Received: 6 August 2024 | Accepted: 12 May 2025

DOI: 10.1111/jora.70035

JOURNAL OF Research on Adolescence

EMPIRICAL ARTICLE

Physical activity and two-year change in adolescent well-being in nine countries

Christina Bertrand[1] | Laurence Steinberg[2] | Natasha Duell[3] | Laura Di Giunta[4] | Kenneth A. Dodge[5] | Sevtap Gurdal[6] | Daranee Junla[7] | Jennifer E. Lansford[5] | Paul Oburu[8] | Concetta Pastorelli[4] | Ann T. Skinner[5] | Emma Sorbring[6] | Marc H. Bornstein[9,10,11] | Liliana Maria Uribe Tirado[12] | Saengduean Yotanyamaneewong[7] | Liane Peña Alampay[13] | Suha M. Al-Hassan[14] | Dario Bacchini[15] | Lei Chang[16] | Kirby Deater-Deckard[17]

Correspondence
Kirby Deater-Deckard, Department of Psychological and Brain Sciences, University of Massachusetts Amherst, 135 Hicks Way, Amherst, MA 01002, USA.
Email: kdeaterdeck@umass.edu

Funding information
Eunice Kennedy Shriver National Institute of Child Health and Human Development, Grant/Award Number: RO1-HD054805; Fogarty International Center, Grant/Award Number: RO3-TW008141

Abstract

The benefits of physical activity (PA) for well-being are well known; however, studies examining longitudinal effects across diverse international samples in late adolescence are limited. This study advances prior work by combining a partial longitudinal design with a multinational sample to assess the predictive effect of PA on biennial change in older adolescents' well-being, while testing for sex differences. The sample included 903 adolescents (50.4% female) from nine countries, who completed The European Health and Behavior Survey at age 16 and the EPOCH Measure of Adolescent Well-Being at ages 16 and 18. Multilevel modeling estimated the average impact of PA on change in well-being, controlling for baseline well-being. To further interrogate the findings, an additional analysis tested the effect using relative difference scores of well-being to provide a direct measure of simple change. Meta-analytic techniques then captured the degree of cross-country consistency in the estimated effect. Results indicated that more PA at age 16 significantly predicted greater EPOCH well-being at age 18, controlling for prior well-being at age 16, and that adolescent sex did not moderate this effect. The relative difference score analysis confirmed these results. The meta-analysis revealed no significant heterogeneity in the predictive effect across countries. Findings extend previous research by demonstrating the cross-cultural consistency of PA benefits during a critical developmental transition period. They suggest that PA is a modifiable behavior that can be utilized globally to enhance adolescent well-being, though individual differences and context-specific factors should be considered in public health policies and interventions.

KEYWORDS
adolescence, EPOCH well-being, physical activity, positive youth characteristics

The authors are indebted to the Parenting Across Cultures group, our community partners, and are extremely grateful to the families who shared their time and experiences with us. Research reported in this manuscript was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development Grant under Award Number RO1-HD054805 and Fogarty International Center Grant RO3-TW008141. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or Fogarty International Center.

Parts of the findings presented in this article were disseminated at the 2024 American College of Sports Medicine annual meeting (Free communication slide presentation, results from physical activity and EPOCH well-being at age 16 only). This study was not preregistered. The data that support the findings of this study are available from the corresponding author upon reasonable request. Code for analyses is available upon request.

Procedures for the project were approved by the Duke University Institutional Review Board (IRB; Protocol number: 2032), as well as by university IRBs in all participating countries. Informed consent/assent was obtained from all parents and adolescents included in the study. Participants completed measures separately to ensure privacy.

For affiliations refer to page 10.

INTRODUCTION

Physical activity (PA) is consistently mentioned as a pillar of health with profound benefits for both physical and mental well-being. Regular PA is associated with reduced risk of non-communicable diseases such as cardiovascular disease, cancer, and diabetes, as well as the general risk of all-cause mortality (Ahmed et al., 2012; Mctiernan et al., 2019). Beyond physical health, PA is frequently connected to positive mental health outcomes, with the ability to reduce symptoms of depression and anxiety, improve cognitive functions, and enhance overall well-being (Biddle et al., 2019; Costigan et al., 2019; Hillman et al., 2008). Given these wide-ranging benefits, current guidelines recommend that adolescents perform at least 60 minutes of moderate-to-vigorous daily PA, mainly aerobic, along with 3 days weekly of vigorous-intensity aerobic and muscle/bone strengthening activities (Powell et al., 2019; Physical Activity Guidelines Advisory Committee, 2018). However, data regarding adolescent PA are troubling: around the globe, more than 80% of adolescents do not meet the recommended levels of PA, following a decades long decline (Guthold et al., 2020). Low PA poses a serious public health concern considering its potential role in promoting long-term well-being and positive developmental outcomes (Eberhardt et al., 2020; Leone et al., 2023).

Importance of PA during adolescence

Understanding the association between PA and well-being is crucial at all ages but perhaps especially in adolescence because it is a critical developmental period marked by profound biological and social changes (Graber et al., 2010; Larsen & Luna, 2018). These transitions affect both PA patterns and well-being outcomes, making adolescence an opportune time to examine how PA contributes to well-being trajectories (Cairney et al., 2014; Dorn et al., 2019). The complexity of development during this stage is seen in the wide variation in well-being among adolescents, with public health agencies such as the World Health Organization (WHO, 2020) and United Nations International Children's Emergency Fund (UNICEF, 2021) indicating that mental health challenges affect 1 in 7 adolescents in the world. While longitudinal research on PA and well-being exists, studies examining these effects specifically during late adolescence (e.g., ages 16–18) remain limited. However, this developmental window represents a critical transition toward emerging adulthood, a time characterized by increased agency and identity formation, with the potential to be a very positive developmental stage, specifically with sufficient physical and mental health (Wood et al., 2018), making it particularly important to understand how PA influences well-being during this time.

Moreover, although research in adolescence has increased over the past decade, there remains a need to study older adolescents (Van Sluijs et al., 2021). Despite the well-established recognition of PA's mental health benefits, most adolescent studies are cross-sectional and focus on static well-being. Studying change in well-being provides information about developmental trajectories, which is especially important in late adolescence given the significant personal, social, and academic transitions occurring at this time. The present study aimed to address this gap using a partial longitudinal design to assess how PA at age 16 predicts change in well-being (measured biennially) at age 18, accounting for baseline well-being in a diverse international sample of adolescents. By focusing on older adolescents and change in positive well-being characteristics, this study contributes to understanding of how PA may support healthy developmental trajectories in the transitional period between adolescence and emerging adulthood.

Beyond psychopathology: Focusing on well-being

In addition to addressing the need for more studies with older adolescents, it is important to consider how well-being is measured and conceptualized in adolescent mental health research. Much of the existing mental health research focuses on low levels of negative emotionality and psychopathology (e.g., Bell et al., 2019; Costigan et al., 2019; McMahon et al., 2017), but well-being is not merely the absence of psychological problems. Rather, well-being encompasses critical positive aspects of mental health that contribute to long-term developmental success, particularly in adolescence, including but not limited to the five characteristics captured by the EPOCH measure introduced above (Kern et al., 2016; Rothenberg et al., 2021). Engagement captures involvement and focus on activities, which is crucial for academic and personal development. Perseverance reflects persistently pursuing goals, essential for long-term success. Optimism relates to hopefulness about the future, which can promote resiliency and healthy adaptation. Connectedness encompasses positive relationships, crucial for socioemotional development, and happiness reflects positive mood and life satisfaction, indicative of overall well-being. These characteristics may be particularly malleable during late adolescence as youth transition toward emerging adulthood (Kern et al., 2016; Rothenberg et al., 2021; Wood et al., 2018).

While many well-being measures take a broader approach, the EPOCH measure is designed to capture five positive youth characteristics that have been repeatedly associated with adolescent well-being and flourishing (Kern et al., 2016), making it uniquely suited to examining how modifiable behaviors like PA may nurture adolescent well-being that can persist into adulthood (Ahmed et al., 2012; Kern et al., 2016; for a review see Rocliffe et al., 2024). Although the EPOCH measure has been validated across diverse adolescent populations, it remains underutilized in large-scale, multinational adolescent PA research, with most prior EPOCH research focused on validation or cross-sectional associations (Maurer et al., 2021; Zeng & Kern, 2019). To our knowledge, the current study extends

JOURNAL OF Research on Adolescence

existing research by applying the EPOCH measure in a partial longitudinal, multinational sample of older adolescents to examine how PA contributes to changes in specific *positive* psychological traits during a unique and transitional developmental period.

Direct associations between PA and well-being

In terms of the effect of PA on subsequent well-being, it may contribute to each EPOCH characteristic in distinct ways. For example, PA can improve focus and cognitive function, thereby enhancing engagement (Belcher et al., 2021). It also provides opportunities for social engagement and interpersonal connectedness, particularly through group PAs (Umstattd Meyer et al., 2021; Won et al., 2023). Regular PA may reinforce behavioral discipline, potentially fostering perseverance, though the link between PA and perseverance has not been thoroughly examined and existing evidence for PA's positive influence on perseverance is mixed (Marentes-Castillo et al., 2024; Rutberg et al., 2020; Yin et al., 2023). Further, according to the Psychosocial Mechanism Hypothesis (Lubans et al., 2016) and empirical evidence, PA can improve positive mood and overall mental health, increase self-confidence and self-efficacy, and thereby enhance optimism and happiness (Iwon et al., 2021; Zhang & Chen, 2019).

Physiologically, PA releases endorphins, increases blood flow and oxygenation, regulates neurotransmitters, exerts neuroplastic effects, and produces neurotrophins such as brain-derived neurotrophic factor (BDNF), all of which help to boost mood and reduce stress (Azevedo et al., 2020; Belcher et al., 2021; Mikkelsen et al., 2017). It is also important to note that the association between PA and well-being may be bidirectional, with well-being potentially influencing PA engagement (Ibáñez Román et al., 2023; Kim et al., 2020; Lubans et al., 2016). Examination of these psychosocial and physiological pathways offers insight into how PA can contribute to the growth and maintenance of the five psychological characteristics of EPOCH well-being. Given that both PA (Brown et al., 2024; Pearson et al., 2015; Redublado et al., 2024) and the EPOCH well-being characteristics are malleable, targeting PA as a potential intervention could support the development of these five characteristics during adolescence, improving adolescent well-being with long-term benefits that extend into adulthood.

Although the potential of PA to enhance well-being is recognized, most existing research has been conducted in Western industrialized national contexts (Rothenberg et al., 2021) and has often focused on broad age ranges or young adolescents. Though some studies have examined PA and well-being across multiple countries, they often report only global PA trends (e.g., prevalence or decline; Van Sluijs et al., 2021) rather than testing whether the relationship between PA and well-being varies across cultural contexts, specifically in older adolescents (Aubert et al., 2021). Yet, questions regarding whether and how PA and well-being covary in distinct cultural contexts is an important one: social norms, environmental factors, and cultural perspectives on PA can influence both adolescents' PA participation and the psychological benefits they derive from it. For example, public health infrastructure, gender norms around movement, and attitudes toward leisure-time activity may differ across cultural settings, potentially influencing consistency in the strength of the PA—well-being association (Guthold et al., 2020).

Thus, the present study aimed to extend existing research by using a partial longitudinal design and meta-analytic techniques to assess the consistency in the PA–well-being association across older adolescent samples from nine international sites. This approach offers the opportunity to better understand whether the benefits of PA for well-being are stable across different national contexts or influenced by country-level factors during the transition from adolescence to emerging adulthood. Such findings have important implications for global public health strategies that use movement to improve adolescent well-being, with effects that may persist into adulthood.

Sex differences in the association between PA and well-being

Beyond potential country-level differences, the association between adolescent PA and well-being may also vary by individual difference factors, such as sex. These differences are often explored in the literature presumably based on self-reported binary sex assigned at birth, though the studies cited in the present paper did not always specify how sex or gender was measured. Although PA generally declines during adolescence for both sexes, males remain more active on average (Cairney et al., 2014), with this gap potentially widening during late adolescence as youth transition toward adulthood. Prior findings indicate that increased activity appears beneficial for mental health in both sexes (Halliday et al., 2019). For instance, team sports or group physical activities may enhance well-being more than individual activities for both males and females (Murphy et al., 2020) However, others suggest that females may face greater PA-related psychosocial issues, such as lower self-esteem, perceived competence, and body image concerns, particularly during the dynamic period of adolescence (Cowley et al., 2021; Pawlowski et al., 2018). Moreover, some evidence suggests that PA intensity may influence outcomes differently, with vigorous PA potentially benefiting males more and moderate PA more advantageous for females (Hands & Parker, 2016).

Despite these findings, there remains a limited number of studies testing whether sex moderates PA's influence on changes in adolescent well-being over time, particularly in late adolescence, and across diverse international contexts. This represents an important gap in the literature that the current study addressed by exploring the potential moderating role of sex within a longitudinal, multinational

framework. By examining whether sex differences influence the association between PA and well-being changes in older adolescents across nine countries, this study contributes a more complete understanding of how PA interventions might be optimized for different populations during this distinct developmental stage.

The current study

The present study examined whether PA at age 16 statistically predicted biennial change in EPOCH well-being characteristics among adolescents from nine international sites. Longitudinal research on PA and well-being exists, but studies that concurrently test these effects across culturally diverse international samples during late adolescence are rare. This study contributes to the existing literature by using a partial longitudinal design to test predictive effects of PA on positive well-being change across 2 years in a sample of older adolescents, while also examining whether adolescent sex moderates this association. Additionally, meta-analytic techniques were used to estimate the consistency across nine countries in the statistical effect size of PA on change in adolescent EPOCH well-being across global contexts.

Moreover, the use of the EPOCH measure allows for assessing positive developmental outcomes compared to well-being measures that often primarily capture emotional states or distress. Though some multi-country longitudinal PA studies exist, this study is among the first to apply the EPOCH measure to examine how PA predicts biennial change in EPOCH well-being across diverse cultural contexts. Thus, this study attempts to address key gaps in knowledge: Prior work has included samples from various countries, but fewer studies have explicitly examined whether PA's potential effects generalize consistently across diverse cultural and national contexts around the globe. Additionally, much of the literature has examined inactivity and risk for psychopathology at the cost of not examining the presence of PA as a predictor of positive well-being change, as we have done in the current study.

Specifically, using multilevel modeling, hierarchical regression, and meta-analysis techniques, we aimed to estimate (1) the predictive effect of PA on adolescent well-being at age 18, accounting for baseline EPOCH at age 16, and testing the association using a direct measure of change (i.e., relative difference score); (2) the moderating role of sex on the association; (3) the pooled effect size, which denotes the overall strength and direction of the effect for the total sample; and (4) the degree of consistency of the effect across nine countries.

Based on the well-documented benefits of PA, which are likely to be observed across distinct contexts, we hypothesized that higher PA at age 16 would predict greater well-being at age 18, accounting for baseline well-being. Although we expected this effect to be consistent across countries, we also tested whether the strength of this association was consistent across sites given cross-national differences in social norms and access to PA. With existing research showing sex-based differences in PA engagement (Cairney et al., 2014; Murphy et al., 2020), as well as psychosocial barriers to PA, perhaps especially for females (Cowley et al., 2021; Pawlowski et al., 2018), we explored whether adolescent binary sex would statistically moderate PA as a statistical predictor of two-year change in EPOCH well-being. However, given the mixed evidence on sex differences in the well-being benefits of PA (Costigan et al., 2019; Halliday et al., 2019), no directional hypothesis was made for this moderation effect. The current study's unique combination of a partial longitudinal design, diverse multinational sample, focus on older adolescents, and examination of cross-country consistency extends prior research by providing a more comprehensive understanding of the benefits of PA for adolescent well-being. Ultimately, findings may help to inform public health policies, interventions, and future research in adolescent health and well-being, particularly regarding how PA can be encouraged as a modifiable means for improving positive well-being across diverse international contexts.

METHODS

Participants

Participants included 903 adolescents (50.4% female) from sites across nine countries (China, $N = 95$; Colombia, $N = 78$; Italy, $N = 183$; Jordan, $N = 93$; Kenya, $N = 46$; the Philippines, $N = 79$; Sweden, $N = 51$; Thailand, $N = 81$; the United States, $N = 197$) who are part of the Parenting Across Cultures (PAC) study. PA was measured only once at age 16 and well-being was assessed at age 16 and age 18, using an adapted European Health and Behavior Survey and EPOCH measure, respectively. Youth were $M = 16.33$ years old (SD = 0.99) and $M = 18.64$ years old (SD = 0.93).

Procedure

Families were recruited to participate through letters sent to schools at each site. Response rates ranged from 24% to 100%, in part due to differences in school involvement in the recruitment process. When possible, members of the research team brought recruitment letters and forms to the schools, and teachers sent them home with the children, who then returned the forms with their contact information if the parent wanted to learn more about the study (for additional details see Lansford et al., 2018). Economic diversity in the sample was ensured by sampling from private and public schools and including high- to low-income families in representative proportions for each site. However, the samples are not nationally representative for each country.

Children and their parents completed the measures at each time point via face-to-face interviews (in the participant's home, at the child's school, at the research site, or in another location chosen by the participant), telephone

interviews, or by written questionnaires. All questionnaires/interview questions were forward- and back-translated by translators fluent in English and the target language to clarify any item-by-item ambiguities in linguistic or semantic content (Erkut, 2010). During the translation process, translators also noted any items that did not translate well (i.e., were inappropriate, not culturally sensitive, had multiple meanings), and suggested improvements (Peña, 2007). The procedures were approved by Institutional Review Boards in each country. Parents and children provided consent/assent and completed measures separately to ensure privacy. Participants were offered modest compensation for their time at rates deemed appropriate by each of the participating institutions.

Measures

Physical activity (PA)

PA engagement level was collected once at age 16 using three items from a self-report measure that was adapted from The European Health and Behavior Survey (Wardle & Steptoe, 1991). This survey has shown evidence for reliability and validity across different contexts, including for PA engaged in at work, during transportation, and intentional PA as exercise. Correlations between self-reported PA and direct measures of PA using accelerometers are typically moderate (Baumeister et al., 2016). The questions ask about PA frequency over the prior 7 days, and responses are coded on a 5-point scale (1 = *none* and 5 = *2+ times each day*). Specifically, they were asked: 1. How many days they engaged in a physical activity for at least 20 minutes that made them sweat and breathe hard (e.g., basketball, running, swimming, fast bicycling, dancing); 2. A physical activity for at least 30 minutes that did not make them sweat or breathe hard (e.g., fast walking, slow bicycling, skating, pushing a lawn mower, mopping floors); and 3. Exercises to strengthen or tone their muscles (e.g., push-ups, weights, sit-ups). Higher scores indicate more PA. Since the PA measure included distinct PA doses, we tested each PA type separately. Results indicated that all three were similarly associated with well-being, with nearly identical effect sizes, so we used a composite measure in the analyses. Each indicator was standardized, indicators were averaged, and the resulting score was standardized again to compute an overall PA composite *z* score. Average PA at age 16 years was 2.37 (SD = 1.01).

EPOCH measure of adolescent well-being

This measure was collected twice, approximately 2 years apart, at ages 16 and 18 (on average). Participants completed the EPOCH measure of adolescent well-being (Kern et al., 2016), which assesses a number of items reflecting positive adjustment and well-being, which collectively compose the five different positive youth characteristics captured by the EPOCH: Engagement (being absorbed and involved in an activity or the world itself); Perseverance (the tenacity to stick with things and pursue a goal despite challenges); Optimism (having a sense of hope and confidence about the future); Connectedness (feeling loved, supported, and valued by others); and Happiness (a general feeling of cheer and contentment with life). Each of the five characteristics is assessed using four items rated on a 1 = *not at all like me* to 5 = *very much like me* scale.

The EPOCH measure has demonstrated strong psychometric properties across diverse adolescent samples, supporting its five-factor structure, internal and temporal consistency, and predictive validity (Kern et al., 2016). As reported in the original validation study, subscale reliability ranges from $\alpha = .76$ to .88, with Happiness being the most reliable. It has been validated across multiple countries, including Sweden, China, and Malaysia, showing adequate model fit and expected associations with well-being and mental health indicators (Maurer et al., 2021; Taheri et al., 2022; Zeng & Kern, 2019). The internal consistency for countries included in the present study has been found to range from $\alpha = .65$ to .86, with Engagement ($\alpha = .65$) being the only subscale below the .80 threshold (Rothenberg et al., 2021).

Additionally, measurement invariance across cultural groups in our sample was assessed using the alignment technique (Muthén & Asparouhov, 2014), which is well-suited for multinational longitudinal studies with varying sample sizes. Results indicated strong measurement invariance across cultural groups, with all five characteristics demonstrating low levels of non-invariance (ranging from 0% to 4%), well below the 25% threshold for acceptable non-invariance (Muthén & Asparouhov, 2014), suggesting the measure reliably captures well-being across the countries represented in this study (Rothenberg et al., 2021). Each item was averaged to compute an overall EPOCH score with a resulting scale of 1 to 5 for both ages 16 and 18. Higher scores reflect higher levels of the five flourishing characteristics.

Adolescent sex

Adolescent binary sex was reported by mothers, fathers, and youth and was coded as 0 = male, 1 = female. This was then standardized to center the variable for subsequent statistical analyses. It is important to note that in our dataset, binary sex (described as "female" and "male") was participant-reported and did not change in self-reports across ages; "nonbinary" and "transgender" options were not provided at the time of data collection.

Data analysis plan

Multilevel modeling (MLM) was used to account for the nested nature of the data (i.e., participants nested within country) and to test the hypothesis that higher amounts of PA at age 16 would statistically predict greater well-being at

age 18, controlling for prior well-being at age 16. Models were estimated using Restricted Maximum Likelihood (REML), and the Kenward-Roger adjustment was applied to correct standard errors and degrees of freedom (Elff et al., 2016; McNeish & Stapleton, 2016). To determine the appropriateness of multilevel modeling, the intraclass correlation coefficient (ICC) for well-being at age 18 was calculated, resulting in a value of 0.131, indicating that 13.1% of the variance in well-being was attributable to differences between countries, while most of the variance (86.9%) was within sites. Though this ICC is moderate, prior research suggests MLM is appropriate when ICC values exceed 0.05–0.10 and when theoretical considerations justify accounting for nested data (Hox et al., 2017). Note that ICC reflects variance in the outcome across countries, which is distinct from between-site variation in effect sizes examined via meta-analysis.

Furthermore, methodological work supports MLM even with small numbers of clusters when estimating fixed effects, particularly when using REML and the Kenward-Roger adjustment (Elff et al., 2016; McNeish & Stapleton, 2016). Similar analytic strategies have also been applied to the current dataset with 12 highest-level units (Lansford et al., 2018). All predictors were initially modeled as fixed effects and random effects were estimated to examine potential variability in intercepts and slopes across participants and countries. This approach ensured accurate estimation of fixed effects while allowing for the exploration of within- and between-site variance components.

To further interrogate the association between PA and change in well-being, a relative difference score approach was used. While the primary analysis accounted for baseline well-being within the MLM, the relative difference score provided a direct measure of simple change. First, a relative difference score was calculated for well-being between ages 16 and 18. Then, the correlation between PA and the relative difference score was examined to determine whether PA was associated with change in well-being. Following this, a hierarchical regression analysis was conducted using the relative difference score as the outcome, removing prior well-being at age 16 as a predictor. This allowed for testing whether PA predicted simple changes in well-being in a way that was consistent with the initial multilevel model results. Adolescent sex was included as a moderator in the multilevel and relative difference score models. Finally, meta-analysis was used to estimate the degree of consistency across the international sites in the estimated effect sizes for the total sample. Analyses were conducted using IBM SPSS version 27.

For the random-effects meta-analysis, following the technique utilized by Folker et al. (2024), we used the standardized effect size from each site-specific model to understand the average effect size for the entire sample, and the variability in effect sizes across sites. This meta-analytic approach allowed us to calculate the overall effect of PA on adolescent EPOCH well-being characteristics across nine global locales. Meta-analytic estimates of the standardized regression coefficients were weighted by the sample size of each site. As recommended by Harrer et al. (2021), between-site variability in the effect sizes is reported using τ^2 and I^2. These metrics capture the magnitude of between-site variability in effect size to convey the degree to which the statistical effect of PA on adolescent EPOCH well-being replicated across the samples.

RESULTS

Table 1 presents descriptive statistics and bivariate correlations between the main study variables. Both PA and EPOCH scores were widely and normally distributed. On average, adolescents engaged in PA 2.37 days per week (SD = 1.01, range = 1–5). The distribution of PA engagement varied, with approximately 51.6% of adolescents engaging in PA at least twice per week and 22.9% engaging in PA four or more times per week. Well-being scores at ages 16 and 18 were $M = 3.55$ (SD = 0.66, range = 1.65–5.00) and $M = 3.61$ (SD = 0.68, range = 1.60–5.00), respectively. The bivariate associations aligned with expected patterns based on prior research, with PA at 16, EPOCH at 16, and EPOCH at 18 all positively associated. As expected, males engaged in more PA than females.

Multilevel model results

A multilevel moderation model with both fixed and random effects was run to test the hypothesis that PA at age 16 would predict well-being at age 18, controlling for well-being at age 16, and to explore whether adolescent sex moderated this association. Fixed effects results indicated that higher PA at age 16 significantly predicted greater well-being at age 18, even after controlling for prior well-being and adolescent sex. The interaction between PA and adolescent sex was not significant. Random effects were included to assess variability in intercepts and slopes across sites. Results indicated significant average well-being at age 18 varied *within* sites, but did not differ on average *between* sites, indicating that individual and context-specific factors played a greater role than country-level differences. Likewise, there was no

TABLE 1 Descriptive statistics and bivariate correlations between EPOCH well-being scores, physical activity, and binary sex.

	1	2	3	4
1. EPOCH age 16	–			
2. EPOCH age 18	.54**	–		
3. PA age 16	.14**	.17**	–	
4. Sex	.03	.04	−.24**	–
Mean	3.55	3.61	2.37	1.50
SD	0.66	0.68	1.02	0.50

Abbreviations: PA, physical activity; SD, standard deviation; sex, adolescent binary sex, coded as 1 = male, 2 = female.

**$p < .01$.

JOURNAL OF Research on Adolescence

between-site variance in the predictive effect of PA, well-being at age 16, adolescent sex, or the interaction between PA and Sex, indicating consistency in these predictive effects across sites. Full model estimates are presented in Table 2.

A hierarchical linear regression analysis was conducted using the relative difference score in well-being as the outcome variable to test whether PA at age 16 predicted simple changes in well-being and whether adolescent sex moderated this association. In Step 1, PA and sex were entered as predictors of the relative difference score in well-being. PA was a significant predictor of well-being change, such that higher PA at age 16 was associated with greater increases in well-being from age 16 to age 18. However, sex was not a significant predictor of well-being change. In Step 2, the PA × sex interaction was included and was not significant. Full estimates are reported in Table 3.

TABLE 2 Hierarchical linear model results for physical activity (PA) predicting EPOCH well-being at age 18, controlling for EPOCH well-being at age 16, moderated by adolescent sex.

Variable	Parameter	Estimate	SE	*p*-value
Fixed effects				
Intercept	γ_{00}	0.03	0.08	.667
PA age 16	γ_{10}	0.09	0.03	.002
EPOCH age 16	γ_{20}	0.48	0.04	<.001
Sex	γ_{30}	0.04	0.05	.924
PA × sex	γ_{40}	0.005	0.03	.869
Random effects				
Within-site variance	σ^2	0.64	0.03	<.001
Between-site variance	τ_{00}	0.07	0.04	.055
PA variance	τ_{s1}	0.00	0.00	—
EPOCH age 16 variance	τ_{s2}	0.01	0.01	.280
Sex variance	τ_{s3}	0.02	0.01	.257
PA × sex variance	τ_{s4}	0.00	0.00	—

Note: SPSS does not provide *p*-values for the random effects of PA and PA × sex due to near non-zero estimates considered redundant.

Abbreviations: PA, physical activity; sex, adolescent binary sex, coded as 1 = male, 2 = female.

TABLE 3 Regression results for physical activity predicting relative difference in EPOCH well-being between ages 16 and 18.

Variable	Estimate (β)	SE	*p*-value	95% CI [LL, UL]
Step 1				
PA (age 16)	0.09	0.03	<.001	[0.05, 0.11]
Sex	0.01	0.03	.820	[−0.06, 0.07]
Step 2				
PA × sex	0.05	0.03	.131	[−0.02, 0.08]

Abbreviations: PA, physical activity; sex, adolescent binary sex, coded as 1 = male, 2 = female.

Meta-analysis results

Given that the interaction between PA and adolescent sex as a predictor of EPOCH scores was not significant, the meta-analysis was performed only on the main effect of PA as a statistical predictor of EPOCH at age 18 controlling for EPOCH at age 16. The meta-analysis revealed that the overall pooled association was significant between PA at age 16 and adolescent EPOCH characteristics at age 18, controlling for prior well-being at age 16 ($\beta = .04$, CI [0.01, 0.08], $p = .02$). The prediction interval ranged from −.002 to .08, suggesting that the calculated effect size in future studies would fall within this range. The between-study heterogeneity was estimated at $\tau^2 = 0.00$, with an I^2 value of 0.00%, indicating no detectable variation in the effect of PA on well-being across counties in this sample. Figure 1 displays the weighted effect size and CIs for each country.

DISCUSSION

The present study extends existing research by examining whether PA statistically predicts changes in EPOCH well-being as adolescents begin the transition into emerging adulthood—in a diverse sample of older adolescents across nine international sites. Though prior research has examined PA and well-being associations, our study's unique combination of a partial longitudinal design, focus on older adolescents (ages 16–18), and diverse multinational sample provides a more complete picture of how PA influences positive well-being during this key developmental stage.

We found that more PA at age 16 significantly predicted greater well-being at age 18, accounting for well-being at age 16. This finding suggests that PA may support growth in positive psychological characteristics, such as those captured by the EPOCH. Thus, PA appears to be linked to improvements in well-being over time, which has implications for understanding developmental trajectories of positive psychological features. Given that late adolescence is accompanied by many significant changes that can impact well-being (Wood et al., 2018), the ability of PA to promote positive shifts during this period may be impactful for long-term psychological functioning.

The statistical predictive effect of change in well-being from prior PA was not moderated by adolescent sex; this was consistent with prior work suggesting that PA provides well-being benefits for both sexes (McMahon et al., 2017; Murphy et al., 2020; Schmidt et al., 2020). These findings were confirmed using both multilevel modeling and relative difference score approaches. Additionally, multilevel modeling revealed significant *within-site* variance in average EPOCH well-being at age 18 (controlling for age 16), but no *between-site* variance in well-being at age 18 (again, controlling for age 16 well-being). There were also no significant site differences in the predictive effects of PA, EPOCH well-being at age 16, adolescent sex, or the interaction between PA and sex. These findings align with our hypothesis and indicate that

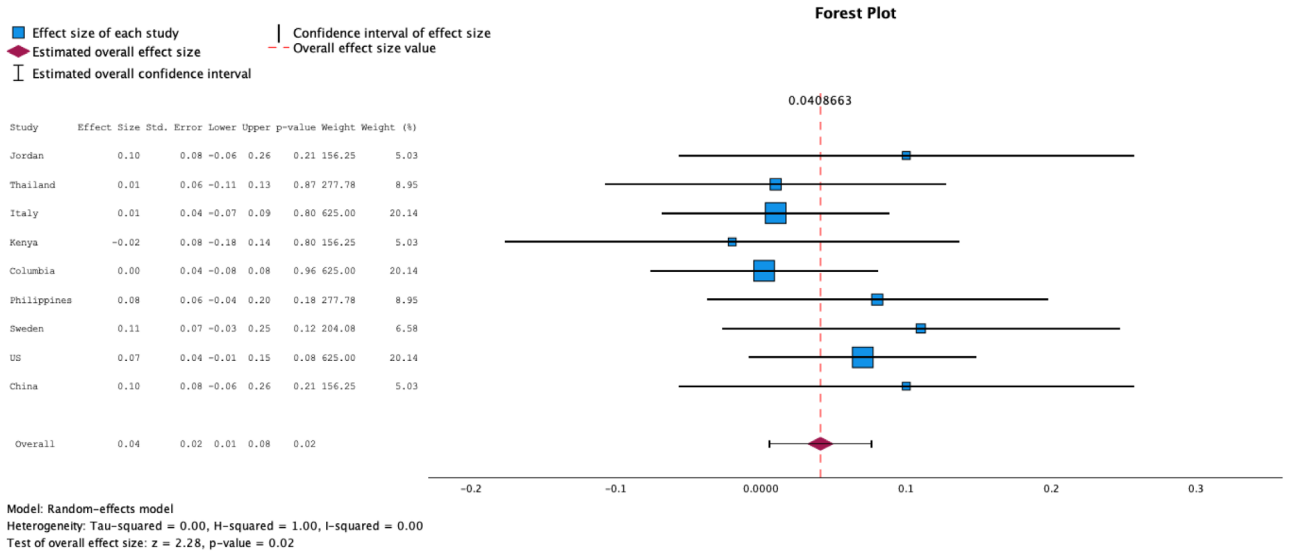

FIGURE 1 Forest plot for random-effects meta-analysis for physical activity at age 16 predicting EPOCH well-being at age 18, controlling for EPOCH well-being at age 16. There was no significant between-site heterogeneity in the effect of physical activity on EPOCH well-being at age 18 controlling for EPOCH at age 16 ($\tau^2 = 0.00$, $I^2 = 0.00$).

the average effect of PA on well-being was similar across the distinct international study sites during this critical developmental transition. However, given the relatively small sample sizes in each country, these results should be interpreted with caution. Nonetheless, the results suggest that PA can be considered as a useful intervention target for improving adolescent well-being across sexes and in different parts of the world.

The multilevel model and hierarchical regression findings were corroborated by the meta-analysis, which treated each site as a distinct study to quantify the consistency of effects across these international study sites. The meta-analyzed pooled effect size for the PA—well-being association was statistically significant, indicating that across the sites, PA significantly predicted well-being. This result confirmed the findings from both the multilevel and relative change score models reported above. One benefit of using the meta-analytic technique is that it allows for the measurement of the degree of variability in model estimates between different studies, or in the context of our study, between international study sites. There was no detectable between-site heterogeneity in the predictive effect of PA on well-being within the study sample. Future work should consider sources of within-site variation such as individual differences in PA preferences, baseline PA and well-being levels, physiological functioning, and environmental influences that may affect the link between PA and well-being, such as differences in access to PA opportunities and socioeconomic conditions.

PA behaviors vary widely between individuals and habitual engagement in PA during adolescence provides mental, cognitive, and physical health benefits that likely extend into adulthood (Ahmed et al., 2012; Kern et al., 2016; Rocliffe et al., 2024). Consequently, PA has been targeted as a means to improve a host of health outcomes, including well-being. However, as seen for all sites in the present study as well as in the extant literature, effect sizes for studies involving PA are generally small. For example, two cross-sectional studies found small, positive associations between PA and well-being (Casanova et al., 2023; McMahon et al., 2017). Similarly, PA intervention studies show consistent results, with one review by Biddle et al. (2019) revealing small and occasionally moderate effect sizes for PA interventions aimed at reducing depression and anxiety and improving self-esteem. Likewise, a meta-analysis focusing on PA interventions with adolescent girls reported small effect sizes, noting that their findings were broadly comparable to other analyses in the literature (Pearson et al., 2015).

However, Pearson et al. (2015) argued that modest effect sizes can be viewed optimistically because behavior change is challenging—especially in environments that inhibit PA and reinforce sedentary behaviors. Thus, even small effects are promising, as they demonstrate potential for improvement, which can be enhanced with appropriate support (i.e., from parents, schools, and communities), considering various moderators, and accounting for the specific characteristics (i.e., dose: type, duration, intensity) of the activity (McMahon et al., 2017; Pearson et al., 2015; Van Sluijs et al., 2021). Moreover, small effects at earlier times can aggregate to large effects at later times (Bornstein, 2014), highlighting the long-term potential of even modest behavior changes, particularly as young people transition from adolescence to emerging adulthood. For example, vigorous-intensity activities, team sports, and exercise session durations longer than 30 minutes engaged in over time have been associated with significant improvements in well-being (Costigan et al., 2019; McMahon et al., 2017). Future research should explore potential moderators and different doses of PA to optimize PA's benefits on mental health and well-being.

Importantly, the association between PA and well-being may be bidirectional (Ibáñez Román et al., 2023; Kim et al., 2020; Lubans et al., 2016). The underlying mechanisms that facilitate this bidirectional association are not yet well understood, but several potential mechanisms have been offered. Individuals with greater well-being may experience greater motivation, energy, perseverance, and maintain a positive outlook, making them more likely to participate in regular PA (Brown et al., 2024). Dopamine may be a key neurotransmitter in these effects, as it plays an important role in motivation and mood regulation and is critical for the motor and cognitive—motivational reward systems (Marques et al., 2021). Other mechanisms by which well-being may increase PA include greater self-efficacy, better stress resilience, stronger support networks, and better goal-setting capabilities (Brown et al., 2024). These factors likely interact in complex ways, and the strength of their effects may vary depending on individual factors, the type and intensity of PA, and the specific features of well-being that are measured (Fornaro et al., 2017; Marques et al., 2021). Studying the potential reciprocal association in future work, especially during late adolescence as adolescents transition to emerging adulthood would better inform intervention strategies and provide a more comprehensive understanding of how to effectively enhance PA engagement and well-being during this developmentally significant period.

Finally, the absence of a significant sex moderation effect suggests that the well-being benefits PA provides may be similar for older male and female adolescents, which is consistent with prior research indicating the PA provides broad psychological benefits regardless of sex (McMahon et al., 2017; Murphy et al., 2020; Schmidt et al., 2020). While some prior studies have indicated that the effects of PA on well-being vary by sex due to variations in PA engagement between sexes and psychosocial barriers for females (Cowley et al., 2021; Pawlowski et al., 2018), the present study's findings suggest that the positive influence of PA on flourishing characteristics of well-being is robust across sexes when using a self-reported PA measure.

This has important implications for the literature on PA and well-being, as it suggests that barriers to PA may influence participation rates between sexes more than its influence on positive well-being characteristics across diverse cultural contexts. In other words, while males and females may differ in how frequently they engage in PA, once they do, the well-being benefits they experience may be similar across different countries and cultural settings. However, the mechanisms through which PA enhances well-being may differ between sexes, including differences in motivation, social context, and type of activity (Cowley et al., 2021; Hands & Parker, 2016; Pawlowski et al., 2018). This contributes to the growing body of evidence supporting that PA is generally beneficial for adolescent well-being. Still, given the limitations of self-reported PA measures, future research should examine whether sex-based differences in PA experiences (e.g., motivation, social context, access to opportunities) influence well-being beyond self-reported engagement levels alone, which may not fully capture differences in PA dose (e.g., type, duration, and intensity). Objective measures of PA, complete longitudinal designs, and qualitative approaches could provide more information about the nuances in the moderating role of sex on the PA and well-being association over time, particularly in late adolescence and across diverse international contexts.

The current study adds to the ongoing consideration of targeting PA for improving well-being as adolescents transition out of adolescence and into emerging adulthood. First, it showed that PA benefits both male and female adolescents during this developmental period. Second, there was significant *within*-site (but not *between-site*) variability in PA's impact on well-being from age 16 to 18 years, with the meta-analysis indicating no detectable heterogeneity in the effect across diverse regions and cultures for the present study's sample. Thus, across a variety of distinct geospatial and cultural contexts, increasing adolescent PA could be a promising way to improve well-being. These findings reinforce the importance of providing equitable access to PA opportunities for adolescents across diverse international contexts (Guthold et al., 2020), supporting its potential as a globally applicable intervention strategy. The small yet meaningful effect sizes observed indicate that movement should be integrated into adolescents' daily routines, especially for those with limited access to structured PA programs (Kliziene et al., 2021).

These findings support the importance of moving past blanket recommendations for increasing adolescent PA and toward policies and interventions that account for individual and environmental factors influencing PA engagement (Guthold et al., 2020; Van Sluijs et al., 2021). This is supported by the significant within-site variance found in the multilevel model, suggesting that other individual-level factors (e.g., participant physiology, friend group, school environment, socioeconomic status) that were not included in the present study may play a crucial role in how PA influences well-being in adolescence (Pereira et al., 2020; Salway et al., 2019; Steenholt et al., 2018), reiterating that broad PA recommendations may not be sufficient, and that systemic approaches that include tailored support for individual differences may be the most successful (Van Sluijs et al., 2021).

The limitations of the study include that PA was measured via self-report, which is susceptible to recall and response biases (Baumeister et al., 2016). Additionally, the validity of self-report measures may vary across populations, ethnicities, languages, and geographic locations (Sattler et al., 2020). However, for large-scale multinational studies like the current one, self-reported PA remains one of the most feasible and efficient approaches for measuring general patterns of activity. Furthermore, our measure of PA was rather general with respect to PA dose (e.g., type, duration, and intensity). Variations in the type (e.g., aerobic versus strength training, or individual versus team-based) and intensity of PA may differentially impact PA's effect on well-being, so capturing distinct PA doses is important for future research. Second, our partial longitudinal design is a significant strength of

the present study, but a complete longitudinal design (i.e., including multiple simultaneous waves of assessment of PA and well-being) would allow for a comprehensive test of the longitudinal and potentially bidirectional effects linking PA and well-being. Additionally, having more assessments would be beneficial to capture change over a longer period of development.

Third, our study included community samples that were not representative of the entire country, limiting generalizability. The relatively small number of countries and sample sizes within each country also may have also limited power to detect between-country differences. Although it is often recommended that studies have more than 20 clusters for multilevel modeling, prior work supports its use for estimating fixed effects with fewer groups when theoretically justified to account for nesting (Elff et al., 2016; McNeish & Stapleton, 2016). Moreover, this modeling approach has been applied to the same dataset with 12 highest-level units in previous publications (e.g., Lansford et al., 2018). Still, the small number of sites limited power to identify subtle cross-national differences as significant. Future research should aim to replicate findings in larger, nationally representative samples of older adolescents to strengthen conclusions about cross-country consistency during this critical developmental transition. Fourth, the current study did not consider the possibility of qualitatively distinct sub-groups that may have quite different associations between PA and changes in well-being. Such analyses in future work could address some of the reasons that effect sizes are generally quite small in research on PA and mental health.

In conclusion, the current study contributes to the extant literature by showing that PA at age 16 positively predicts short-term changes in well-being at age 18 across diverse cultural and international contexts, providing valuable insights about this critical developmental transition period. There was no detectable between-site heterogeneity in the effect, and it was not moderated by adolescent sex. It is important for future research to consider variations in PA dose, and the possibility that these variations may act on the PA—well-being link differently for males and females (Murphy et al., 2020). Further, additional cross-national, longitudinal experiments focused on older adolescents are needed to test causality and possible bidirectionality of the link between PA and well-being. Addressing these gaps will be important to inform policy and interventions aimed at creating enriching environments that incorporate physical movement and promote adolescent well-being as they prepare for the transition to emerging adulthood.

AFFILIATIONS

[1]University of Massachusetts Amherst, Amherst, Massachusetts, USA
[2]Temple University, Philadelphia, Pennsylvania, USA
[3]California Polytechnic State University, San Luis Obispo, California, USA
[4]Università di Roma "La Sapienza,", Roma, Italy
[5]Duke University, Durham, North Carolina, USA
[6]University West, Trollhättan, Sweden
[7]Chiang Mai University, Chiang Mai, Thailand
[8]Maseno University, Kisumu, Kenya
[9]Eunice Kennedy Shriver National Institute of Child Health and Human Development, Bethesda, Maryland, USA
[10]UNICEF, New York, New York, USA
[11]Institute for Fiscal Studies, London, UK
[12]Universidad de San Buenaventura, Bolívar, Colombia
[13]Ateneo de Manila University, Quezon City, Philippines
[14]Abu Dhabi Early Childhood Authority, Abu Dhabi, UAE
[15]University of Naples "Federico II", Naples, Italy
[16]University of Macau, Zhuhai, China
[17]Helsinki Collegium for Advanced Studies, University of Massachusetts Amherst, Helsinki, Finland

ACKNOWLEDGMENTS

The authors are indebted to the Parenting Across Cultures group, our community partners, and are extremely grateful to the families who shared their time and experiences with us. Research reported in this manuscript was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development Grant under Award Number RO1-HD054805 and Fogarty International Center Grant RO3-TW008141. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or Fogarty International Center.

FUNDING INFORMATION

This research was funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development Grant RO1-HD054805 and Fogarty International Center Grant RO3-TW008141.

CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Christina Bertrand https://orcid.org/0000-0003-0201-2155
Natasha Duell https://orcid.org/0000-0003-2325-9333
Dario Bacchini https://orcid.org/0000-0001-6140-9377
Lei Chang https://orcid.org/0000-0001-6457-0254

REFERENCES

Ahmed, H. M., Blaha, M. J., Nasir, K., Rivera, J. J., & Blumenthal, R. S. (2012). Effects of physical activity on cardiovascular disease. *The American Journal of Cardiology*, *109*(2), 288–295. https://doi.org/10.1016/j.amjcard.2011.08.042

Aubert, S., Brazo-Sayavera, J., González, S. A., Janssen, I., Manyanga, T., Oyeyemi, A. L., Picard, P., Sherar, L. B., Turner, E., & Tremblay, M. S. (2021). Global prevalence of physical activity for children and adolescents; inconsistencies, research gaps, and recommendations: A narrative review. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 81. https://doi.org/10.1186/s12966-021-01155-2

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., Leitão, 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. https://doi.org/10.3390/ijerph17176056

Baumeister, S. E., Ricci, C., Kohler, S., Fischer, B., Töpfer, C., Finger, J. D., & Leitzmann, M. F. (2016). Physical activity surveillance in the European Union: Reliability and validity of the European health interview survey-physical activity questionnaire (EHIS-PAQ). *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 61. https://doi.org/10.1186/s12966-016-0386-6

Belcher, B. R., Zink, J., Azad, A., Campbell, C. E., Chakravartti, S. P., & Herting, M. M. (2021). The roles of physical activity, exercise, and fitness in promoting resilience during adolescence: Effects on mental well-being and brain development. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *6*(2), 225–237. https://doi.org/10.1016/j.bpsc.2020.08.005

Bell, S. L., Audrey, S., Gunnell, D., Cooper, A., & Campbell, R. (2019). The relationship between physical activity, mental wellbeing and symptoms of mental health disorder in adolescents: A cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 138. https://doi.org/10.1186/s12966-019-0901-7

Biddle, S. J. H., 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. https://doi.org/10.1016/j.psychsport.2018.08.011

Bornstein, M. H. (2014). Human infancy… and the rest of the lifespan. *Annual Review of Psychology*, *65*(1), 121–158. https://doi.org/10.1146/annurev-psych-120710-100359

Brown, C. E. B., Richardson, K., Halil-Pizzirani, B., Atkins, L., Yücel, M., & Segrave, R. A. (2024). Key influences on university students' physical activity: A systematic review using the theoretical domains framework and the COM-B model of human behaviour. *BMC Public Health*, *24*(1), 418. https://doi.org/10.1186/s12889-023-17621-4

Cairney, J., Veldhuizen, S., Kwan, M., Hay, J., & Faught, B. E. (2014). Biological age and sex-related declines in physical activity during adolescence. *Medicine & Science in Sports & Exercise*, *46*(4), 730–735. https://doi.org/10.1249/MSS.0000000000000168

Casanova, F., O'Loughlin, J., Karageorgiou, V., Beaumont, R. N., Bowden, J., Wood, A. R., & Tyrrell, J. (2023). Effects of physical activity and sedentary time on depression, anxiety and well-being: A bidirectional Mendelian randomisation study. *BMC Medicine*, *21*(1), 501. https://doi.org/10.1186/s12916-023-03211-z

Costigan, S. A., Lubans, D. R., Lonsdale, C., Sanders, T., & Del Pozo Cruz, B. (2019). Associations between physical activity intensity and well-being in adolescents. *Preventive Medicine*, *125*, 55–61. https://doi.org/10.1016/j.ypmed.2019.05.009

Cowley, E. S., Watson, P. M., Foweather, L., Belton, S., Thompson, A., Thijssen, D., & Wagenmakers, A. J. M. (2021). "Girls aren't meant to exercise": Perceived influences on physical activity among adolescent girls—The HERizon project. *Children*, *8*(1), 31. https://doi.org/10.3390/children8010031

Dorn, L. D., Hostinar, C. E., Susman, E. J., & Pervanidou, P. (2019). Conceptualizing puberty as a window of opportunity for impacting health and well-being across the life span. *Journal of Research on Adolescence*, *29*(1), 155–176. https://doi.org/10.1111/jora.12431

Eberhardt, T., Niessner, C., Oriwol, D., Buchal, L., Worth, A., & Bös, K. (2020). Secular trends in physical fitness of children and adolescents: A review of large-scale epidemiological studies published after 2006. *International Journal of Environmental Research and Public Health*, *17*(16), 5671. https://doi.org/10.3390/ijerph17165671

Elff, M., Heisig, J. P., Schaeffer, M., & Shikano, S. (2016). No need to turn Bayesian in multilevel analysis with few clusters: How frequentist methods provide unbiased estimates and accurate inference.

Erkut, S. (2010). Developing Multiple Language Versions of Instruments for Intercultural Research. *Child Development Perspectives*, *4*(1), 1. https://doi.org/10.1111/j.1750-8606.2009.00111.x

Folker, A. E., Deater-Deckard, K., Lansford, J. E., Di Giunta, L., Dodge, K. A., Gurdal, S., Liu, Q., Long, Q., Oburu, P., Pastorelli, C., Rothenberg, W. A., Skinner, A. T., Sorbring, E., Steinberg, L., Tapanya, S., Tirado, L. M. U., Yotanyamaneewong, S., Alampay, L. P., Al-Hassan, S. M., … Chang, L. (2024). Intraindividual variability in parental acceptance-rejection predicts externalizing and internalizing symptoms across childhood/adolescence in nine countries. *Journal of Family Psychology*, *38*(2), 333–344. https://doi.org/10.1037/fam0001133

Fornaro, M., Solmi, M., Veronese, N., De Berardis, D., Buonaguro, E. F., Tomasetti, C., Perna, G., Preti, A., & Carta, M. G. (2017). The burden of mood-disorder/cerebrovascular disease comorbidity: Essential neurobiology, psychopharmacology, and physical activity interventions. *International Review of Psychiatry*, *29*(5), 425–435. https://doi.org/10.1080/09540261.2017.1299695

Graber, J. A., Nichols, T. R., & Brooks-Gunn, J. (2010). Putting pubertal timing in developmental context: Implications for prevention. *Developmental Psychobiology*, *52*(3), 254–262. https://doi.org/10.1002/dev.20438

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Halliday, A. J., Kern, M. L., & Turnbull, D. A. (2019). Can physical activity help explain the gender gap in adolescent mental health? A cross-sectional exploration. *Mental Health and Physical Activity*, *16*, 8–18. https://doi.org/10.1016/j.mhpa.2019.02.003

Hands, B., & Parker, H. (2016). Male and female differences in health benefits derived from physical activity: Implications for exercise prescription. *Journal of Womens Health, Issues and Care*, *5*(4), 1–5. https://doi.org/10.4172/2325-9795.1000238

Harrer, M., Cuijpers, P., Furukawa, T. A., & Ebert, D. D. (2021). *Doing meta-analysis with R: A hands-on guide*. Chapman and Hall/CRC. https://doi.org/10.1201/9781003107347

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58–65. https://doi.org/10.1038/nrn2298

Hox, J. J., Moerbeek, M., & Van De Schoot, R. (2017). *Multilevel analysis: Techniques and applications* (3rd ed.). Routledge. https://doi.org/10.4324/9781315650982

Ibáñez Román, J. E., Ekholm, O., Algren, M. H., Koyanagi, A., Stewart-Brown, S., Hall, E. E., Stubbs, B., Koushede, V., Thygesen, L. C., & Santini, Z. I. (2023). Mental wellbeing and physical activity levels: A prospective cohort study. *Mental Health and Physical Activity*, *24*, 100498. https://doi.org/10.1016/j.mhpa.2022.100498

Iwon, K., Skibinska, J., Jasielska, D., & Kalwarczyk, S. (2021). Elevating subjective well-being through physical exercises: An intervention study. *Frontiers in Psychology*, *12*, 702678. https://doi.org/10.3389/fpsyg.2021.702678

Kern, M. L., Benson, L., Steinberg, E. A., & Steinberg, L. (2016). The EPOCH measure of adolescent well-being. *Psychological Assessment*, *28*(5), 586–597. https://doi.org/10.1037/pas0000201

Kim, C., Kim, J., & Thapa, B. (2020). Bidirectional association between leisure time physical activity and well-being: Longitudinal evidence. *Journal of Leisure Research*, *51*(5), 559–580. https://doi.org/10.1080/00222216.2020.1807428

Kliziene, I., Cizauskas, G., Sipaviciene, S., Aleksandraviciene, R., & Zaicenkoviene, K. (2021). Effects of a physical education program on physical activity and emotional well-being among primary school children. *International Journal of Environmental Research and Public Health*, *18*(14), 7536. https://doi.org/10.3390/ijerph18147536

Lansford, J. E., Godwin, J., Al-Hassan, S. M., Bacchini, D., Bornstein, M. H., Chang, L., Chen, B.-B., Deater-Deckard, K., Di Giunta, L., Dodge, K. A., Malone, P. S., Oburu, P., Pastorelli, C., Skinner, A. T., Sorbring, E., Steinberg, L., Tapanya, S., Alampay, L. P., Uribe Tirado, L. M., & Zelli, A. (2018). Longitudinal associations between parenting and youth adjustment in twelve cultural groups: Cultural normativeness of parenting as a moderator. *Developmental Psychology*, *54*(2), 362–377. https://doi.org/10.1037/dev0000416

Larsen, B., & Luna, B. (2018). Adolescence as a neurobiological critical period for the development of higher-order cognition. *Neuroscience &*

Biobehavioral Reviews, *94*, 179–195. https://doi.org/10.1016/j.neubiorev.2018.09.005

Leone, M., Levesque, P., Bourget-Gaudreault, S., Lemoyne, J., Kalinova, E., Comtois, A. S., Bui, H. T., Léger, L., Frémont, P., & Allisse, M. (2023). Secular trends of cardiorespiratory fitness in children and adolescents over a 35-year period: Chronicle of a predicted foretold. *Frontiers in Public Health*, *10*, 1056484. https://doi.org/10.3389/fpubh.2022.1056484

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), e20161642. https://doi.org/10.1542/peds.2016-1642

Marentes-Castillo, M., Castillo, I., Tomás, I., & Álvarez, O. (2024). Interest and perseverance are not enough to be physically active: The importance of self-efficacy toward healthy eating and healthy weight to move more in adolescents. *Sports*, *12*(2), 41. https://doi.org/10.3390/sports12020041

Marques, A., Marconcin, P., Werneck, A. O., Ferrari, G., Gouveia, É. R., Kliegel, M., Peralta, M., & Ihle, A. (2021). Bidirectional association between physical activity and dopamine across adulthood—A systematic review. *Brain Sciences*, *11*(7), 829. https://doi.org/10.3390/brainsci11070829

Maurer, M. M., Daukantaitė, D., & Hoff, E. (2021). Testing the psychometric properties of the Swedish version of the EPOCH measure of adolescent well-being. *PLoS One*, *16*(10), e0259191. https://doi.org/10.1371/journal.pone.0259191

McMahon, E. M., Corcoran, P., O'Regan, G., Keeley, H., Cannon, M., Carli, V., Wasserman, C., Hadlaczky, G., Sarchiapone, M., Apter, A., Balazs, J., Balint, M., Bobes, J., Brunner, R., Cozman, D., Haring, C., Iosue, M., Kaess, M., Kahn, J.-P., & Wasserman, D. (2017). Physical activity in European adolescents and associations with anxiety, depression and well-being. *European Child & Adolescent Psychiatry*, *26*(1), 111–122. https://doi.org/10.1007/s00787-016-0875-9

McNeish, D. M., & Stapleton, L. M. (2016). The effect of small sample size on two-level model estimates: A review and illustration. *Educational Psychology Review*, *28*(2), 295–314. https://doi.org/10.1007/s10648-014-9287-x

Mctiernan, A., Friedenreich, C. M., Katzmarzyk, P. T., Powell, K. E., Macko, R., Buchner, D., Pescatello, L. S., Bloodgood, B., Tennant, B., Vaux-Bjerke, A., George, S. M., Troiano, R. P., & Piercy, K. L. (2019). Physical activity in cancer prevention and survival: A systematic review. *Medicine & Science in Sports & Exercise*, *51*(6), 1252–1261. https://doi.org/10.1249/MSS.0000000000001937

Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas*, *106*, 48–56. https://doi.org/10.1016/j.maturitas.2017.09.003

Murphy, J., Sweeney, M. R., & McGrane, B. (2020). Physical activity and sports participation in irish adolescents and associations with anxiety, depression and mental wellbeing. Findings from the physical activity and wellbeing (paws) study. *Physical Activity and Health*, *4*(1), 107–119. https://doi.org/10.5334/paah.58

Muthén, B., & Asparouhov, T. (2014). IRT studies of many groups: The alignment method. *Frontiers in Psychology*, *5*, 978.

Pawlowski, C. S., Schipperijn, J., Tjørnhøj-Thomsen, T., & Troelsen, J. (2018). Giving children a voice: Exploring qualitative perspectives on factors influencing recess physical activity. *European Physical Education Review*, *24*(1), 39–55. https://doi.org/10.1177/1356336X16664748

Pearson, N., Braithwaite, R., & Biddle, S. J. H. (2015). The effectiveness of interventions to increase physical activity among adolescent girls: A meta-analysis. *Academic Pediatrics*, *15*(1), 9–18. https://doi.org/10.1016/j.acap.2014.08.009

Peña, E. D. (2007). Lost in translation: Methodological considerations in cross-cultural Research. *Child Development*, *78*(4), 1255–1264. https://doi.org/10.1111/j.1467-8624.2007.01064.x

Pereira, S., Reyes, A., Moura-Dos-Santos, M. A., Santos, C., Gomes, T. N., Tani, G., Vasconcelos, O., Barreira, T. V., Katzmarzyk, P. T., & Maia, J. (2020). Why are children different in their moderate-to-vigorous physical activity levels? A multilevel analysis. *Jornal de Pediatria*, *96*(2), 225–232. https://doi.org/10.1016/j.jpedp.2018.09.003

Physical Activity Guidelines Advisory Committee (2018). 2018 Physical Activity Guidelines Advisory Committee Scientific Report. U.S. Department of Health and Human Services.

Powell, K. E., King, A. C., Buchner, D. M., Campbell, W. W., DiPietro, L., Erickson, K. I., Hillman, C. H., Jakicic, J. M., Janz, K. F., Katzmarzyk, P. T., Kraus, W. E., Macko, R. F., Marquez, D. X., McTiernan, A., Pate, R. R., Pescatello, L. S., & Whitt-Glover, M. C. (2019). The scientific Foundation for the Physical Activity Guidelines for Americans, 2nd edition. *Journal of Physical Activity & Health*, *16*(1), 1–11. https://doi.org/10.1123/jpah.2018-0618

Redublado, H. J. C., Velez, L. C., Serano, A. V., & Kilag, O. K. T. (2024). Enhancing physical activity and movement skills in youth: A systematic review of school-based interventions. *International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence*, *1*(3), 73–78. https://doi.org/10.5281/ZENODO.11045531

Rocliffe, P., Adamakis, M., O'Keeffe, B. T., Walsh, L., Bannon, A., Garcia-Gonzalez, L., Chambers, F., Stylianou, M., Sherwin, I., Mannix-McNamara, P., & MacDonncha, C. (2024). The impact of typical school provision of physical education, physical activity and sports on adolescent mental health and wellbeing: A systematic literature review. *Adolescent Research Review*, *9*(2), 339–364. https://doi.org/10.1007/s40894-023-00220-0

Rothenberg, W. A., Lansford, J. E., Bornstein, M. H., Uribe Tirado, L. M., Yotanyamaneewong, S., Alampay, L. P., Al-Hassan, S. M., Bacchini, D., Chang, L., Deater-Deckard, K., Di Giunta, L., Dodge, K. A., Gurdal, S., Liu, Q., Long, Q., Malone, P. S., Oburu, P., Pastorelli, C., Skinner, A. T., … Steinberg, L. (2021). Cross-cultural associations of four parenting behaviors with child flourishing: Examining cultural specificity and commonality in cultural normativeness and intergenerational transmission processes. *Child Development*, *92*(6), e1138–e1153. https://doi.org/10.1111/cdev.13634

Rutberg, S., Nyberg, L., Castelli, D., & Lindqvist, A.-K. (2020). Grit as perseverance in physical activity participation. *International Journal of Environmental Research and Public Health*, *17*(3), 807. https://doi.org/10.3390/ijerph17030807

Salway, R., Emm-Collison, L., Sebire, S. J., Thompson, J. L., Lawlor, D. A., & Jago, R. (2019). A multilevel analysis of neighbourhood, school, friend and individual-level variation in primary school children's physical activity. *International Journal of Environmental Research and Public Health*, *16*(24), 4889. https://doi.org/10.3390/ijerph16244889

Sattler, M. C., Jaunig, J., Tösch, C., Watson, E. D., Mokkink, L. B., Dietz, P., & Van Poppel, M. N. M. (2020). Current evidence of measurement properties of physical activity questionnaires for older adults: An updated systematic review. *Sports Medicine*, *50*(7), 1271–1315. https://doi.org/10.1007/s40279-020-01268-x

Schmidt, S. K., Reinboth, M. S., Resaland, G. K., & Bratland-Sanda, S. (2020). Changes in physical activity, physical fitness and well-being following a school-based health promotion program in a Norwegian region with a poor public health profile: A non-randomized controlled study in early adolescents. *International Journal of Environmental Research and Public Health*, *17*(3), 896. https://doi.org/10.3390/ijerph17030896

Steenholt, C. B., Pisinger, V. S. C., Danquah, I. H., & Tolstrup, J. S. (2018). School and class-level variations and patterns of physical activity: A multilevel analysis of Danish high school students. *BMC Public Health*, *18*(1), 255. https://doi.org/10.1186/s12889-018-5155-9

Taheri, A., Pourshahriari, M., Abdollahi, A., & Hosseinian, S. (2022). Psychometric assessment of the Persian translation of the EPOCH measure among adolescent girls. *Current Psychology*, *41*(7), 4961–4970. https://doi.org/10.1007/s12144-020-01013-7

Umstattd Meyer, M. R., Prochnow, T., Pickett, A. C., Perry, C. K., Bridges Hamilton, C. N., Abildso, C. G., & Pollack Porter, K. M. (2021). The effects of play streets on social and community connectedness in

rural communities. *International Journal of Environmental Research and Public Health*, *18*(19), 9976. https://doi.org/10.3390/ijerph18199976

UNICEF. (2021). *Mental health*. UNICEF Data. https://data.unicef.org/topic/child-health/mental-health/

Van Sluijs, E. M. F., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., Oyeyemi, A. L., Ding, D., & Katzmarzyk, P. T. (2021). Physical activity behaviours in adolescence: Current evidence and opportunities for intervention. *The Lancet*, *398*(10298), 429–442. https://doi.org/10.1016/S0140-6736(21)01259-9

Wardle, J., & Steptoe, A. (1991). The European health and behaviour survey: Rationale, methods and initial results from the United Kingdom. *Social Science & Medicine*, *33*(8), 925–936. https://doi.org/10.1016/0277-9536(91)90263-C

Won, D., Bang, H., Davis, L., & Park, S. (2023). The role of adolescents' participation in physical education and leisure-time sport activity on their social connectedness, depression, and aggressive behaviour. *Asia Pacific Journal of Education*, 1–20. https://doi.org/10.1080/02188791.2023.2243650

Wood, D., Crapnell, T., Lau, L., Bennett, A., Lotstein, D., Ferris, M., & Kuo, A. (2018). Emerging adulthood as a critical stage in the life course. In N. Halfon, C. B. Forrest, R. M. Lerner, & E. M. Faustman (Eds.), *Handbook of life course health development* (pp. 123–143). Springer International Publishing. https://doi.org/10.1007/978-3-319-47143-3_7

World Health Organization. (2020). *Global health estimates for 2019*. World Health Organization. https://www.who.int/data/global-health-estimates

Yin, Y., Zhang, C., Chen, Z., Qi, Y., & Qiu, C. (2023). The impact of perceived school climate on exercise behavior engagement among obese adolescents: A dual mediation effect test of exercise benefits and perseverance qualities. *Frontiers in Psychology*, *14*, 1220362. https://doi.org/10.3389/fpsyg.2023.1220362

Zeng, G., & Kern, M. L. (2019). The Chinese EPOCH measure of adolescent wellbeing: Further testing of the psychometrics of the measure. *Frontiers in Psychology*, *10*, 1457. https://doi.org/10.3389/fpsyg.2019.01457

Zhang, Z., & Chen, W. (2019). A systematic review of the relationship between physical activity and happiness. *Journal of Happiness Studies*, *20*(4), 1305–1322. https://doi.org/10.1007/s10902-018-9976-0

How to cite this article: Bertrand, C., Steinberg, L., Duell, N., Di Giunta, L., Dodge, K. A., Gurdal, S., Junla, D., Lansford, J. E., Oburu, P., Pastorelli, C., Skinner, A. T., Sorbring, E., Bornstein, M. H., Uribe Tirado, L. M., Yotanyamaneewong, S., Alampay, L. P., Al-Hassan, S. M., Bacchini, D., Chang, L., & Deater-Deckard, K. (2025). Physical activity and two-year change in adolescent well-being in nine countries. *Journal of Research on Adolescence*, *35*, e70035. https://doi.org/10.1111/jora.70035