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Psychological Pathways Linking Multidimensional Family Environment Factors to Adolescent Physical Activity: The Sequential Mediation of Self-Efficacy and Intrinsic Motivation

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ABSTRACT: Background: Associations between different dimensions of the family environment and adolescent physical activity (PA) may differ, yet empirical evidence on these differences remains limited. This study aimed to clarify the mechanism of this path difference and further explore the functional roles of self-efficacy and intrinsic motivation.

Methods: A three-wave longitudinal study was conducted among 913 Chinese adolescents, who completed measures of family environment (home PA equipment availability [HPEA], home electronic device availability [HEDA], perceived parental autonomy support [PPAS], and perceived parental exercise habits [PPEH]), self-efficacy, intrinsic motivation, and PA. Structural equation modeling (SEM) was performed using maximum likelihood estimation with robust standard errors (MLR) to examine the mediating effects.

Results: The prospective associations between all family environment dimensions (T1) and PA (T3) were significantly mediated by intrinsic motivation (T2), as well as by the sequential mediation pathway via self-efficacy (T2) and intrinsic motivation (HPEA, PPAS, PPEH: bs = 0.015–0.063, 95% CI [0.004, 0.095]; HEDA: bs = −0.039 to −0.014, 95% CI [−0.065, −0.004]). Conversely, the independent indirect effect of self-efficacy (T2) and the direct effects of PPAS (T1) and PPEH (T1) were not significant (95% CIs included zero). Significant direct effects on PA (T3) were found for HPEA (T1) (b = 0.058, 95% CI [0.001, 0.116]) and HEDA (T1) (b = −0.067, 95% CI [−0.117, −0.017]).

Conclusions: Association patterns between different dimensions of the family environment and PA vary. Intrinsic motivation plays a key role, being partly driven by self-efficacy as an important antecedent.

1. INTRODUCTION

Adolescent participation in regular physical activity (PA) provides numerous immediate and long-term health benefits, such as increased muscular strength and cardiometabolic health, improved cognitive development and academic achievement, and diminished risks of depression and other mental health problems (Chaput et al., 2020; Janssen & LeBlanc, 2010; Sluijs et al., 2021). Conversely, a sedentary lifestyle and too much screen time can increase the risk of obesity and cardiovascular diseases, and also lead to a decline in mental health and a lower quality of life (Carson et al., 2016; Chaput et al., 2020; Tremblay et al., 2011). Although increasingly scientific evidence emphasizes the importance of regular PA, most adolescents around the world still fail to reach the recommended amount of activity. According to the Global Status Report on Physical Activity 2022, more than 81% of adolescents aged 11–17 fail to achieve the required 60 minutes of moderate-to-vigorous PA per day, with inactivity

rates at 80% for males and 89% for girls in China with inactivity rates at 80% for males and 89% for girls in China (World Health Organization, 2022). Consistent results from large-scale national surveys and recent peer-reviewed studies show that the PA level of Chinese adolescents is still low, and there are significant differences in gender, educational stages, and urban-rural contexts (Guo et al., 2024; Liu, Ke, et al., 2023; X. Yang et al., 2021). These research results show that the lack of PA among adolescents is a significant public health problem, both globally and in China.

Adolescent PA behaviors are influenced by many factors, including individual biological and psychological characteristics, social and policy factors, and the built environment (Sallis et al., 2008). Family is one of the most direct and lasting environments in the daily interactions of adolescents, which has a significant impact on their PA behaviors. Extensive empirical studies have further supported the critical importance of the family environment. Various types of parental support, such as role modeling, encouragement, logistical assistance, rule establishment, and joint participation, are positively related to the PA level of adolescents (Champion et al., 2022; Petersen et al., 2020; Rhodes, Guerrero, et al., 2020; Rhodes, Perdew, et al., 2020). In addition to parent support, family PA resources, such as the exercise equipment, also play an important role in promoting adolescents' PA participation (Parker et al., 2022; Sirard et al., 2010; Zeng et al., 2022). However, most existing studies rely on cross-sectional designs, which limit the ability to examine the temporal and dynamic associations between the family environment and adolescents' PA. Previous studies have focused on a single aspect of the family environment, leading to a limited understanding of its multidimensional nature. Furthermore, limited research has examined variations in pathways linking diverse family environmental factors to adolescent PA, particularly through longitudinal designs (Petersen et al., 2020; Rhodes, Perdew, et al., 2020; Sluijs et al., 2021; Vega-Díaz et al., 2023).

We adopts Self-Determination Theory (SDT) as the main theoretical framework to explore the psychological mechanisms underlying the relationship between the family environment and adolescent PA. SDT argues that regular participation in PA is mainly driven by autonomous motivation, especially intrinsic motivation, which depends on the satisfaction of basic psychological needs, including the need for competence (Ntoumanis & Moller, 2025; Ryan & Deci, 2017; Standage, 2023). In the past, in PA studies, the assessment of ability satisfaction usually focused on general psychological feelings, representing an individual's overall evaluation of their own ability. Therefore, these measures may not adequately reflect individual confidence fluctuations in specific situations, such as PA. Conversely, self-efficacy (defined as an individual's belief in their own performance capabilities for a specific task) can more accurately reflect an individual's state of confidence in a particular situation (Bandura, 1997). Research demonstrates that in the field of PA, there is a conceptual overlap between competence and self-efficacy, but they are different variables (Rodgers et al., 2014). In addition, a study shows that integrating self-efficacy into the SDT framework can significantly enhance the model's predictive power for behavior (Sweet et al., 2012). From this perspective, we argue that self-efficacy is a more direct and task-specific assessment of beliefs, and is a key prerequisite for motivation internalization. Therefore, we incorporate self-efficacy into the SDT framework and combines intrinsic motivation to construct a sequence mediation model to clarify the sequence path that transforms ability beliefs into motivation.

In summary, we used a three-wave longitudinal design to systematically examine the prospective associations between family environment and adolescent PA, while assessing the independent and sequential mediating effects of self-efficacy and intrinsic motivation. Based on the above, the following hypotheses are proposed: (H1) the associations between different family environment dimensions and adolescent PA will demonstrate significant variability; (H2) self-efficacy and intrinsic motivation will independently mediate these associations; and (H3) self-efficacy and intrinsic motivation will have a serial mediating effect on the associations between the family environment and adolescent PA.

2. MATERIALS AND METHODS

2.1 Participants and Procedure

We adopted a multistage cluster random sampling design. First, six middle schools were randomly selected from the central urban area of a medium-sized city in Eastern China, comprising three junior high schools and three senior high schools. Because final-year students are required to prepare for high school or college entrance examinations, their participation in PA may be constrained; therefore, only first- and second-year students were included in the present study. Within each selected school, classes were randomly selected, and questionnaires were administered to all students in the selected classes. Data collection is carried out at three time points, each with an interval of six months. In November 2024 (T1), May 2025 (T2), and November 2025 (T3), respectively. Variables and family demographics were assessed at T1; self-efficacy and intrinsic motivation at T2; and

PA at T1 and T3. A total of 980 questionnaires were distributed. After data screening, participants who did not answer carefully (such as multiple questions with the same answer, or a significant number of unanswered questions) and those who missed visits due to transfer or health reasons were excluded. The final sample is 913 participants who completed all stages of the survey. Among them, there are 436 boys (47.8%) and 477 girls (52.2%), with an age range of 13–18 years (M = 15.32, SD = 1.57).

The study has been approved by the local Institutional Ethics Committee. All participants and their parents or legal guardians have signed a written informed consent form.

2.2 Measurements

Confirmatory factor analyses (CFA) were conducted for all scales to examine their structural validity. Based on the CFA results, items with low factor loadings were removed (see Table S1 in the Appendix). The refined scales demonstrated acceptable model fit.

2.2.1 Family Environment

According to the socio-ecological model (Sallis et al., 2008), he family environment can be composed of two main dimensions: the physical environment and the social environment. The physical environment refers to the objective material conditions within the family that influence PA behaviors, such as the availability of exercise equipment and media devices. In contrast, the social environment mainly includes the encouragement, support, and role modeling of parents to children's everyday PA participation. Within this framework, the family physical environment was measured by the availability of home PA equipment (HPEA) and home electronic devices (HEDA). The family social environment was inflected by perceived parental autonomy support (PPAS) and perceived parental exercise habits (PPEH). Previous studies have also shown that family physical resources and parents' support and role modeling behaviors are closely related to adolescents' PA levels, which provides a strong theoretical basis for selecting these four variables as key indicators of the family environment (Petersen et al., 2020; Rhodes, Guerrero, et al., 2020).

HPEA was assessed using relevant items adapted from the FLASHE study questionnaire, which evaluates the resources in the family physical environment. This scale has shown strong reliability and validity among Chinese adolescents (Qiu et al., 2021; Zeng et al., 2022). The original scale contains eight items. Based on CFA, one item with a low factor loading was removed. The final seven items comprised bicycles (excluding stationary bikes), basketball hoops, general sports equipment (e.g., balls, rackets), skateboards or scooters, weightlifting equipment, cardio equipment (e.g., treadmills, ellipticals), and interactive gaming systems (e.g., Wii, Xbox Kinect). All items were scored using the five-point Likert scale, ranging from 1 (not applicable) to 5 (used at least once a week). In the present study, Cronbach's α for this scale was 0.869 at T1.

HEDA was measured using the Family Electronic Media Use Assessment Scale developed by J. Yang (2017). The original scale consisted of seven items intended to assess Chinese adolescents' daily access to electronic screen media and internet-enabled devices, including television sets, laptop computers, desktop computers, mobile phones, tablet computers, internet connections, and DVD players. Internet connection and DVD player items were excluded due to low factor loadings in the CFA. All items were scored using the five-point Likert scale, from 1 (not applicable) to 5 (multiple use). This scale has been validated to have high confidence and validity among Chinese adolescents J. Yang (2017). In the present study, Cronbach's α for this scale was 0.885 at T1.

PPAS was assessed using a four-item scale developed by Dong (2021), which was adapted from the Family Support Subscale of the Multidimensional Scale of Perceived Social Support (Zimet et al., 1988). The scale evaluates parental support, understanding, and emotional encouragement for adolescent PA. To be consistent with the broader topic of this study, the term "physical exercise" has been modified to "physical activity". All items were scored using a five-point Likert scale, from 1 (never) to 5 (always). This scale has been validated to have strong reliability and validity among Chinese adolescents (Dong, 2021). In the present study, Cronbach's α for this scale was 0.794 at T1.

PPEH were measured using a three-item scale developed by Dong (2021). The scale examines parents' exercise behavior in the past few months from the three dimensions of frequency, duration, and regularity. All items were scored using a five-point Likert scale. This scale has been validated to possess strong reliability and validity among Chinese adolescents (Dong, 2021). In the present study, Cronbach's α for this scale was 0.757 at T1.

2.2.2 Self-efficacy

Self-efficacy was measured using the Chinese version of the Exercise Self-Efficacy Scale (SEE-C). The scale was originally developed by Resnick and Jenkins (2000) and later translated and adapted into Chinese by Lee et al. (2009). The original SEE-C contains nine items to evaluate the participants' confidence in adhering to exercise under various potentially impactful situations. Based on CFA, three items with low factor loadings were eliminated, and six items were finally retained. Although the original scale adopts a 10-point system, to be consistent with other measures, we changes it to a 5-point Likert scale. The scale scores from 1 (completely unconfident) to 5 (very confident). This scale has been validated to have strong reliability and validity among the Chinese population (Lee et al., 2009; Wong et al., 2020). In the present study, Cronbach's α for this scale was 0.858 at T2.

2.2.3 Intrinsic motivation

Intrinsic motivation was assessed using a four-item scale (Dong, 2021), adapted from the Situational Motivation Scale (Guay et al., 2000). A sample item is, "I think participating in physical activity is very enjoyable." All items were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This scale has been validated to possess strong reliability and validity among Chinese adolescents (Dong, 2021). In the present study, Cronbach's α for this scale was 0.855 at T2.

2.2.4 PA

PA was measured using the Chinese version of the PA Questionnaire for Adolescents (PAQ-A) (X. Li et al., 2015). The questionnaire was originally developed by Kowalski et al. (2004). Unlike many PA questionnaires, PAQ-A does not need to recall the duration or intensity of the exercise in detail, thereby reducing the burden and memory bias of participants. The original questionnaire consisted of nine items, with the ninth item serving as a special-condition inquiry and therefore excluded from scoring. Based on CFA, Item 3, which assessed PA during the lunch break, was removed due to low factor loading, resulting in a final scale of seven items used for analysis. This scale has been validated to possess strong reliability and validity among Chinese adolescents (Qin et al., 2024). In the present study, Cronbach's α was 0.876 at T1 and 0.868 at T3.

2.3 Statistical Analysis

In the present study, descriptive statistics and Pearson correlations were analyzed using SPSS 29.0. Mediation effects were tested in Mplus 8.3 using maximum likelihood estimation with robust standard errors (MLR), with missing data addressed via full information maximum likelihood (FIML). To account for the multistage cluster sampling design, in which students were nested within classes, the TYPE = COMPLEX option was employed, with class specified as the cluster variable. According to Hoyle (2012), model fit is considered acceptable when the chi-square to degrees of freedom ratio ($\chi 2/df$) is below 5.00, the comparative fit index (CFI) and Tucker-Lewis index (TLI) exceed 0.90, and the root mean square error of approximation (RMSEA) is below 0.08.

Given that gender and age may be associated with PA among adolescents, both variables were included in the model as controls. Additionally, PA (T1) was entered as a covariate in the longitudinal model to control for baseline variations in the primary outcome over time.

3. RESULTS AND DISCUSSION

3.1 Preliminary Analysis

The correlation matrix for the key study variables is shown in Table 1. Results indicated that HPEA (T1), PPAS(T1), and PPEF (T1) were all significantly positively correlated with intrinsic motivation (T2) and self-efficacy (T2). Furthermore, these three family-related variables showed significant positive associations with PA (T3). In contrast, HEDA (T1) was significantly negatively correlated with intrinsic motivation (T2), self-efficacy (T2), and PA (T3). Additionally, a significant positive correlation was observed between intrinsic motivation (T2) and self-efficacy (T2), and both variables were significantly positively associated with PA (T3). Finally, PA (T1) was significantly positively correlated with PA (T3).

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Table 1. Descriptive statistics and correlations among the key variables

Variables	M	SD	1	2	3	4	5	6	7	8
1. HPEA (T1)	3.008	0.931	1							
2. HEDA (T1)	2.973	1.043	−0.241***	1						
3. PPAS (T1)	2.885	0.877	0.194***	−0.349***	1					
4. PPEH (T1)	2.901	0.909	0.212***	−0.279***	0.372***	1				
5. PA (T1)	2.470	0.752	0.366***	−0.221***	0.254***	0.301***	1			
6. Intrinsic motivation (T2)	2.949	1.014	0.275***	−0.426***	0.380***	0.283***	0.443***	1		
7. Self-efficacy (T2)	3.007	0.911	0.445***	−0.358***	0.169***	0.282***	0.544***	0.420***	1	
8. PA (T3)	2.567	0.783	0.300***	−0.285***	0.250***	0.236***	0.569***	0.415***	0.392***	1

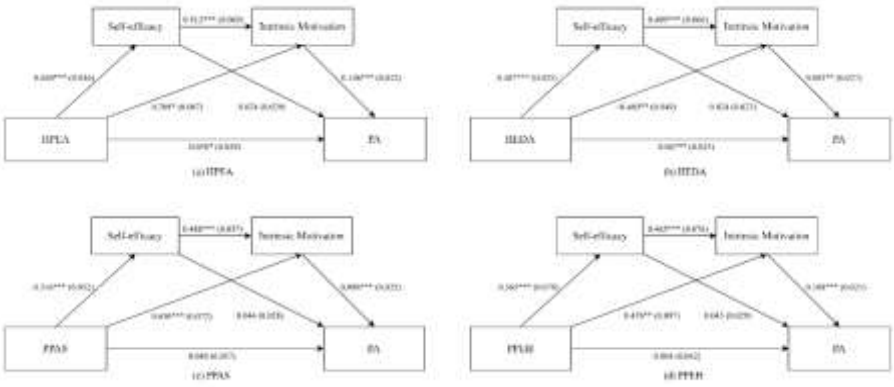
Note: N = 913. PA = physical activity; HPEA = home PA equipment availability; HEDA = home electronic device availability; PPAS = perceived parental autonomy support; PPEH = perceived parental exercise habits. T1= time 1; T2= time 2; T3= time 3. * p < .05; ** p < .01; *** p < .001.

3.2 Path Analysis

The path analysis results for the four hypothesized models demonstrated acceptable model fit (e.g., $\chi 2/df < 5$, CFI > .90, TLI > .90, and RMSEA < .08). As shown in Figure 1 and Table 2, after controlling for gender, age, and baseline PA (T1), HPEA (T1), PPAS (T1), and PPEF (T1) significantly positively predicted both self-efficacy (T2) and intrinsic motivation (T2) across all models (bs = 0.209–0.650, SEs = 0.046–0.097, all p < .01). Conversely, HEDA (T1) was significantly negatively associated with both mediators (bs = −0.460 to −0.407, SEs = 0.025–0.049, all p < .001). Regarding the association between the mediators, self-efficacy (T2) exhibited a significant positive effect on intrinsic motivation (T2) in all models (bs = 0.409–0.512, SEs = 0.057–0.076, all p < .001).

As for the prediction of PA (T3), intrinsic motivation (T2) was a significant positive predictor of PA (T3) (bs = 0.085–0.108, SEs = 0.021–0.027, all p < .01). However, the path from self-efficacy (T2) to PA (T3) was consistently non-significant (bs = 0.024–0.044, SEs = 0.023–0.029, all p > .05). For the direct effects, the paths from HPEA (T1) and HEDA (T1) to PA (T3) remained statistically significant (HPEA: b = 0.058, SE = 0.029, p < .05; HEDA: b = −0.067, SE = 0.025, p < .01), whereas the direct effects of PPAS (T1) and PPEF (T1) on PA (T3) were non-significant (bs < 0.10, all ps > .05).

Figure 1. Multiple mediation models of the association between family environment dimensions and adolescent physical activity



Note: (a) HPEA model; (b) HEDA model; (c) PPAS model; (d) PPEH model. Unstandardized coefficients are presented with standard errors in parentheses. Note: PA = physical activity; HPEA = home PA equipment availability; HEDA = home

electronic device availability; PPAS = perceived parental autonomy support; PPEH = perceived parental exercise habits. * p < .05; ** p < .01; *** p < .001.

Table 2. Path coefficients for the serial mediation models

Path	Model 1 (HPEA)	Model 2 (HEDA)	Model 3 (PPAS)	Model 4 (PPEH)
	b (SE) [95% CI]	b (SE) [95% CI]	b (SE) [95% CI]	b (SE) [95% CI]
Dependent Variable: Self-efficacy (T2)				
X →Self-efficacy	0.640*** (0.046) [0.550, 0.730]	−0.407*** (0.025) [−0.456, −0.358]	0.316*** (0.052) [0.214, 0.417]	0.565*** (0.078) [0.413, 0.717]
R2	0.301	0.182	0.060	0.179
Dependent Variable: Intrinsic Motivation (T2)				
X →Intrinsic motivation	0.209** (0.067) [0.078, 0.341]	−0.460*** (0.049) [−0.557, −0.364]	0.650*** (0.072) [0.509, 0.791]	0.476*** (0.097) [0.286, 0.667]
Self-efficacy →Intrinsic motivation	0.512*** (0.063) [0.389, 0.636]	0.409*** (0.066) [0.280, 0.538]	0.488*** (0.057) [0.376, 0.600]	0.465*** (0.076) [0.316, 0.615]
R2	0.247	0.350	0.383	0.297
Dependent Variable: PA (T3)				
X → PA	0.058* (0.029) [0.001, 0.116]	−0.067** (0.025) [−0.117, −0.017]	0.040 (0.037) [−0.032, 0.112]	0.004 (0.042) [−0.077, 0.086]
Self-efficacy → PA	0.024 (0.029) [−0.033, 0.080]	0.024 (0.023) [−0.022, 0.069]	0.044 (0.028) [−0.010, 0.098]	0.043 (0.029) [−0.014, 0.099]
Intrinsic motivation → PA	0.106*** (0.023) [0.060, 0.151]	0.085** (0.027) [0.031, 0.139]	0.098*** (0.025) [0.049, 0.147]	0.108*** (0.021) [0.067, 0.148]
R2	0.417	0.427	0.408	0.409

Note. N = 913. b = unstandardized regression coefficient; SE = standard error; 95% CI = 95% confidence interval. X represents HPEA (Model 1), HEDA (Model 2), PPAS (Model 3), and PPEH (Model 4). PA = physical activity; HPEA = home PA equipment availability; HEDA = home electronic device availability; PPAS = perceived parental autonomy support; PPEH = perceived parental exercise habits. The predictor (X), mediators, and outcome (PA) were measured at T1, T2, and T3, respectively. * p < .05; ** p < .01; *** p < .001.

3.3 Mediation Analysis

After controlling for gender, age, and baseline PA (T1), the mediation analysis revealed several key pathways (Table 3). The serial mediation path from the predictor (T1) to PA (T3) via self-efficacy (T2) and intrinsic motivation (T2) was statistically significant across all models (HPEA, PPAS, PPEH: bs = 0.015–0.035, 95% CI [0.004, 0.055]; HEDA: b = −0.014, 95% CI [−0.025, −0.004]). Similarly, the simple mediation path from the predictor (T1) to PA (T3) via intrinsic motivation (T2) was significant (HPEA, PPAS, PPEH: bs = 0.022–0.063, 95% CI [0.009, 0.095]; HEDA: b = −0.039, 95% CI [−0.065, −0.013]). In contrast, the simple mediation path from the predictor (T1) to PA (T3) via self-efficacy (T2) was consistently non-significant (HPEA, PPAS, PPEH: bs = 0.014–0.024, 95% CI [−0.028, 0.054]; HEDA: b = −0.010, 95% CI [−0.028, 0.009]), as the 95% confidence intervals included zero across all models.

Table 3. Indirect effects for the serial mediation models

Indirect Path	Model 1 (HPEA)	Model 2 (HEDA)	Model 3 (PPAS)	Model 4 (PPEH)
	Effect [95% CI]	Effect [95% CI]	Effect [95% CI]	Effect [95% CI]
Total indirect effect	0.072*** [0.037, 0.107]	−0.063*** [−0.095, −0.031]	0.093*** [0.058, 0.127]	0.104*** [0.065, 0.142]
X →Self-efficacy →PA	0.015 [−0.021, 0.051]	−0.010 [−0.028, 0.009]	0.014 [−0.001, 0.029]	0.024 [−0.005, 0.054]
X →Intrinsic motivation →PA	0.022** [0.009, 0.035]	−0.039** [−0.065, −0.013]	0.063*** [0.032, 0.095]	0.051** [0.020, 0.083]

X →Self-efficacy → Intrinsic motivation → PA	0.035** [0.015, 0.055]	−0.014** [−0.025, −0.004]	0.015** [0.004, 0.026]	0.028** [0.011, 0.045]

Note. N = 913. Effect = unstandardized indirect effect; 95% CI = 95% confidence interval. X represents HPEA (Model 1), HEDA (Model 2), PPAS (Model 3), and PPEH (Model 4). PA = physical activity; HPEA = home PA equipment availability; HEDA = home electronic device availability; PPAS = perceived parental autonomy support; PPEH = perceived parental exercise habits. The predictor (X), mediators, and outcome (PA) were measured at T1, T2, and T3, respectively. * $p < .05$; ** $p < .01$; *** $p < .001$.

3.4 Discussion

Using a three-wave longitudinal design, we investigated the prospective associations and underlying psychological mechanisms between the family environment and adolescent PA. The results across four models indicated that although family-based factors significantly predicted adolescent self-efficacy, self-efficacy alone did not independently mediate the association between the family environment and PA. In contrast, both the independent mediating role of intrinsic motivation and the serial mediation pathway from self-efficacy to intrinsic motivation were supported. Furthermore, the direct paths exhibited domain-specific differences, as physical environment factors (HPEA and HEDA) remained significantly associated with PA after accounting for the mediators, suggesting partial mediation. Conversely, social environment factors (PPAS and PPEH) were linked to PA primarily through indirect pathways, suggesting that they may relate to PA mainly through a process of psychological internalization. In conclusion, while the family environment is an essential prerequisite for PA, different environmental domains exhibit varying association patterns, yet they jointly promote PA by fostering a transition from perceived competence to autonomous enjoyment.

We reveal distinct pathways through which family environmental factors predict adolescent PA, consistent with the predictions of H1. Upon incorporating mediators into the model, the direct paths from physical environmental factors (HPEA and HEDA) to PA remained significant. In contrast, the direct paths from social environmental factors (PPAS and PPEH) were no longer statistically significant. According to the Social Ecological Model (Sallis et al., 2008), home PA equipment serves as a proximal physical environmental factor, facilitating activity participation by lowering behavioral thresholds and increasing opportunities for exercise. This aligns with previous research identifying HPEA as a key predictor that exerts a direct promotive effect on adolescent PA (Parker et al., 2022; Zeng et al., 2022). Furthermore, the negative association observed between HEDA and PA is consistent with previous research (Anjana et al., 2024; Zablotsky, 2025). Home electronic devices encroach upon time and opportunities for PA by promoting sedentary screen time.

Conversely, PPAS and PPEH were associated with PA only through indirect pathways. Prior studies have similarly noted that parental support and role modelling do not consistently exert a direct influence on behavior; instead, they function primarily through the activation of key psychological mediators (de Oliveira Barbosa et al., 2024; Qi et al., 2024). Based on the SDT, external social support usually requires individuals to meet their sense of competency needs, which then internalizes into autonomous motivation and ultimately transforms into continuous behavioral engagement (Flannery, 2017). This theoretical framework is consistent with the pathways observed in this study.

The results of this study show that self-efficacy does not independently mediate the association between family environment and PA, while intrinsic motivation shows a significant and independent intermediary effect. Therefore, Hypothesis 2 (H2) was partially supported. This finding highlights the complexity of the triggers of adolescents' PA behaviors, showing that a single ability perception is not enough to drive continuous PA participation independently. Although adolescents may be confident in their physical abilities, this confidence may still be in a latent state if they lack autonomous exercise motivation. While self-efficacy is widely recognized as an important predictor of PA, previous studies have shown that in models involving multiple synergistic factors, its mediating effect may become unstable, and its explanatory power is often weakened by motive and emotional variables (Barbosa et al., 2024; Olander et al., 2013). Conversely, we finds that intrinsic motivation has a significant mediating effect, consistent with the previous research results that have identified it as a core explanatory variable for PA (K. Li et al., 2014; Liu, Ge, et al., 2023; Schneider, 2018). This endogenous driving force, derived from emotional pleasure and intrinsic interest, constitutes a stable psychological mechanism that links external support with behavioral performance.

The results of this study show that there is a significant sequence mediation effect, indicating that the family environment predicts adolescent PA through a continuous psychological process from self-efficacy to intrinsic motivation, thus providing empirical support for the hypothesis of H3. The psychological mechanism behind this path shows that the perceptual competence in SDT constitutes the cognitive basis for behavioral activation (Ryan & Deci, 2000); however, its ability to drive continuous participation in PA depends on whether the individual can successfully internalize it into a self-scheme. Specifically, positive family environmental factors, such as parents' role models and autonomy support, can not only provide adolescents with a sense of self-efficacy but also promote their change in motivation, so that this self-confidence can be internalized into a spontaneous exercise habit characterized by internal interest and fun (Deci & Ryan, 2000). For adolescents who are in the stage of autonomous budding, if they lack the guidance of intrinsic motivation, even if they have strong perception ability, their PA behavior is often volatile or non-sustainable, and it is difficult to form a stable behavior pattern. Therefore, this serial pathway highlights the role of the family environment as a catalytic factor, which enables the perceived competence to stimulate and maintain the individual's intrinsic interest in PA and the motivation to explore. These findings show that family-based interventions should not be limited to enhancing PA confidence; on the contrary, their main goal should be to create an environment to promote the transformation of perceived competence into lasting, intrinsic PA motivation.

4. CONCLUSION

In conclusion, the present study provides longitudinal evidence for the prospective associations between the family environment and adolescents' PA behaviors. The findings demonstrate, first, that the association between the family environment and adolescent PA is dimension-specific. Physical environmental factors (HPEA and HEDA) predicted PA both directly and indirectly through psychological mediating pathways, whereas social environmental factors (PPAS and PPEH) predicted PA exclusively through indirect psychological pathways. Second, intrinsic motivation emerged as the central psychological mechanism linking the family environment to adolescents' PA. Regardless of the specific dimensions of the family environment, intrinsic motivation consistently plays a significant mediating role. Finally, although self-efficacy could not independently function as a significant mediator, it contributed indirectly by facilitating intrinsic motivation and enhancing adolescents' intrinsic interest in PA, thereby promoting engagement in PA.

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AUTHOR CONTRIBUTIONS

Meng Liu: Writing – original draft, Writing – review and editing, Investigation, Data curation, Methodology, Conceptualization, Formal analysis.

Hazizi Abu Saad: Writing – review and editing, Conceptualization, Supervision.

Soh Kim Geok: Methodology, Conceptualization.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s)

ETHICS STATEMENT

The study was approved by the Ethics Committee of Zibo Central Hospital (Reference No. 2024-233). The study was conducted in strict accordance with the Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all participants and their parents or legal guardians.

DATA AVAILABILITY STATEMENT

The data is available on request from the corresponding author

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