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Physical Activity Does not Prevent Academic Difficulties for Youth Exposed to Individual and Family Vulnerabilities

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Previous studies focusing on psychological adjustment have shown that physical activity has a protective role, particularly in young adolescents exposed to individual vulnerabilities such as difficult temperament or family adversity. This study examined whether the protective role of physical activity is replicated in the academic dimension of adjustment in these at-risk adolescents transitioning from primary to secondary school. Participants (N = 1,312; 47% boys) were selected from the Quebec Longitudinal Study of Child Development. The results showed that physical activity did not protect against academic and engagement difficulties among adolescents in general nor among those identified as high-risk. To adequately guide practice, further replication studies are needed to determine when physical activity acts as a protective factor and when it does not.

Keywords: Difficult temperament, family adversity, physical activity, academic adjustment, early adolescence, longitudinal

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The data has been obtained from a third party. The data analyzed in this study was obtained from the *Institut de la statistique du Québec* (*ISQ*) and, as stipulated in clauses 10 and 11 of the *ISQ* Act (Canada), access to the data is restricted to the parties identified in the partnership agreement signed to ensure the conduct of the study and which describes the author's right. In the QLSCD cohort, the participants only consented to share their data with the study's financial partners, affiliated researchers, and their collaborators. Those partners and researchers have only access after signing a data-sharing agreement. For other researchers, requests to access these data can be directed to the *ISQ* Research Data Access Services - Home (Service d'accès aux données). For more information, contact SAD@stat.gouv.qc.ca. However, it is possible to access the study sample by visiting the following Web site: https://www.jesuisjeserai.stat.gouv.qc.ca/informations_chercheurs/documentation_technique/doc_tech.html

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Between 15% and 31% of young adolescents experience difficulties with physical (e.g., puberty), social (e.g., exposure to new peers and teachers), and organizational (e.g., exposure to a larger school, academic expectations of teachers) changes associated with the transition from primary to secondary school (Eccles & Roeser, 2015; Evans et al., 2018; Maguire & Yu, 2015; Waters et al., 2012). These changes affect emotional, behavioral, and, most prominently, academic adjustment, including academic achievement known as goal attainment and knowledge in various school subjects (e.g., mathematics, language arts) as well as students' engagement corresponding to young adolescents' school involvement at various levels (affective, cognitive, behavioral; Fredricks et al., 2004; Goldstein et al., 2015; Kiuru et al., 2020; Steinmayr et al., 2014).

This decline reflects multiple changes in the school environment, requiring significant adaptations on the part of students. Unlike in primary school, many secondary school teachers are assigned to multiple classes, which makes it challenging to foster close, high-quality relationships with all students (Eccles & Roeser, 2015). In addition, secondary school teachers often adopt a performance-oriented classroom climate characterized by an increased emphasis on high academic achievement and social comparison (Evans et al., 2018). These changes often thwart young adolescents' developmental need to feel safe, connected to others, and free to choose according to their values and goals, especially during this critical transition period (Eccles & Roeser, 2009). This gap between adolescents' needs and their new school environment practices can reduce academic achievement and engagement (Reeve, 2015), particularly among adolescents with fewer internal or external resources to adapt (Eccles & Roeser, 2015, Evangelou et al., 2008). Notably, those exposed to certain types of contextual (e.g., family adversity; negative experiences affecting well-being; Hughes et al., 2017) and individual vulnerabilities (e.g., difficult temperament; emotional reactivity and regulation difficulties; Rothbart & Derryberry, 1981) may be more affected by the changes in routine associated with the critical period of school transition (Vaz et al., 2014).

Given the importance of academic achievement and engagement for educational attainment and psychological well-being over time, it is essential to identify ways to support resilience via positive activities and experiences, developing strengths and assets needed to meet the challenges of the primary to secondary school transition (Bharara, 2020; Datu & Buenconsejo, 2021). Implementing activities promoting resilience is critical during adolescence, a period of increased plasticity offering a window of opportunity to positively impact development in both the short and long term (Dahl & Suleiman, 2017).

Difficult Temperament and Family Adversity: Risks for Academic Adjustment During the Primary to Secondary School Transition

Several adolescents with a difficult temperament, characterized by negative reactivity and low self-regulatory capacity (e.g., difficulty concentrating and inhibiting), report academic difficulties, as predicted by the Goodness-of-Fit Theory (Al-Hendawi, 2013; Nasvytienė & Lazdauskas, 2021; Thomas & Chess, 1977). According to this theory, there must be a fit between the school environment and the adolescent's temperament to promote positive development. Due to their characteristics, young adolescents with difficult temperaments tend to experience more negative emotions and attitudes toward learning situations (Lehikoinen et al., 2019). Because they are temperamentally less equipped to regulate such negative emotions and attitudes toward school when they arise, these adolescents are more likely to experience anxiety, anger, and failure to meet academic demands, which affects their academic achievement and engagement (Lehikoinen et al., 2019; Sanson et al., 2009). While a difficult temperament may contribute to academic maladjustment, other factors, such as a family environment characterized by adversity, also contribute to risk.

Low income and impaired family functioning are two of the most important indicators of family adversity, given their well-documented impact on health, psychosocial, and academic adjustment (Scully et al., 2020; Suglia et al., 2022). Young adolescents from low-income families have lower academic achievement and engagement levels on average than their more advantaged peers, and this gap increases over time (Chmielewski, 2019; Korous et al., 2022). Several factors can explain their lower level of academic adjustment, including low-income parents having fewer material and social resources to meet their children's needs, which might, in turn, lead to increased family conflict and tension (Masarik & Conger, 2017). Impaired family functioning resulting from such conflicts and tensions may contribute to lower academic achievement and engagement levels, especially during the transition from primary to secondary school. Similar to the Goodness-of-Fit Theory, the Expectancy-Value Model of Achievement Motivation suggests that levels of school engagement and subsequent achievement result from the influence of the social context, including family and school (Eccles & Wigfield, 2020, 2024). Thus, when young adolescents are exposed to the changes associated with the school transition without sufficient resources in their families, and sometimes while dealing with conflict, they might not acquire personal resources such as feeling efficacious and valuing learning, which can affect their academic engagement and achievement.

Resilience Factors in Primary to Secondary School Transition

Difficult temperament and family adversity influence psychosocial and academic adjustment (Forbes et al., 2017; Simpson et al., 2018). In order to prevent these negative consequences, research has identified individual, academic, and social resilience factors that facilitate the transition from primary to secondary school (Bailey, 2017; Bharara, 2020; Belcher et al., 2021). Besides individual resources like self-regulation and social resources like friendship quality, which preserve academic engagement over

the school transition (Bharara, 2020; Eccles & Roeser, 2015; Xia et al., 2016), extracurricular activities also contribute to better academic achievement at this juncture (Bharara, 2020; Schwartz et al., 2015). Among extracurricular activities, PA, especially in school and community contexts, stands out for its accessibility and potential to improve health and well-being and prevent some inequalities from increasing during the transition from primary to secondary school. It has been shown to mitigate the impact of risk factors such as difficult temperament and family adversity on internalizing problems among young adolescents navigating this passage (Alawie et al., 2025, Ryu & Gao, 2023). If PA similarly modulates the impact of risk factors associated with academic functioning, it could further reduce inequalities and support resilience in this vital development sphere. If the protective role of PA replicates for academic adjustment, the introduction of PA in early adolescence would constitute a promising and cost-effective approach to prevent rising distress and declines in school engagement and thus support the well-being of young adolescents in many areas of adjustment simultaneously (Bailey, 2017).

Direct and Protective Effects of PA on Academic Adjustment

A large body of empirical evidence shows that PA can directly improve mental health and cognition in young adolescents (Álvarez-Bueno et al., 2017; Bailey et al., 2018; Heinze et al., 2021; Owen et al., 2018). A meta-analysis of 26 quasi-experimental and randomized trials found that physical education, PA integrated into academic instruction, and extracurricular PA were associated with better overall academic achievement and better achievement in mathematics (Álvarez-Bueno et al., 2017). A second meta-analysis found similar trends for academic engagement, with moderation analysis showing that PA, particularly PA in breaks during academic instruction, was associated with improved engagement (Owen et al., 2016). Several neurobiological and psychosocial mechanisms can explain the positive influence of PA.

Meta-analytic findings suggest that PA could contribute to academic adjustment via its impact on attention regulation and executive functions or via its impact on mood, aspects that are all important for learning and school engagement (Jeon & Ha, 2017, Liu et al., 2020). A systematic review and meta-analysis of 36 randomized trials showed that acute and chronic exercise improved executive function, such as inhibitory control, working memory, and cognitive flexibility (Liu et al., 2020). In addition to these executive function benefits, chronic closed-skill (e.g., performing routine motor tasks in a stable environment) and moderate-intensity intervention exercises showed improvements in core symptoms of attention deficit disorder, particularly on the inattention dimension, compared to control youth who performed sedentary activities or received no treatment (Huang et al., 2023; Zhang, 2012). A second systematic review and meta-analysis, including 16 randomized trials, showed that prolonged exercise reduces hyperactivity of the hypothalamic-pituitary-adrenal (HPA) axis, one of the key stress systems (Heinze et al., 2021, Jeon & Ha, 2017). This reduction is associated with lower levels of depressive and anxiety symptoms (Anderson & Shivakumar, 2013). PA can also support psychological well-being when practiced at moderate to high intensity and when it contributes to the satisfaction of young adolescents' basic needs for autonomy, competence, and relatedness (Doré et al., 2020). PA allows for the development of quality peer relationships and learning various skills (e.g., problem-solving, teamwork), thus contributing to better mental health (Hermens et al., 2017). The resulting positive effects can, in turn, help young adolescents adopt behaviors that promote academic engagement, such as help-seeking (Li et al., 2022, Reschly et al., 2008).

Besides its direct impact on psychological and academic adjustment through multiple biological and social pathways, PA also seems to have the potential to modulate key risk factors associated with poorer adjustment among young adolescents, although PA's protective role has been much less studied. Also, extant studies focusing on PA as a moderator of other risks have focused on psychological rather than academic outcomes. The handful of available studies produced mixed findings, showing that PA can mitigate or amplify the risks posed by key individual and contextual risk factors like difficult temperament and family adversity (Alawie et al., 2025; Moon & Han, 2022; Ryu & Gao, 2023; Shorter & Elledge, 2020). A cross-sectional study of young adolescents in grades 7-9 found that the negative association between exposure to emotional abuse and physical health and self-esteem was reduced among those who engaged in high-frequency PA compared to those who did not engage in PA (Ryu & Gao, 2023). However, PA did not lessen the association between emotional abuse and depression, nor between physical abuse and physical health, self-esteem, and depression (Ryu & Gao, 2023).

Regarding internalizing and externalizing symptoms, two recent studies found that PA could both reduce and amplify individual- or family-level risks. One study found a protective role of PA by showing that its low levels of practice were associated with higher levels of anxiety symptoms in young adolescents with difficult temperaments (Alawie et al., 2025). However, PA did not moderate associations between temperament and family adversity and depression and hyperactivity/inattention symptoms; it did amplify the association between impaired family functioning and physical aggressiveness (Alawie et al., 2025). Finally, in a study of grades 9–12 adolescents, participation in extracurricular activities, including sports, was found to amplify the benefits of some family advantages (e.g., family cohesion) with regard to levels of high school attendance but also the risks associated with family conflicts with regards to substance use (Shorter & Elledge, 2020).

Overall, these studies provide mixed empirical support for the potential protective role of PA for adolescents exposed to adversity. For emotional outcomes such as anxiety, depression, or self-esteem, PA appears to play a moderating or neutral role; however, for externalized behavioral outcomes such as substance use or aggression, it appears to increase risk (Alawie et al., 2025, Shorter & Elledge, 2020) Because extant studies have paid little attention to educational outcomes, it is difficult to determine whether PA would reduce or amplify individual and family risk factors in that domain. Thus, replication studies with these outcomes are needed to determine whether PA can play a protective role regarding risk factors exacerbating declines in academic adjustment over

the primary-secondary school transition, and if so for which risk factors and which aspects of academic adjustment. Doing so requires longitudinal studies, including measures of key individual and contextual sources of adversity and academic adjustment. This question is essential because if PA plays such a protective role, it could help reduce social inequalities in education often exacerbated during the school transition (Vandell et al., 2015; Vaz et al., 2014).

The Study Aims and Hypothesis

Using a prospective longitudinal design, this study pursues two objectives. The first aim is to examine direct associations between PA and academic achievement and engagement reported by adolescents at age 13, above and beyond key controls measured at 17 months old (cognitive ability) and 12 years old (including previous academic adjustment and previous levels of PA). The second main objective is to examine if PA practice moderates the risk of lower academic adjustment associated with difficult temperament at 17 months old and exposure to two separate forms of family adversity, namely impaired family functioning and low income at 12 years old. It is expected that high levels of PA practice will be directly associated with higher academic achievement and engagement in young adolescents, and it will lessen (moderate) the risk posed by the considered sources of individual and family vulnerabilities.

Method

Ethics

The Institutional Review Board (IRB) of the *Institut de la Statistique du Québec* (*ISQ*) and the *Université de Montréal* approved the study. Accordingly, all participants signed a written informed consent form, approved by the *ISQ* Ethics Committee, to participate and to have data from their medical records used in this research. This study posed no risk to individuals or their privacy because the data were coded and anonymized prior to access, with practices such as replacing identifying information with a code or number physically separate from the participants' names. Ethical approval was obtained for this secondary analysis (2022–3038: CEREP-22-042-D).

Participants

Participants are from the Quebec Longitudinal Study of Child Development (QLSCD), launched by the *ISQ* in 1997–1998. The QLSCD study aims to identify factors that contribute to adjustment and academic success during four developmental phases: infancy, childhood, adolescence, and young adulthood. The study initially targeted 2,940 singleton 5-month-old infants born in 13 regions of Quebec, randomly selected from a provincial birth registry following a stratified (by region) sampling procedure. Infants born in two northern regions of Quebec were excluded because of their lower population density and distance from the data collection centres. The families of the targeted infants were contacted to check initial eligibility. Of these, 172 could not be contacted, and others were ineligible because they were already participating in another longitudinal study (5), did not speak French or English (81), had an infant who had died or had severe physical or mental disorders for which no instrument was adapted (7). Of the remaining 2,675 families, 2,223 (83%) consented to participate in the study. Among these, 2,120 were targeted for the longitudinal follow-up (the other families (n = 103) had been oversampled for a particular project).

Families targeted for the longitudinal follow-up were recontacted annually or biennially until the target children reached the age of 13 in 2011 when the outcomes of the present study were measured. Some families did not respond to the 2011 questionnaires and were thus excluded from the present study, leaving a final analytical sample of 1,312 participants (53% female and 47% male). To account for attrition, we used sample weights designed to compensate for the loss of information from nonrespondents so that the sample remains representative of the original target population in terms of critical sociodemographic variables despite differential attrition (Haziza & Beaumont, 2007). A weight was assigned to the 1,312 participants who still responded to some questionnaires in the 2011 phase (Fontaine & Courtemanche, 2012).

Procedures

This study collected data when the participants were 17 months, 12 years, and 13 years old. Because they were minors (i.e., under the age of 14), one or both parents signed and dated the written consent form. Data were collected through various methods, such as interviewer- and self-administered paper and computerized questionnaires. At 17 months of age, cognitive skills, including mental attention and behavioral inhibition, were assessed by researchers through experimentation and reported levels of difficult temperament by mothers. When children reached 12 years of age, mothers also reported on their family's material situation using a computerized questionnaire administered by an interviewer. Additionally, mothers reported levels of family functioning at age 12 using a self-administered questionnaire sent by mail. Adolescents reported their level of PA, school engagement, and achievement at ages 12 and 13, both at school and home, in the interviewer's presence.

Measures

Difficult Temperament (17 Months old)

Using a subset of six items from the Infant Characteristics Questionnaire (ICQ; Bates et al., 1979), mothers rated the extent to which their 17-month-old child exhibited signs of a difficult temperament. These items (α =.79; e.g., "How much does he/she cry and fuss in general?") were rated on a 7-point response scale ranging from 1 (*very little; much less than the average baby/child*) to 7 (*a lot; much more than the average baby/child*). The final scores were standardized on a scale of 0 to 10, with higher scores denoting higher levels of difficult temperament, a standard procedure used

by the *ISQ* throughout the QLSCD study to facilitate comparisons across scales and over time.

Family Adversity (12 Years old)

Using a subset of seven items from the McMaster Family Assessment Device (FAD; Epstein et al., 1983), mothers reported the level of family functioning. These items (α = .83; e.g., "We are capable of making decisions about how to solve our problems") were rated on a 4-point response scale ranging from 1 (*strongly agree*) to 4 (*strongly disagree*). To distinguish between healthy and impaired family functioning, the sum of these items was dichotomized, with scores less than one standard deviation (*SD*) above the mean indicating healthy family functioning (0) and scores equal to or greater than one standard deviation above the mean indicating impaired family functioning (1). Low family income, as reported by the mothers, was defined as the median of the household income across all individuals (50%) in which an individual above this threshold is considered to have sufficient income (0), and an individual below this threshold is considered to have insufficient income (1; Paquet, 2002).

PA (13 Years old)

The duration, or the number of minutes and hours per day, of PA from the Physical Activity Index obtained with questionnaires from the Quebec Health Survey for High School Students (Indice de l'activité physique de l'Enquête québécoise sur la santé des jeunes du secondaire; Nolinz, 2018) was reported by youth using the following item: "In general, on a typical day, how much time do you spend doing [organized/unorganized] physical activities?" PA was rated on a 7-point response scale ranging from 1 (*less than 10 minutes per day*) to 7 (*2 hours or more per day*).

Academic Achievement (13 Years old)

Academic achievement was assessed by asking young adolescents to report their language arts and mathematics grades, expressed as a percentage (0 to 100%). Due to the high correlation between grades in these two subjects (r = .58), they were averaged into an overall measure of achievement in language arts and mathematics.

Academic Engagement (13 Years old)

Levels of academic engagement were reported by young adolescents using the Social and Personal Adjustment for Quebec Adolescent Questionnaire (Leblanc & McDuff, 1997), which consists of 4 items (α =.55; e.g., "Do you like school?") rated on a 4-point response scale ranging from 0 (e.g., *I do not like school at all*) to 3 (e.g., *I really like school*; see also Simonato et al., 2018).

Individual and Academic Control Variables

Sex assigned at birth (0 for girls, 1 for boys), baseline PA practice, academic achievement (r = .61), and engagement (α = .56) at age 12 were the same as those used at age 13, as described above, and were controlled for due to their potential influence on the associations between study predictors and outcomes. At 17 months, the child's cognitive abilities, including mental attention and behavioral inhibition, were assessed using the Imitation Sort Task (Alp, 1994), given the well-established longitudinal links between early attentional skills and later academic adjustment (Ahmed et al., 2019, McClelland et al., 2013). In this task, the child was exposed to a three-level task of increasing difficulty in which he was asked to repeat an object placement sequence shown by the experimenter. The child performed two trials at each level, and the experimenter noted whether each trial was successful (*0*) or unsuccessful (*1*). Each trial was then summed, with scores ranging from 0 to 6, reflecting the level of task success, with higher scores indicating better cognitive abilities. The Imitation Sorting Task has demonstrated good test-retest reliability over six months (r = .75) and strong construct validity (Alp, 1994).

Statistical Analysis

Descriptive and correlational analyses were conducted using SPSS Statistic 27 software. All linear regression assumptions (e.g., linearity, normality of residuals, multicollinearity) were met and respected, except for homoscedasticity and univariate and multivariate extreme values. However, the violation of homoscedasticity is unlikely to have unduly affected results, considering the robustness of multiple linear regression analysis to this problem and the large sample size (Tabachnick & Fidell, 2012, 2018). To reduce the risk of type I and type II errors and undue influence on regression coefficients, univariates (standardized scores higher or lower than 3.29) and multivariate outliers (with a chi-squared statistic above the critical value of 27.88 corresponding to $p < .001$) were excluded from the analysis (Tabachnick & Fidell, 2012, 2018). Missing data were found for predictors (1.1 to 27.7 %), moderator (28.6%), and outcomes (7.9 to 8.2 %). Multiple imputation (20 imputed datasets) was used to reduce bias in parameter estimates (Baraldi & Enders, 2010; Graham et al., 2007).

Subsequently, stepwise multiple linear regression analyses were conducted to assess the associations between predictors and outcomes and examine the moderating effect of PA on these associations. This approach allowed for a comprehensive understanding of the relationships between the variables under study. Two sets of analyses were conducted, one for each outcome (academic achievement and engagement), each of which comprised three steps. The first step included the control (sex, cognitive abilities, initial academic achievement and engagement, and PA) and the predictor variables (difficult temperament, low family income, impaired family functioning). In the second and third steps, the moderator (PA) (second step) and interactions between predictors and moderator (third step) were added, each separately (mean-centred temperament × mean-centred PA, low family income × mean-centred PA, impaired family functioning × mean-centred PA). The continuous variables (predictor and moderator) used to create the interaction terms were centred at the mean to assess the leading associations between predictors and

outcomes and the moderating effect of PA, a practice reducing the risk of multicollinearity (Iacobucci et al., 2016; Kraemer & Blasey, 2004). Statistical significance was established at $p < .05$ for correlational analysis and given a large number of analyzed regression sets performed, Bonferroni correction was applied for main and moderating effects to control for type I error (Emerson, 2020). This correction established statistical significance for regression results at $p < .001$.

Additional Analyses

Additional exploratory analyses were conducted to examine the potential protective role of PA in relation to other dimensions of academic adjustment (Tables A3 to A14 in Appendix). Specifically, multiple linear regression analyses were conducted following the steps described above with the following outcomes: teacher-reported academic achievement and engagement, youth-reported self-concept, and intrinsic motivation in language arts and mathematics.

Results

Bivariate Associations

Table 1 presents descriptive statistics and Pearson correlations between study variables (see Table A1 in the Appendix for detailed confidence intervals). Boys reported higher levels of initial PA but lower levels of initial and subsequent academic achievement and engagement compared to girls at ages 12 and 13. As expected, difficult temperament and low family income were associated with lower academic achievement and engagement levels at age 13. Again, as expected, impaired family functioning was associated with lower subsequent academic engagement but not with lower achievement. Furthermore, PA at age 13 was linked to higher academic achievement and engagement.

Direct Effect and Protective Role of PA on Academic Adjustment

Tables 2 and 3 present the results of multiple linear regression analyses examining PA's direct and moderating effect on academic achievement and engagement, respectively. The initial models, including only the controls and predictors, are presented in the appendix (Table A2).

Academic Achievement

In the model including the control and predictor variables (table A2 in the Appendix), initial levels of academic achievement were associated with higher subsequent levels and difficult temperament was associated with lower academic achievement. This model explained 34% of the variance of academic achievement. After accounting for the control and predictor variables, results illustrated in Table 2 showed that PA was not significantly associated with levels of academic achievement (b = .24; 95 % CI [−.18, .66]). This model did not explain a greater proportion of the variance of academic achievement than the previous model. The two-way interactions presented in Table 2 between difficult temperament and PA, between impaired family functioning and PA, and between low income and PA were not statistically significant in predicting academic achievement (b = .10; 95 % CI [−.16, .36], b = .67; 95 % CI [−.18, 1.52], b = −.63; 95 % CI [−1.58, .32], respectively). Models including the interactions explain between 34% and 35% of the variance of academic achievement, which is not significantly more than the model, which includes only control and predictor variables.

Academic Engagement

In the model including the control and predictor variables (Table A2 in the Appendix), boys reported lower levels of academic engagement than girls and initial levels of academic

Table 1. Descriptive Statistics and Correlations Between the Study Variables

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Sex (male)											
2. Cognitive ability	−.04										
3. PA (T1)	.11***	.03									
4. Academic achievement (T1)	−.12***	.06	.07								
5. Academic engagement (T1)	−.18***	.04	.06	.53***							
6. Difficult temperament	.06*	−.08**	−.002	−.04	−.03						
7. Impaired family functioning	.03	−.04	−.03	−.05	−.06	.13***					
8. Low income	−.06*	−.04	−.04	−.18***	−.07*	−.01	.02				
9. PA (T2)	−.001	.05	.22***	.09*	.06	−.07	−.03	−.07			
10. Academic achievement (T2)	−.09**	.07*	.04	.60***	.38***	−.08**	−.03	−.13***	.09**		
11. Academic engagement (T2)	−.16***	−.00	−.01	.41***	.54***	−.08**	−.10**	−.06*	.08*	.50***	
Mean	.47	2.56	4.73	79.58	14.18	−.02	.43	.17	−.06	77.30	14.38
SD	.50	1.06	1.83	9.24	2.47	1.52	.48	.37	1.49	9.66	2.10
Median	.00	2.00	5.00	80.50	14.75	−.26	.00	.00	.08	77.50	15.00

Note. *$p < .05$. ** $p < .01$. * ** $p < .001$.

Table 2. Associations Between Difficult Temperament, low Family Income, Impaired Family Functioning, and Academic Achievement at age 13: Direct and Moderating Effect of PA (Minutes and Hours/day)

	Academic achievement															
	Direct effect of PA				Difficult temperament × PA				Impaired family functioning × PA				Low–income × PA			
	b	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***
Sex	−.12	.49	−.24	.808	−.12	.48	−.25	.807	−.15	.49	−.31	.755	−.10	.49	−.20	.839
Cognitive ability	.23	.23	.99	.324	.21	.23	.93	.355	.26	.23	1.09	.275	.21	.23	.89	.374
PA (T1)	−.09	.22	−.41	.682	−.09	.22	−.42	.675	−.08	.22	−.39	.702	−.09	.22	−.39	.698
Academic achievement (T1)	.60	.03	21.53	<.001	.60	.03	21.75	<.001	.60	.03	21.50	<.001	.60	.03	21.50	<.001
Difficult temperament	−.31	.16	−1.87	.062	−.27	.17	−1.63	.104	−.33	.16	−2.04	.042	−.31	.17	−1.86	.064
Impaired family functioning	−.16	.56	−.28	.782	−.17	.56	−.31	.759	−.15	.55	−.28	.783	−.14	.56	−.25	.804
Low income	−.05	.62	−.08	.936	−.02	.62	−.04	.972	−.12	.62	−.19	.847	−.30	.65	−.46	.644
PA (T2)	.24	.21	1.15	.252	.24	.21	1.17	.245	.01	.28	.03	.978	.35	.24	1.46	.151
Two–way interaction					.10	.13	.78	.440	.67	.43	1.58	.119	−.63	.48	−1.32	.191
R^2	.34				.35				.35				.34			
F (DF1, DF2), significance	*F* (8, 1298) = 85.14, *p* < .001				*F* (9,1297) = 75.84, *p* < .001				*F* (9,1297) = 79.07, *p* < .001				*F* (9,1297) = 75.65, *p* < .001			
ΔR2	.000				.001				.010				.000			
F change *(DF1, DF2),* significance	*F* (1,1298) = .68, *p* =.409				*F* (1, 1297) = 1.25, *p* = .263				*F* (1, 1297) = 20.32, *p* < .001				*F* (1, 1297) = .14, *p* =.713			

Note. DF: Degree of freedom.

engagement were associated with their subsequent higher levels. Difficult temperament and impaired family functioning were associated with lower levels of academic engagement. This model explained 31 % of the variance of academic engagement. Table 3 showed that PA moderator was not significantly associated with higher academic engagement (*b* = .06; 95 % CI [−.03, .15]). This model did not explain a greater proportion of the variance of academic engagement than the model including control and predictor variables. The two-way interactions presented in Table 3 between difficult temperament and PA, between impaired family functioning and PA, and between low income and PA were not significantly associated with academic engagement (*b* = −.05; 95 % CI [−.09, .002], *b* = −.01; 95 % CI [−.19, .18], *b* = −.10; 95 % CI [−.29, .09], respectively). The final models, including the two-way interactions, did not explain more variance than the model including only control and predictor variables.

In supplemental analyses, teacher-reported academic achievement and engagement and other outcomes that capture academic adjustment (intrinsic motivation and self-concept in mathematics and language arts) were examined, and similar patterns were found. After inserting the controls and predictors, no direct or moderated effects of PA on these aspects of academic adjustment were found (see tables A3 to A14 in the Appendix for details).

Table 3. Associations Between Difficult Temperament, low Family Income, Impaired Family Functioning, and Academic Engagement at age 13: Direct and Moderating Effect of PA (Minutes and Hours/day)

	Academic engagement															
	Direct effect of PA				Difficult temperament X PA				Impaired family functioning X PA				Low–income X PA			
	b	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***	***b***	***SE***	***t***	***p***
Sex	−.25	.11	−2.19	.030	−.25	.11	−2.17	.031	−.25	.11	−2.17	.031	−.24	.11	−2.16	.032
Cognitive ability	−.07	.05	−1.27	.205	−.06	.05	−1.10	.274	−.07	.05	−1.25	.214	−.07	.05	−1.34	.182
PA (T1)	−.06	.04	−1.54	.129	−.06	.04	−1.53	.130	−.06	.04	−1.54	.128	−.06	.04	−1.53	.131
Academic engagement (T1)	.44	.02	19.30	< .001	.43	.02	19.23	< .001	.44	.02	19.27	< .001	.44	.02	19.29	< .001
Difficult temperament	−.08	.03	−2.23	.017	−.10	.04	−2.69	.007	−.08	.03	−2.18	.018	−.08	.03	−2.39	.017
Impaired family functioning	−.32	.12	−2.68	.008	−.31	.12	−2.61	.010	−.32	.12	−2.68	.008	−.32	.12	−2.65	.009
Low income	−.15	.15	−1.05	.296	−.16	.15	−1.10	.272	−.15	.15	−1.05	.296	−.19	.15	−1.29	.197
PA (T2)	.06	.05	1.25	.214	.06	.05	1.25	.216	.06	.06	1.01	.316	.08	.05	1.42	.161
Two–way interaction					−.05	.02	−1.88	.063	−.01	.09	−.52	.958	−.10	.10	−1.04	.301
R^2	.31				.31				.31				.31			
F (DF1, DF2), significance	*F* (8, 1298) = 72.79, *p* < .001				*F* (9,1297) = 65.67, *p* < .001				*F* (9,1297) = 64.66, *p* < .001				*F* (9,1297) = 64.95, *p* < .001			
ΔR2	.001				.003				.000				.001			
F change *(DF1, DF2),* significance	*F* (1,1298) = .98, *p* =.324				*F* (1, 1297) = 6.36, *p* = .012				*F* (1, 1297) = .05, *p* = .833				*F* (1, 1297) = 1.83, *p* = .176			

Note. DF: Degree of freedom.

Discussion

For some time, researchers and practitioners have agreed with the Goodness-of-Fit Theory, which suggests that the changes associated with the transition from primary to secondary school impose significant adjustment costs on young adolescents. Preventing the emergence or worsening of difficulties at this critical junction via the implementation of protective strategies could reduce the psychosocial and academic risks associated with this passage. This study examined whether PA was associated with higher academic achievement and engagement in young adolescents and whether its practice reduced the risks of academic maladjustment in young adolescents exposed to individual and family vulnerabilities. Results did not support the initial hypotheses as PA was not significantly associated with improved academic achievement and engagement, nor did it moderate the impact of exposure to individual and family risks beyond initial levels of academic adjustment.

PA and Academic Achievement and Engagement in Young Adolescents

In the present study, the practice of PA did not lead to better academic achievement in mathematics and language arts and engagement, as expressed by interest in school and the importance of getting good grades. Thus, in the present study, PA did not appear to negatively or positively influence academic achievement and engagement. This result is not unique, as other studies have also failed to find a significant apparent effect of PA specifically on academic adjustment (Barbosa et al., 2020; Rasberry et al., 2011). However, it also contrasts previous studies showing small to moderate positive associations between PA and academic achievement and engagement (Barbosa et al., 2020; Owen et al., 2016, 2018; Rasberry et al., 2011; Spruit et al., 2016).

The discrepancies may be due to several factors, including measurement considerations as well as the types of PA in which adolescents engage. For the academic adjustment outcomes, the measures used in the present study are broadly similar to those used in previous studies that found a significant direct association between PA and these outcomes (Barbosa et al., 2020; Spruit et al., 2016). However, these studies tended to use PA measures that differed from the general one used in the present study. In this study, the PA measure corresponds to its duration without distinctions as a function of types (e.g., organized and unorganized) or intensity. Yet, previous studies suggest that organized PA, which includes well-defined goals and the presence of an instructor, and PA practiced at a sufficiently intense level (e.g., moderate to vigorous) are most likely to have an impact on academic outcomes as compared to broader measures of PA as the one used in our study (Jeon & Ha, 2017; Owen et al., 2016; Rasberry et al., 2011; Spruit et al., 2016). It is thus possible that some of the adolescents in the sample engaged in low-intensity PA, providing few cognitive gains, or that they engaged in a high level of PA but without other essential features (e.g., organized PA, extracurricular, cognitive stimulation) that potentiate PA's impact on academic engagement and achievement. Organized and extracurricular PA activities allow for the development of quality relationships with significant coaches or adults and peers and the learning of many values, such as perseverance, persistence, and teamwork, with the latter characteristics contributing to a greater sense of belonging to the school and better academic engagement (Fredricks et al., 2019; Vandell et al., 2022). These types of PA also provide greater cognitive stimulation, the latter contributing to improved cognitive function and academic achievement (Best et al., 2011; Schmidt et al., 2015). This finding was confirmed in an experimental study in which the experimental group that performed high levels of cognitive stimulation PA had a better cognitive function in specific domains (shifting) essential for academic achievement compared to the second experimental group that performed only high levels of PA without cognitive stimulation and the control group (low levels of PA and cognitive stimulation; Schmidt et al., 2015).

PA's Lack of a Significant Moderating Role

PA did not reduce the risk for academic achievement and engagement maladjustment borne by young adolescents with difficult temperaments, exposed to impaired family functioning, and from low-income families. These findings align with those of a handful of studies showing that PA did not mitigate, and in some cases even exacerbated, associations between some forms of family adversity (e.g., physical abuse, low family income, conflict) and some adverse psychosocial outcomes, including internalizing and externalizing problems (Alawie et al., 2025; Ryu & Gao, 2023). They contrast, however, with other studies showing that PA could alleviate risks, particularly in relation to psychosocial adjustment difficulties in young adolescents with individual vulnerabilities and exposure to other forms of family adversity (e.g., difficult temperament, emotional abuse; Alawie et al., 2025; Khambati et al., 2018; Ryu & Gao, 2023). In this case, the general measure of PA used in the present study cannot contribute to explaining why the results align with some previous findings but not others, as extant studies that examined the moderating role of PA also relied on general measures similar to that of the present study (e.g., duration) and sometimes did not even distinguish PA from other forms of extracurricular activities (e.g., arts; Alawie et al., 2025; Khambati et al., 2018; Shorter & Elledege, 2020). It seems important for future studies to assess the specific characteristics of PA (e.g., type of activity, type of setting, duration, presence of coach/mentor) to identify with more precision the specific conditions under which PA contributes to academic adjustment.

Other studies focusing on emotional or behavioral outcomes that found no significant mitigating role of PA regarding known individual or family risks or that its practice exacerbated such risks proposed several explanations to explain these null or negative findings that might also apply to educational outcomes. Some have suggested that PA might not mitigate family risks because adolescents in disadvantaged family environments, as a rule, do not practice PA in high-quality contexts or with enough support to reap its benefits (U.S. Centers for Disease Control and Prevention, 2024). According to the Whole School, Whole Community, Whole

Child (WSCC) Model, the benefits of PA can only be realized if families' needs for security and stability are met (Lewallen et al., 2015). Also, as explained, a high-quality, organized context might be needed for PA to impact adolescents' adjustment positively.

Other factors, such as publication bias, are also essential to consider in order to understand the patterns of results in the field. The results are mixed among the published studies on the moderating role of PA, but not because some studies find no significant moderating role for PA, and others do. Instead, the results are mixed within studies. In other words, no published study reports null findings across the board. However, many studies report a significant moderation effect for PA regarding the associations between some risk factors and some outcomes, alongside null findings showing no significant moderating role of PA for other risk factors or the same risk factors but other outcomes. This pattern suggests that null findings across the board might not have been published. If so, a file drawer problem may have been applied in this case, whereby only significant findings are published to the detriment of nonsignificant ones (National Academies of Sciences, Engineering and Medicine, 2019). If PA indeed does not moderate individual and family risks with regard to academic engagement and achievement outcomes, it could explain why all published studies focus on emotional and behavioral adjustment rather than academic functioning, a surprising fact considering that this adjustment domain is as vital as the others, and frequently studied.

However, assessing the role of potential publication bias in general, particularly in this case, is complicated by several common practices. Often, details necessary to gauge the state of the literature regarding such biases need to be included, both in methodological descriptions (e.g., recruitment of participants, assumption assessments) and statistical reporting (Amrhein et al., 2019). In the case of the PA moderation studies reviewed, most featured many methodological strengths, including large sample sizes, measures with good psychometric properties, and completeness and transparency in study design descriptions, although some did not report whether assumptions were met for their statistical analysis (Shorter & Elledge, 2020). Systematically providing this information in the future would help explain differences in findings and provide a more exhaustive view of the literature on the role that PA may play in the level of adjustment of young adolescents transitioning to secondary school.

This study has several strengths, including its longitudinal design and large sample size. However, it also has limitations. Although the study's longitudinal design provides a sense of directionality for the links between key variables, its correlational (although longitudinal) nature does not allow for the establishment of causal relationships. In addition, a significant limitation of this study is the use of a single self-reported item to measure the duration of PA. This method is subject to potential biases, particularly those related to social desirability (Prince et al., 2008). While this measure provides relevant data, it does not cover all dimensions of PA, including frequency, intensity, and the distinction between organized and non-organized PA.

This methodological choice was made due to the constraints of the used database, which did not include specific measures to differentiate types of PA during the transition period between primary and secondary school. Additionally, although indicators relating to frequency and intensity were available, daily duration was chosen for practical reasons.

Indeed, young adolescents from vulnerable backgrounds, including those from low-income families, are more likely to face barriers, including a lack of financial resources, limited access to sports facilities, and poor parental support for PA (Tandon et al., 2021). These constraints can hinder the practice of regular, organized PA, particularly at moderate to high intensities. In this context, the duration indicator more accurately captures the reality of these young adolescents, who can meet the daily recommendations (60 minutes on average per day; Bull et al., 2020) through simple PA, such as walking during recess or after school. Although these activities are generally low-intensity, they can yield physical health benefits, including improved cardiorespiratory fitness, which is associated with better academic adaptation (D'Agostino et al., 2018; Gil-Espinosa et al., 2019). Additionally, the use of a self-reported PA duration item has been validated in previous studies of the adolescent population (García-Hermoso et al., 2017; Liu et al., 2023).

Another limitation of this study concerns the use of self-reported school grades by young adolescents. Although this type of measure tends to slightly overestimate school results compared to actual grades from official records, this overestimation remains modest (Sticca et al., 2017). Moreover, self-reported grades are commonly used in the social sciences, particularly in longitudinal studies using databases such as QLSCD (Gonzalez-Sicilia et al., 2019; Pagani et al., 2024). Several research studies have also shown high correlations between self-reported grades and official grades ($r \geq .76$), supporting their validity as an indicator of academic achievement (Sticca et al., 2017). Finally, although actual grades from official records were unavailable in the databases used for the present study, additional analyses examined associations of interest using teacher-reported school grades. The results were comparable to those derived from self-reported youth grades and revealed no significant difference between the two types of measures.

Although this study adds to the literature by examining the moderating role of PA in relation to specific individual and family vulnerabilities, future studies need to examine these relationships by including other qualitative dimensions of PA (organized and non-organized) and by differentiating extracurricular activities to delineate the role of PA in academic adjustment, to find out whether some of these characteristics contribute to promoting resilience and alleviating some of the challenges associated with the transition from primary to secondary school experienced by young adolescents.

Conclusion

In the present study, the self-reported duration of PA was not directly associated with academic achievement and engagement, nor did it reduce the impact of other known risk factors for

poor academic adjustment during the transition from primary to secondary school. The absence of a significant protective role of PA in relation to academic achievement and engagement is at odds with other studies that have considered the moderating role of PA, which have all found that PA moderated the impact of some risk factors in relation to other adjustment domains in the psychosocial sphere. These results suggest that PA is not an effective strategy to protect young adolescents from the negative influence on academic adjustment of individual or family vulnerability, even though it might play a protective role with regard to other outcomes. The results are also suggestive of a potential file drawer effect in this field: that is, among published studies looking at the protective role of PA, the present study is the only one reporting no moderation effect, a surprising result considering that PA does not seem to consistently moderate risk. In the future, it is essential that more studies are carried out to determine the presence and extent of a protective role for PA in relation to the different spheres of adaptation and that these studies be published regardless of the result's statistical significance. Publishing nonsignificant results is crucial for stakeholders to fully understand whether PA can facilitate vulnerable adolescents' transition into secondary schooling and, if so, for what aspects of adaptation specifically.

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Appendix
Additional Analyses

Table A1. 95 % Confidence Intervals (CI) and Statistical Significance for Pearson Bivariate Correlations

Variables	*r*	95 % CI		*p*
		LL	*UL*	
Sex and cognitive ability	-0.04	-0.1	0.02	0.22
PA (T1) and sex	0.11	0.05	0.17	<.001
PA and cognitive ability	0.03	-0.03	0.1	0.303
Academic achievement (T1) and sex	-0.12	-0.17	-0.06	< .001
Academic achievement (T1) and cognitive ability	0.06	0	0.12	0.061
Academic achievement (T1) and PA (T1)	0.07	0	0.14	0.055
Academic engagement (T1) and sex	-0.18	-0.24	-0.13	< .001
Academic engagement (T1) and cognitive ability	0.04	-0.02	0.1	0.216
Academic engagement (T1) and PA (T1)	0.06	-0.01	0.13	0.082
Academic engagement (T1) and academic achievement (T1)	0.53	0.48	0.58	< .001
Difficult temperament and sex	0.06	0.01	0.11	0.032
Difficult temperament and cognitive ability	-0.08	-0.14	-0.02	0.005
Difficult temperament and PA (T1)	-0.002	-0.07	0.07	0.955
Difficult temperament and academic achievement (T1)	-0.04	-0.1	0.02	0.202
Difficult temperament and academic engagement (T1)	-0.03	-0.09	0.03	0.281
Impaired family functioning and sex	0.03	-0.03	0.09	0.282
Impaired family functioning and cognitive ability	-0.04	-0.1	0.02	0.159
Impaired family functioning and PA (T1)	-0.03	-0.09	0.04	0.401
Impaired family functioning and academic achievement (T1)	-0.05	-0.1	0.01	0.123
Impaired family functioning and academic engagement (T1)	-0.06	-0.11	0.001	0.053
Impaired family functioning and difficult temperament	0.13	0.08	0.19	< .001
Low income and sex	-0.06	-0.11	0	0.049
Low income and cognitive ability	-0.04	-0.1	0.02	0.165
Low income and PA (T1)	-0.04	-0.1	0.03	0.283
Low income and academic achievement (T1)	-0.18	-0.23	-0.12	< .001
Low income and academic engagement (T1)	-0.07	-0.12	-0.01	0.021
Low income and difficult temperament	-0.01	-0.07	0.04	0.633
Low income and impaired family functioning	0.02	-0.04	0.07	0.567
PA (T2) and sex	-0.001	-0.07	0.07	0.977
PA (T2) and cognitive ability	0.05	-0.02	0.12	0.139
PA (T2) and PA (T1)	0.22	0.14	0.3	< .001
PA (T2) and academic achievement (T1)	0.09	0.02	0.16	0.014
PA (T2) and academic engagement (T1)	0.06	-0.01	0.13	0.071
PA (T2) and difficult temperament	-0.07	-0.15	0.02	0.13
PA (T2) and impaired family functioning	-0.03	-0.1	0.03	0.308
PA (T2) and low income	-0.07	-0.15	0.01	0.074
Academic achievement (T2) and sex	-0.09	-0.15	-0.04	0.001
Academic achievement (T2) and cognitive ability	0.07	0.01	0.13	0.016
Academic achievement (T2) and PA (T1)	0.04	-0.04	0.12	0.293
Academic achievement (T2) and academic achievement (T1)	0.6	0.55	0.64	< .001
Academic achievement (T2) and academic engagement (T1)	0.38	0.33	0.43	< .001
Academic achievement (T2) and difficult temperament	-0.08	-0.13	-0.02	0.008
Academic achievement (T2) and impaired family functioning	-0.03	-0.09	0.03	0.282
Academic achievement (T2) and low income	-0.13	-0.18	-0.07	< .001
Academic achievement (T2) and PA (T2)	0.09	0.03	0.16	0.008
Academic engagement (T2) and sex	-0.16	-0.22	-0.11	< .001
Academic engagement (T2) and cognitive ability	-0.002	-0.06	0.06	0.959
Academic engagement (T2) and PA (T1)	-0.01	-0.08	0.07	0.88
Academic engagement (T2) and academic achievement (T1)	0.41	0.36	0.46	< .001
Academic engagement (T2) and academic engagement (T1)	0.54	0.49	0.58	< .001
Academic engagement (T2) and difficult temperament	-0.08	-0.14	-0.03	0.004
Academic engagement (T2) and impaired family functioning	-0.1	-0.15	-0.04	0.001
Academic engagement (T2) and low income	-0.06	-0.12	-0.01	0.028
Academic engagement (T2) and PA (T2)	0.08	0	0.15	0.043
Academic engagement (T2) and academic achievement (T2)	0.5	0.45	0.55	< .001

Table A2. Associations Between Predictors and Self-Reported Academic Achievement and Engagement at age 13 Years

	Model 1											
	Academic achievement						Academic engagement					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	−.11	.49	−.23	−1.07	.84	.817	−.25	.11	−2.21	−.47	−.03	.028
Cognitive ability	.24	.23	1.01	−.22	.69	.312	−.07	.05	−1.23	−.17	.04	.219
PA (T1)	−.05	.21	−.23	−.47	.37	.817	−.05	.04	−1.33	−.12	.02	.188
Academic achievement/engagement (T1)	.60	.03	21.57	.55	.66	<.001	.44	.02	19.42	.39	.48	<.001
Difficult temperament	−.33	.16	−2.02	−.65	−.01	.044	−.09	.03	−2.54	−.15	−.02	.011
Impaired family functioning	−.16	.56	−.29	−1.26	.94	.776	−.32	.12	−2.68	−.56	−.09	.008
Low income	−.10	.62	−.16	−1.32	1.12	.871	−.17	.15	−1.12	−.45	.13	.264
R^2	.34						.31					
F (DF1, DF2), significance	*F* (7, 1299) = 97.23, *p* < .001						*F* (7, 1299) = 83.05, *p* < .001					
ΔR2	.34						.31					
F change *(DF1, DF2)*, significance	*F* (7,1299) = 97.23, *p* < .001						*F* (7,1299) = 83.05, *p* < .001					

Note. DF: Degree of freedom.

Table A3. Associations Between Predictors, PA, and Teacher-Reported Academic Achievement at age 13

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	−2.69	.52	−5.17	−3.71	−1.67	<.001	−2.69	.52	−5.18	−3.71	−1.67	<.001
Cognitive ability	−.32	.27	−1.20	−.84	.21	.232	−.32	.27	−1.20	−.84	.20	.230
PA (T1)	−.03	.17	−.15	−.35	.30	.88	−.04	.17	−.25	−.39	.30	.803
Academic achievement (T1)	.46	.03	14.09	.40	.52	<.001	.46	.03	13.95	.40	.52	< .001
Difficult temperament	−.13	.18	−.76	−.48	.21	.448	−.12	.18	−.68	−.47	.23	.495
Impaired family functioning	−.21	.57	−.36	−1.32	.91	.717	−.21	.57	−.36	−1.32	.91	.717
Low income	−1.26	.75	−1.68	−2.73	.22	.094	−1.23	.74	−1.047	−2.69	.23	.097
PA (T2)							.11	.23	.48	−.34	.56	.632
R^2	.19						.19					
F (DF1, DF2), significance	*F* (7, 1296) = 42.65, *p* < .001						*F* (8, 1295) = 37.78, *p* < .001					
ΔR2	.19						.002					
F change *(DF1, DF2)*, significance	*F* (7,1296) = 42.65, *p* < .001						*F* (1,1295) = 3.20, *p* =.074					

Note. DF: Degree of freedom.

Table A4. Interactions Between Predictors and PA in Teacher-Reported Academic Achievement at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	−2.69	.52	−5.17	−3.71	−1.67	<.001	−2.66	.52	−5.14	−3.68	−1.65	<.001	−2.68	.52	−5.15	−3.70	−1.66	<.001
Cognitive ability	−.31	.27	−1.17	−.84	.21	.243	−.34	.27	−1.28	−.87	.19	.203	−.33	.27	−1.25	−.86	.19	.213
PA (T1)	−.04	.17	−.24	−.38	.30	.811	−.04	.17	−.25	−.39	.30	.805	−.04	.18	−.25	−.39	.30	.805
Academic achievement (T1)	.46	.03	13.89	.39	.52	< .001	.46	.03	13.83	.39	.52	< .001	.46	.03	13.83	.40	.52	< .001
Difficult temperament	−.14	.18	−.77	−.50	.22	.444	−.10	.18	−.55	−.45	.26	.584	−.12	.18	−.67	−.47	.23	.501
Impaired family functioning	−.19	.57	−.34	−1.31	.92	.734	−.21	.57	−.37	−1.33	.91	.714	−.19	.57	−.34	−1.31	.92	.734
Low income	−1.25	.74	−1.68	−2.71	.21	.094	−1.19	.75	−1.59	−2.65	.28	.112	−1.40	.75	−1.87	−2.88	.07	.063
PA (T2)	.11	.23	.48	−.34	.56	.633	.25	.28	.87	−.32	.81	.388	.18	.26	.72	−.33	.69	.476
Two–way interaction	−.06	.12	−.49	−.29	.18	.623	−.44	.45	−.98	−1.33	.45	.328	−.43	.51	−.85	−1.43	.57	.397
R^2	.19						.19						.20					
F (DF1, DF2), significance	*F* (9,1294) = 33.67, *p* < .001						*F* (9,1294) = 33.83, *p* < .001						*F* (9,1294) = 34.83, *p* < .001					
ΔR2	.001						.001						.01					
F change *(DF1, DF2)*, significance	*F* (1, 1294) = .81, *p* = .369						*F* (1, 1294) = 1.94, *p* = .164						*F* (1, 1294) = 9.28, *p* = .002					

Table A5. Associations Between Predictors, PA, and Teacher-Reported Academic Engagement at age 13

Note. DF: Degree of freedom.

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	−.19	.05	−3.58	−.30	−.09	<.001	−.19	.05	−3.60	−.30	−.09	<.001
Cognitive ability	−.004	.02	−.16	−.05	.04	.876	−.004	.02	−.17	−.05	.04	.864
PA (T1)	−.01	.02	−.70	−.05	.02	.458	−.01	.02	−.76	−.05	.02	.452
Academic engagement (T1)	.40	.05	8.48	.30	.49	<.001	.40	.05	8.55	.30	.49	< .001
Difficult temperament	−.001	.02	.03	−.03	.04	.977	.002	.02	.09	−.03	.04	.926
Impaired family functioning	−.06	.06	−.98	−.17	.06	.332	−.06	.06	−.98	−.17	.06	.330
Low income	−.17	.08	−2.12	−.33	−.01	.037	−.17	.08	−2.09	−.32	−.01	.040
PA (T2)							.01	.02	.48	−.03	.05	.634
R^2	.18						.18					
F (DF1, DF2), significance	*F* (7, 1301) = 41.31, *p* < .001						*F* (8, 1300) = 36.13, *p* < .001					
ΔR2	.18						.00					
F change *(DF1, DF2)*, significance	*F* (7,1300) = 41.31, *p* < .001						*F* (1,1299) = .07, *p* =.79					

Table A6. Interactions Between Predictors and PA in Teacher-Reported Academic Engagement at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	−.19	.05	−3.57	−.30	−.09	<.001	−.19	.05	−3.55	−.30	−.08	<.001	−.19	.05	−3.60	−.30	−.09	<.001
Cognitive ability	−.01	.02	−.24	−.05	.04	.814	−.01	.02	−.24	−.05	.04	.813	−.004	.02	−.18	−.05	.04	.857
PA (T1)	−.02	.02	−.77	−.05	.02	.444	−.01	.02	−.75	−.05	.02	.457	−.01	.02	−.76	−.05	.02	.453
Academic engagement (T1)	.40	.05	8.55	.30	.49	< .001	.40	.05	8.49	.30	.49	< .001	.40	.05	8.59	.30	.49	< .001
Difficult temperament	.01	.02	−.29	−.03	.04	.774	.003	.02	−.15	−.03	.04	.880	.002	.02	−.09	−.03	.04	.927
Impaired family functioning	−.06	.06	−1.02	−.17	.05	.309	−.06	.06	−.98	−.17	.06	.328	−.05	.06	−.97	−.17	.06	.332
Low income	−.16	.08	−2.07	−.32	−.01	.042	−.16	.08	−2.06	−.32	−.01	.043	−.17	.08	−2.10	−.33	−.01	.040
PA (T2)	.01	.02	.47	−.03	.05	.638	.02	.03	.65	−.04	.08	.523	.01	.02	.56	−.03	.06	.578
Two–way interaction	.01	.01	−.71	−.02	.04	.483	.03	.05	−.54	−.12	.07	.591	.01	.06	−.23	−.12	.10	.821
R^2	.18						.18						.19					
F (DF1, DF2), significance	*F* (9,1299) = 32.11, *p* < .001						*F* (9,1299) = 32.09, *p* < .001						*F* (9,1299) = 33.16, *p* < .001					
ΔR2	.00						.00						.01					
F change *(DF1, DF2),* significance	*F* (1, 1298) = .18, *p* = .673						*F* (1, 1298) = .00, *p* = .991						*F* (1, 1298) = 7.86, *p* = .005					

Table A7. Associations Between Predictors, PA, and Self-Reported Concept in Mathematics at age 13

Note. DF: Degree of freedom.

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	.41	.13	3.21	.16	.67	.001	.41	.13	3.22	.16	.67	.001
Cognitive ability	−.002	.06	−.04	−.11	.11	.966	−.003	.06	−.05	−.11	.11	.957
PA (T1)	−.03	.04	−.74	−.10	.05	.462	−.03	.04	−.94	−.10	.04	.350
Self concept in mathematics (T1)	.55	.03	22.07	.50	.59	<.001	.54	.03	21.90	.50	.59	< .001
Difficult temperament	−.08	.04	−2.02	−.16	−.002	.045	−.08	.04	−1.87	−.16	.00	.063
Impaired family functioning	.05	.14	−.37	−.22	.32	.714	.05	.14	.37	−.22	.32	.714
Low income	.42	.16	2.57	.10	.74	.011	.43	.16	2.63	.11	.75	.009
PA (T2)							.05	.05	.94	−.05	.14	.352
R^2	.38						.38					
F (DF1, DF2), significance	*F* (7, 1301) = 111.93, *p* < .001						*F* (8, 1300) = 97.88, *p* < .001					
ΔR2	.38						.00					
F change *(DF1, DF2),* significance	*F* (7,1300) = 111.93, *p* < .001						*F* (1,1299) = .10, *p* =.754					

Table A8. Interactions Between Predictors and PA in Self-Reported Concept in Mathematics at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	.41	.13	3.23	.16	.67	.001	.40	.13	3.21	.16	.65	.001	.41	.13	3.22	.16	.67	.001
Cognitive ability	−.01	.06	−.12	−.12	.10	.903	.00	.04	.05	−.11	.11	.962	−.01	.06	−.10	−.11	.10	.923
PA (T1)	−.03	.04	−.96	−.11	.04	.339	−.03	.04	−.95	−.11	.04	.345	−.03	.04	−.93	−.10	.04	.353
Self concept in mathematics (T1)	.54	.03	21.95	.50	.59	< .001	.55	.03	21.93	.50	.60	< .001	.54	.03	21.90	.50	.59	< .001
Difficult temperament	−.07	.04	−1.75	−.15	.01	.081	−.08	.04	−1.99	−.17	−.00	.048	−.08	.04	−1.87	−.16	−.00	.063
Impaired family functioning	.05	.14	.37	−.22	.32	.740	.05	.14	.38	−.22	.33	.708	.05	.14	.38	−.22	.32	.707
Low income	.43	.16	2.63	.11	.75	.009	.41	.16	2.54	.09	.73	.012	.40	.16	2.46	.08	.72	.015
PA (T2)	.05	.05	.94	−.05	.14	.351	.01	.07	.15	−.13	.14	.882	.06	.05	1.11	−.05	.16	.271
Two–way interaction	.02	.04	.57	−.05	.09	.572	.11	.11	1.01	−.11	.34	.319	−.07	.10	−.70	−.26	.12	.483
R^2	.38						.38						.38					
F (DF1, DF2), significance	*F* (9,1299) = 88.44, *p* < .001						*F* (9,1299) = 88.83, *p* < .001						*F* (9,1299) = 87.12, *p* < .001					
ΔR2	.004						.005						.000					
F change *(DF1, DF2),* significance	*F* (1, 1298) = 8.46, *p* = .004						*F* (1, 1298) = 10.62, *p* = .001						*F* (1, 1298) = 1.01, *p* = .315					

Table A9. Associations Between Predictors, PA, and Self-Reported Concept in Language at age 13

Note. DF: Degree of freedom.

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	−.17	.12	−1.42	−.40	.06	.157	−.17	.12	−1.43	−.40	.06	.154
Cognitive ability	.02	.05	.27	−.09	.12	.786	.02	.05	.27	−.09	.12	.785
PA (T1)	−.03	.04	−.74	−.11	.05	.464	−.03	.04	−.74	−.12	.05	.461
Self concept in reading (T1)	.23	.04	6.46	.16	.31	<.001	.24	.04	6.43	.16	.31	< .001
Self concept in writing (T1)	.28	.03	8.88	.22	.35	<.001	.28	.03	8.90	.22	.35	<.001
Difficult temperament	−.09	.04	−2.38	−.17	−.02	.018	−.09	.04	−2.33	−.17	−.01	.020
Impaired family functioning	−.23	.13	−1.82	−.48	.02	.069	−.23	.13	−1.83	−.48	.02	.069
Low income	.04	.15	.29	−.25	.33	.774	.04	.15	.30	−.24	.33	.765
PA (T2)							.01	.04	.22	−.08	.09	.829
R^2	.23						.23					
F (DF1, DF2), significance	*F* (8, 1298) = 47.96, *p* < .001						*F* (10,1296) = 38.38, *p* < .001					
ΔR2	.23						.00					
F change *(DF1, DF2),* significance	*F* (8,1298) = 47.96, *p* < .001						*F* (1, 1296) = .50, *p* = .482					

Table A10. Interactions Between Predictors and PA in Self-Reported Concept in Language at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	−.17	.12	−1.42	−.40	.06	.155	−.17	.12	−1.45	−.40	.06	.147	−.17	.12	−1.43	−.40	.06	.152
Cognitive ability	.02	.05	.34	−.09	.13	.737	.02	.05	.28	−.09	.12	.779	.02	.05	.30	−.09	.12	.762
PA (T1)	−.03	.04	−.73	−.12	.05	.471	−.03	.04	−.74	−.12	.05	.462	−.03	.04	−.75	−.12	.05	.458
Self concept in reading (T1)	.24	.04	6.54	.17	.31	< .001	.23	.04	6.43	.16	.31	< .001	.24	.04	6.43	.16	.31	< .001
Self concept in writing (T1)	.28	.03	8.87	.22	.34	<.001	.28	.03	8.84	.22	.35	<.001	.28	.03	8.89	.22	.35	<.001
Difficult temperament	−.10	.04	−2.56	−.18	.02	.011	−.09	.04	−2.30	−.17	−.01	.022	−.09	.04	−2.33	−.17	−.01	.020
Impaired family functioning	−.22	.13	−1.78	−.47	.02	.076	−.23	.13	−1.84	−.48	.02	.068	−.23	.13	−1.83	−.48	.02	.068
Low income	.04	.15	.26	−.25	.33	.794	.04	.15	.29	−.24	.33	.768	.06	.15	.41	−.24	.36	.684
PA (T2)	.01	.04	.21	−.08	.09	.831	.01	.05	.12	−.10	.11	.905	.002	.05	.04	−.09	.10	.965
Two–way interaction	−.03	.02	−1.16	−.07	.02	.246	.01	.09	.08	−.18	.19	.933	.04	.10	.43	−.15	.24	.670
R^2	.23						.23						.23					
F (DF1, DF2), significance	*F* (10,1296) = 38.38, *p* < .001						*F* (10,1296) = 38.76, *p* < .001						*F* (10,1296) = 38.33, *p* < .001					
ΔR2	.00						.002						.00					
F change *(DF1, DF2),* significance	*F* (1, 1296) = .50, *p* = .482						*F* (1, 1296) = 3.41, *p* = .065						*F* (1, 1296) = .08, *p* = .782					

Table A11. Associations Between Predictors and PA in Self-Reported Intrinsic Motivation in Mathematics at age 13

Note. DF: Degree of freedom.

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	.12	.14	.80	−.17	.40	.425	.11	.15	.79	−.17	.40	.430
Cognitive ability	−.02	.07	−.32	−.15	.11	.753	−.02	.07	−.32	−.15	.11	.746
PA (T1)	−.06	.04	−1.52	−.15	.02	.132	−.07	.04	−1.56	−.15	.02	.122
Intrinsic motivation in mathematics (T1)	.43	.03	17.09	.38	.48	<.001	.43	.03	17.02	.38	.48	< .001
Difficult temperament	−.01	.05	−.15	−.10	.08	.884	−.01	.05	−.12	−.10	.08	.906
Impaired family functioning	−.17	.14	−1.20	−.45	.11	.229	−.17	.14	−1.19	−.45	.11	.233
Low income	.63	.18	.29	.29	.98	<.001	.64	.18	3.55	.29	.99	<.001
PA (T2)							.02	.06	.28	−.11	.14	.783
R^2	.25						.25					
F (DF1, DF2), significance	*F* (7, 1301) = 61.30, *p* < .001						*F* (8,1300) = 53.61, *p* < .001					
ΔR2	.25						.00					
F change *(DF1, DF2),* significance	*F* (7,1300) = 61.30, *p* < .001						*F* (1, 1299) = .11, *p* = .736					

Table A12. Interactions Between Predictors and PA in Self-Reported Intrinsic Motivation in Mathematics at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	.11	.14	.79	−.17	.40	.433	.11	.15	.75	−.18	.40	.451	.11	.15	.76	−.18	.40	.446
Cognitive ability	−.02	.07	−.33	−.15	.11	.742	−.02	.07	−.29	−.15	.11	.774	−.02	.07	−.28	−.15	.11	.780
PA (T1)	−.07	.04	−1.55	−.15	.02	.123	−.07	.04	−1.54	−.15	.02	.126	−.07	.04	−1.56	−.15	.02	.121
Intrinsic motivation in mathematics (T1)	.43	.03	16.96	.38	.48	< .001	.43	.03	17.02	.38	.48	< .001	.43	.03	17.05	.38	.48	< .001
Difficult temperament	−.01	.05	−.12	−.10	.09	.903	−.01	.05	−.18	−.10	.08	.856	−.01	.05	−.12	−.10	.08	.905
Impaired family functioning	−.17	.14	−1.19	−.45	.11	.234	−.17	.14	−1.20	−.45	.11	.231	−.17	.14	−1.21	−.45	.11	.228
Low income	.64	.18	3.53	.28	.99	< .001	.63	.18	3.51	.28	.99	<.001	.68	.18	3.71	.32	1.03	< .001
PA (T2)	.02	.06	.27	−.11	.14	.787	.002	.08	.31	−.15	.15	.975	.001	.07	.01	−.14	.14	.989
Two–way interaction	.00	.04	−.01	−.07	.07	.996	.05	.10	.45	−.16	.25	.651	.10	.12	.78	−.15	.34	.440
R^2	.25						.25						.25					
F (DF1, DF2), significance	*F* (9,1299) = 48.61, *p* < .001						*F* (9,1299) = 47.84, *p* < .001						*F* (9,1299) = 47.69, *p* < .001					
ΔR2	.004						.001						.00					
F change *(DF1, DF2),* significance	*F* (1, 1298) = 6.71, *p* = .010						*F* (1, 1298) = 1.47, *p* = .226						*F* (1, 1298) = .45, *p* = .505					

Table A13. Associations Between Predictors and PA in Self-Reported Intrinsic Motivation in Language at age 13

Note. DF: Degree of freedom.

	Model 1: Predictor variables						Model 2: PA moderator					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*	
Sex	.20	.15	−1.28	−.49	.10	.201	−.20	.15	−1.28	−.50	.11	.202
Cognitive ability	−.06	.07	−.86	−.19	.07	.388	−.06	.07	−.86	−.19	.07	.389
PA (T1)	−.002	.05	−.04	−.10	.09	.967	−.01	.05	−.11	−.10	.09	.912
Intrinsic motivation in reading (T1)	.20	.03	7.69	.15	.25	<.001	.20	.03	7.78	.15	.25	< .001
Intrinsic motivation in writing (T1)	.19	.03	7.40	.14	.24	<.001	.19	.03	7.35	.14	.24	<.001
Difficult temperament	−.03	.04	−.77	−.12	.05	.440	−.03	.04	−.71	−.12	.06	.477
Impaired family functioning	−.20	.15	−1.31	−.49	.10	.193	−.20	.15	−1.31	−.49	.10	.191
Low income	−.08	.16	−.46	−.39	.24	−.07	.16	.18	−.42	−.39	.25	.677
PA (T2)							.02	.05	.40	−.08	.12	.692
R^2	.15						.15					
F (DF1, DF2), significance	*F* (8, 1300) = 28.82, *p* < .001						*F* (9,1299) = 25.60, *p* < .001					
ΔR2	.15						.00					
F change *(DF1, DF2),* significance	*F* (8,1299) = 28.82, *p* < .001						*F* (1, 1298) = .004, *p* = .952					

Table A14. Interactions Between Predictors and PA in Self-Reported Intrinsic Motivation in Language at age 13

Note. DF: Degree of freedom.

	Model 3																	
	Difficult temperament × PA						Impaired family functioning × PA						Low–income × PA					
	b	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*	*b*	*SE*	*t*	95 % CI		*p*
				LL	*UL*					*LL*	*UL*					*LL*	*UL*	
Sex	−.19	.15	−1.28	−.49	.11	.203	−.20	.15	−1.34	−.50	.10	.183	−.20	.15	−1.33	−.50	.10	.186
Cognitive ability	−.06	.07	−.85	−.19	.07	.397	−.05	.07	−.77	−.18	.08	.443	−.05	.07	−.73	−.18	.08	.465
PA (T1)	−.01	.05	−.11	−.10	.09	.914	−.01	.05	−.10	−.10	.09	.923	−.01	.05	−.12	−.10	.09	.902
Intrinsic motivation in reading (T1)	.20	.03	7.78	.15	.25	< .001	.20	.03	7.76	.15	.25	< .001	.20	.03	7.73	.15	.25	< .001
Intrinsic motivation in writing (T1)	.19	.03	7.33	.14	.24	<.001	.19	.03	7.37	.14	.24	<.001	.19	.03	7.36	.14	.24	<.001
Difficult temperament	−.03	.05	−.75	−.12	.06	.455	−.04	.04	−.85	−.12	.05	.398	−.03	.04	−.73	−.12	.05	.465
Impaired family functioning	−.20	.15	−1.30	−.49	.10	.196	−.20	.15	−1.31	−.50	.10	.192	−.20	.15	−1.34	−.50	.10	.182
Low income	−.07	.16	−.43	−.39	.25	.670	−.08	.16	−.49	−.40	.24	.623	.03	.17	.16	−.30	.36	.871
PA (T2)	.02	.05	.39	−.08	.12	.698	−.01	.07	−.19	−.15	.13	.852	.02	.06	−.37	−.13	.09	.709
Two–way interaction	−.01	.03	−.26	−.07	.05	.799	.10	.12	.83	−.15	.35	.412	.24	.11	2.16	.02	.45	.031
R^2	.15						.15						.15					
F (DF1, DF2), significance	*F* (10,1298) = 23.02, *p* < .001						*F* (10,1298) = 23.48, *p* < .001						*F* (10,1298) = 23.70, *p* < .001					
ΔR2	.00						.003						.004					
F change *(DF1, DF2),* significance	*F* (1, 1297) = .02, *p* = .902						*F* (1, 1297) = 3.92, *p* = .048						*F* (1, 1297) = 5.75, *p* = .017					

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