exercise on sleep and sleep disorders. *npj Biological Timing and Sleep, 2*(1), 5.
Lau, H. Y., Welfel, S. M., LAU, H. Y., & Welfel, S. (2025). Predictors of life satisfaction in US adults: A cross-sectional analysis of health status, physical activity, employment, and intersectional factors. *Cureus, 17*(6).
Lee, Y., Hauck, J., & Brooks, D. (2023). Sex-specific physical activity levels and energy intake in US young adults with depression: National health and nutrition examination survey 2017–2020 pre-pandemic data. *Physical Activity and Health, 7*(1).
Lee, Y. H., Kim, H., Hwang, J., & Noh, S. (2024). Effectiveness of mobile-based progressive and fixed physical activity on depression, stress, anxiety, and quality of life outcomes among adults in South Korea: Randomized controlled trial. *JMIR mHealth and uHealth, 12*(1), Article e55578.
Levin, K. A., Torsheim, T., Vollebergh, W., Richter, M., Davies, C. A., Schnohr, C. W., Due, P., & Currie, C. (2011). National income and income inequality, family affluence and life satisfaction among 13 year old boys and girls: A multilevel study in 35 countries. *Social Indicators Research, 104*(2), 179–194.
Li, H., & Hao, F. (2025). The influence of physical activity on the mental health of high school students: The chain mediating effects of social support and self-esteem. *Scientific Reports, 15*(1), Article 27537.
Liu, R., Qi, X., Mao, W., Luo, H., Xu, Z., & Wu, B. (2025). Social context matters: Neighborhood environment as a moderator of the longitudinal relationship between edentulism and cognitive function among older adults in the United States. *Archives of Gerontology and Geriatrics, 133*, Article 105806.
Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics, 138*(3), Article e20161642.
Lumley, T. (2004). Analysis of complex survey samples. *Journal of Statistical Software, 9*, 1–19.
Martín-Rodríguez, A., Gostian-Ropotin, L. A., Beltrán-Velasco, A. I., Belando-Pedreño, N., Simón, J. A., López-Mora, C., Navarro-Jiménez, E., Tornero-Aguilera, J. F., & Clemente-Suárez, V. J. (2024). Sporting mind: The interplay of physical activity and psychological health. *Sports, 12*(1), 37.
McMahon, E. M., Corcoran, P., O'Regan, G., Keeley, H., Cannon, M., Carli, V., Wasserman, C., Hadlaczky, G., Sarchiapone, M., & Apter, A. (2017). Physical activity in European adolescents and associations with anxiety, depression and well-being. *European Child & Adolescent Psychiatry, 26*(1), 111–122.
Moon, I., & Han, J. (2022). Moderating effects of physical activity on the relationship between adverse childhood experiences and health-related quality of life. *International Journal of Environmental Research and Public Health, 19*(2), 668.
Moor, I., Winter, K., Bilz, L., Bucksch, J., Finne, E., John, N., Kolip, P., Paulsen, L., Ravens-Sieberer, U., & Schlattmann, M. (2020). The 2017/18 health Behaviour in school-aged Children (HBSC) study–methodology of the world health Organization's child and adolescent health study. *Journal of Health Monitoring, 5*(3), 88.
Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining R^2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution, 4*(2), 133–142. https://doi.org/10.1111/j.2041-210x.2012.00261.x.
Nguyen Ho, P. T., Ha, P. B. T., Tong, T., Bramer, W. M., Hofman, A., Lubans, D. R., Vernooij, M. W., & Rodriguez-Ayllon, M. (2023). Mechanisms linking physical activity with psychiatric symptoms across the lifespan: A systematic review. *Sports Medicine, 53*(11), 2171–2190.
Nie, Y., Wang, W., Guo, M., Tang, W., Qu, G., Wang, X., Zhou, F., Ma, W., Qiu, W., & Gao, J. (2025). Analysis of the association between adolescent physical activity and life satisfaction: A systematic review and meta-analysis. *BMC Psychology, 13*(1), 738.
Noetel, M., Sanders, T., Gallardo-Gómez, D., Taylor, P., del Pozo Cruz, B., Van Den Hoek, D., Smith, J. J., Mahoney, J., Spathis, J., & Moresi, M. (2024). Effect of exercise for depression: Systematic review and network meta-analysis of randomised controlled trials. *bmj, 384*.
Ntoumanis, N., Ng, J. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Lonsdale, C., & Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review, 15*(2), 214–244.
Pascoe, M., Bailey, A. P., Craike, M., Carter, T., Patten, R., Stepto, N., & Parker, A. (2020). Physical activity and exercise in youth mental health promotion: A scoping review. *BMJ Open Sport & Exercise Medicine, 6*(1), Article e000677.
Patton, G. C., Sawyer, S. M., Santelli, J. S., Ross, D. A., Afifi, R., Allen, N. B., Arora, M., Azzopardi, P., Baldwin, W., & Bonell, C. (2016). Our future: A lancet commission on adolescent health and wellbeing. *The Lancet, 387*, 2423–2478, 10036.
Pedersen, M. R. L., Bredahl, T. V. G., Elmose-Østerlund, K., & Hansen, A. F. (2022). Motives and barriers related to physical activity within different types of built environments: Implications for health promotion. *International Journal of Environmental Research and Public Health, 19*(15), 9000.
Peris-Baquero, Ó., Moreno-Pérez, J., Navarro-Haro, M., Díaz-García, A., & Osma, J. (2023). Emotion dysregulation and neuroticism as moderators of group unified protocol effectiveness outcomes for treating emotional disorders. *Journal of Affective Disorders, 331*, 313–321.
Pesce, C., Vazou, S., Benzing, V., Álvarez-Bueno, C., Anzeneder, S., Mavilidi, M. F., Leone, L., & Schmidt, M. (2023). Effects of chronic physical activity on cognition across the lifespan: A systematic meta-review of randomized controlled trials and realist synthesis of contextualized mechanisms. *International Review of Sport and Exercise Psychology, 16*(1), 722–760.
Phillips, C. (2017). Brain-derived neurotrophic factor, depression, and physical activity: Making the neuroplastic connection. *Neural Plasticity, 2017*(1), Article 7260130.
Piggin, J. (2020). What is physical activity? A holistic definition for teachers, researchers and policy makers. *Frontiers in Sports and Active Living, 2*, 72. https://doi.org/10.3389/fspor.2020.00072.
Rechel, B., Blackburn, C. M., Spencer, N. J., & Rechel, B. (2009). Access to health care for Roma children in central and eastern Europe: Findings from a qualitative study in Bulgaria. *International Journal for Equity in Health, 8*(1), 24.
Ritchie, I., Nieto, I., Brunn, M., Mayo, X., & Jiménez, A. (2024). Social value framing of physical activity in European member state policies: A content analysis. *Frontiers in Sports and Active Living, 6*, Article 1415007.
Roberts, C., Currie, C., Samdal, O., Currie, D., Smith, R., & Maes, L. (2007). Measuring the health and health behaviours of adolescents through cross-national survey research: Recent developments in the Health Behaviour in School-aged Children (HBSC) study. *Journal of Public Health, 15*(3), 179–186.
Rodger, S., Hibbert, K. M., Leschied, A. W., Stepien, M., Atkins, M.-A., Koenig, A., Woods, J., & Vandermeer, M. (2014). *Mental health education in Canada: An analysis of teacher education and provincial/territorial curricula. Physical and Health Education Canada*.
Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-García, P., Henriksson, H., Mena-Molina, A., & Martínez-Vizcaíno, V. (2019). Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 49*(9), 1383–1410.
Rubtcova, M., & Pavenkov, O. (2018). Influence of innovative pedagogical technique on results of passing of gto complex's standards by Russian students. In *214th international conference on medical & health Science-ICMHS*.
Rutkauskaite, R., Gisladottir, T., Pihu, M., Kjonniksen, L., Lounassalo, I., Huovinen, T., Gruodyte-Raciene, R., Visagurskiene, K., Olafson, O., & Kull, M. (2021). Schoolyard affordances for physical activity: A pilot study in 6 Nordic–Baltic countries. *Sustainability, 13*(21), Article 11640.
Ryzhkin, N., Tumasyan, T., Brovashova, O., Nemtseva, E., & Ivanova, A. (2020). In *GTO complex as the basis of physical education in DSTU. E3S web of conferences*.
Sember, V., Starc, G., Jurak, G., Golobič, M., Kovač, M., Samardžija, P. P., & Morrison, S. A. (2016). Results from the republic of Slovenia's 2016 report card on physical activity for children and youth. *Journal of Physical Activity and Health, 13*(s2), S256–S264.
Slobodskaya, H. R., Safronova, M. V., Kharchenko, I. I., Rezun, E. V., & Kornienko, O. S. (2023). Russian adolescent mental health in 2002, 2015 and during the COVID-19 pandemic in 2021. *Child and Adolescent Mental Health, 28*(1), 158–166.
Sport, E. W. G., & Health. (2008). EU physical activity guidelines recommended policy actions in support of health-enhancing physical activity. *Approved by the EU working group 'sport & Health' at its meeting on 25 September 2008, confirmed by EU member state sport ministers at their meeting in Biarritz on 27–28 November 2008*.
Stalsberg, R., & Pedersen, A. V. (2010). Effects of socioeconomic status on the physical activity in adolescents: A systematic review of the evidence. *Scandinavian Journal of Medicine & Science in Sports, 20*(3), 368–383.
Stillman, C. M., Esteban-Cornejo, I., Brown, B., Bender, C. M., & Erickson, K. I. (2020). Effects of exercise on brain and cognition across age groups and health states. *Trends in Neurosciences, 43*(7), 533–543.

Tyra, A. T., Griffin, S. M., Fergus, T. A., & Ginty, A. T. (2021). Individual differences in emotion regulation prospectively predict early COVID-19 related acute stress. *Journal of Anxiety Disorders, 81*, Article 102411.

Vatandoost, S., Baetens, I., Erjaee, Z., Azadfar, Z., Van Heel, M., & Van Hove, L. (2024). A comparative analysis of emotional regulation and maladaptive symptoms in adolescents: Insights from Iran and Belgium. *Healthcare*.

Vella, S. A., Sutcliffe, J. T., Fernandez, D., Liddelow, C., Aidman, E., Teychenne, M., Smith, J. J., Swann, C., Rosenbaum, S., & White, R. L. (2023). Context matters: A review of reviews examining the effects of contextual factors in physical activity interventions on mental health and wellbeing. *Mental Health And Physical Activity, 25*, Article 100520.

Wang, C., Tian, Z., & Luo, Q. (2023). The impact of exercise on mental health during the COVID-19 pandemic: A systematic review and meta-analysis. *Frontiers in Public Health, 11*, Article 1279599.

Warburton, D. E., Charlesworth, S., Ivey, A., Nettlefold, L., & Bredin, S. S. (2010). A systematic review of the evidence for Canada's physical activity guidelines for adults. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 39.

Way, L. A. (2022). Georgia, Moldova, and Ukraine. *Democracy in Hard Places*, 128–160.

Weinberg, D., Stevens, G. W., Bucksch, J., Inchley, J., & de Looze, M. (2019). Do country-level environmental factors explain cross-national variation in adolescent physical activity? A multilevel study in 29 European countries. *BMC Public Health, 19*(1), 680.

White, R. L., Vella, S., Biddle, S., Sutcliffe, J., Guagliano, J. M., Uddin, R., Burgin, A., Apostolopoulos, M., Nguyen, T., & Young, C. (2024). Physical activity and mental health: A systematic review and best-evidence synthesis of mediation and moderation studies. *International Journal of Behavioral Nutrition and Physical Activity, 21*(1), 134.

Whitley, J., & Gooderham, S. (2015). Mental health promotion efforts for children and youth in Canada and beyond: Evidence in research, policy and practice. *Exceptionality Education International, 25*(1).

World Health Organization. (2020a). Spotlight on adolescent health and well-being. Findings from the 2017/2018 Health Behaviour in school-aged children (HBSC) survey in Europe and Canada. *International report. Volume 1. Key findings*.

World Health Organization. (2020b). *WHO report on health behaviours of 11–15-year-olds in Europe reveals more adolescents are reporting mental health concerns*. World Health Organization. https://www.who.int/europe/news/item/19-05-2020-who-report-on-health-behaviours-of-11-15-year-oldsin-europe-reveals-more-adolescents-are-reporting-mental-health-concerns.

Wu, K., Wang, S., Ding, T., & Li, Y. (2023). The direct effect of exercise on the mental health of scientific and technological professionals and the mediating effects of stress, resilience, and social support. *Frontiers in Public Health, 11*, Article 1074418.