



Teacher autonomy support in physical education and school engagement among vulnerable children: A sequential mediation model

Xi Cui and Jinfu Wang*

School of Physical Education, South China University of Technology, Guangzhou, China

*Correspondence: Jinfu Wang, 202320142029@mail.scut.edu.cn

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Abstract: Physical education engagement is essential for children's healthy development, yet vulnerable populations are often overlooked in motivational research. This study examined the extent to which teacher autonomy support predicts student engagement through basic psychological need satisfaction and autonomous motivation. Four hundred ninety-eight children with parenting separation vulnerability completed validated scales measuring teacher autonomy support, basic psychological need satisfaction, autonomous motivation, and engagement in physical education (females = 69.5%, mean age = 13.18 years, SD = 0.84). Results from sequential mediation model analysis showed that teacher autonomy support is associated with higher student engagement. Need satisfaction, and autonomous motivation mediated the direct effect, with need satisfaction being the stronger mediator. The sequential mediation effect on the relationship between teacher autonomy support and student engagement via both need satisfaction and autonomous motivation was comparatively modest. These findings are consistent with self-determination theory, which posits that autonomy-supportive contexts first satisfy basic psychological needs, which in turn facilitate autonomous motivation, and this motivational sequence ultimately promotes greater engagement. By implication, teacher autonomy support is a student development asset for their higher engagement directly and indirectly. Autonomy-supportive teaching and fostering psychological needs and autonomous motivation may enhance the school engagement of children with vulnerability.

Keywords: Teacher autonomy support; physical education; basic psychological need; autonomous motivation

Introduction

Prolonged separation from family risks children's vulnerability to emotional and social adjustment problems (Jia & Tian, 2010). Within schools, physical education may promote students' sense of belonging, interpersonal interaction, and individual development to a certain extent, and less well studied among children with vulnerability from parent separation (i.e., left-behind children; Shi et al., 2020; Peng et al., 2025). In this context, physical education classes may offer especially valuable opportunities for peer connection and skill development because of their inherently interactive and cooperative nature. However, without appropriate teacher support, these children's psychological needs may not be adequately met, and the potential positive effects of physical education may not be fully realized.

Teacher autonomy support and physical education.

Engagement in physical education refers to a positive, fulfilling, and learning-related psychological state exhibited by students during physical education activities, characterized by three dimensions: vigor, dedication, and absorption (Curran & Standage, 2017; Schaufeli et al., 2002). This three-dimensional structure has been validated in physical education contexts (Curran & Standage, 2017). Previous work suggests that taking part in physical activity can lower psychological risks by increasing positive emotions, strengthening social ties, and improving self-perception (Lubans et al., 2012). The autonomy support that teachers provide in physical education represents an important environmental resource (Fin et al., 2019). Studies have consistently found that students who perceive stronger autonomy support from their teachers report higher engagement, better psychological adjustment, and greater

well-being (Leyton-Román et al., 2020; Guo et al., 2025). Nevertheless, whether the well-established motivational pathways linking teacher autonomy support to engagement apply similarly to left-behind children remains to be examined. Especially under conditions of limited family support, teacher autonomy support may serve not merely as a facilitator but as a compensatory resource for left-behind children—a specificity that provides a theoretical rationale for applying SDT (self-determination theory) mechanisms to this population.

Most available research has concentrated on general developmental outcomes without paying enough attention to what leads to engagement in physical education (Guo et al., 2023). Although basic psychological needs and autonomous motivation have been widely studied in regular educational settings, their combined pathways in physical education, especially for left-behind children, have not been adequately tested. Given that left-behind children may depend more on external sources of support while also benefiting greatly from successful physical activity experiences (Lubans et al., 2012), it is necessary to build an integrated framework that clarifies how these factors work together.

Using self-determination theory as a guide, this study develops a sequential mediation model to explore how basic psychological needs and autonomous motivation function in the link between teacher autonomy support and physical education engagement among left-behind children. By systematically investigating this process, the research aims to deepen current understanding of the psychological pathways that underlie physical activity participation in disadvantaged populations and to offer both



theoretical insights and practical evidence for improving physical education.

Teacher autonomy support and engagement in physical education

According to self-determination theory, autonomy-supportive teaching is regarded as an important pedagogical approach for promoting students' positive development (Reeve & Cheon, 2021). Autonomy-supportive teaching refers to the practice of teachers taking students' perspectives, providing meaningful choices, offering informational feedback, and minimizing pressure and control. A substantial body of research has demonstrated that autonomy-supportive teaching effectively enhances students' intrinsic motivation, learning engagement, and psychological well-being (Standage et al., 2025).

In physical education settings, autonomy-supportive teaching is particularly important, as physical education classes inherently involve physical activity, peer collaboration, and autonomous decision-making (Ntoumanis & Moller, 2025). When physical education teachers adopt autonomy-supportive practices, students not only show greater willingness to participate in class activities but also exhibit higher levels of persistence and more positive emotional experiences (Carriedo et al., 2023; Guo et al., 2025). For left-behind children, who have relatively limited access to family-based psychological need support, teacher-provided autonomy support may serve as a valuable school resource. Thus, teacher autonomy support holds promise as an important environmental factor in promoting left-behind children's engagement in physical education.

The mediating role of basic psychological needs satisfaction

In educational settings, meeting students' basic psychological needs is widely regarded as a key foundation for their engagement. When learners feel that their needs are supported during instruction, they tend to participate more actively and maintain their effort over time (Guo et al., 2023; Boer et al., 2025). For left-behind children, limited family support reduces opportunities for having their basic needs met in daily life, making them more reliant on supportive resources within their schools (Zeng et al., 2025). In this context, autonomy support from physical education teachers may become an important source of need fulfillment. Existing evidence shows that when physical education teachers provide autonomy support, students report higher levels of need satisfaction and display better behavioral outcomes as a result of improved psychological experiences (Sun et al., 2010; Ji et al., 2025; Xu et al., 2025; Carriedo et al., 2023).

The mediating role of autonomous motivation

Autonomous motivation represents an internal force that pushes individuals to take part in activities willingly. Numerous studies have shown a strong positive link between autonomous motivation and engagement. More autonomously motivated individuals tend to show greater

persistence, deeper participation, and more positive emotions (Vasconcellos et al., 2020). The same pattern holds in physical education, where autonomous motivation enhances both behavioral and emotional engagement (Leyton-Román et al., 2020). Autonomous motivation also serves as a mechanism connecting external support to individual action. For left-behind children, whose family support is often limited, school based physical education may offer an important setting where they can experience intrinsic satisfaction and a sense of personal choice (Chen, 2018). In this context, teacher autonomy support may serve as a key external condition for developing autonomous motivation.

The sequential mediating role of basic psychological needs satisfaction and autonomous motivation

As noted earlier, both need satisfaction and autonomous motivation may explain how autonomy support leads to greater engagement. However, rather than functioning as separate independent pathways, these two factors are more likely to operate together in a step-by-step sequence.

This sequential pattern is also consistent with the broader self-system process framework (Connell & Wellborn, 1991), which emphasizes the role of contextual factors in shaping individuals' motivational and behavioral outcomes through psychological need processes. Therefore, examining this ordered mechanism is necessary for gaining a more complete understanding of the underlying psychological processes.

Theoretical foundations. Both self-determination theory and existing theoretical frameworks support the intrinsic link between basic psychological need satisfaction and autonomous motivation, emphasizing that need satisfaction is a necessary precursor for the emergence of autonomous motivation (Ryan & Deci, 2017). Based on self-determination theory (SDT), autonomy-supportive teaching means that teachers listen to students' viewpoints, offer real choices, and give helpful feedback rather than using pressure or control (Reeve & Cheon, 2021; Reeve & Cheon, 2025; Standage et al., 2025). In such supportive environments, students are more likely to self-determine their pathways to school engagement via basic psychological need satisfaction (Leyton-Román et al., 2020).

Self-determination theory proposes that supportive environments help individuals internalize externally guided behaviors into self-endorsed regulations, thereby promoting autonomous motivation (Deci & Ryan, 2000; Ntoumanis & Moller, 2025). When teachers offer choices, acknowledge students' needs, and provide positive feedback, students experience greater autonomy and competence, which strengthens their autonomous motivation (Leyton-Román et al., 2020). This sequential pathway may be especially relevant for left-behind children. Because these children receive limited support from their families, positive and supportive interactions within physical education classes may become a crucial resource for rebuilding their intrinsic motivation (Lubans et al., 2012). Within this process, need satisfaction provides a foundation for motivational development, and autonomous motivation then transforms that foundation into sustained engagement. Therefore, these two factors

are unlikely to act independently. Instead, they appear to form a progressive chain that jointly influences how engaged students become.

Parent-child separation in China

In China, large-scale rural-to-urban migration has given rise to a substantial population of left-behind children (Chen et al., 2025). Due to institutional constraints such as the household registration (hukou) system and unequal distribution of public services in urban areas, a large number of rural migrant workers choose to leave their children in their hometowns under the care of grandparents or other relatives (Huang, 2025). Estimates suggest that the total number of left-behind children in China amounts to tens of millions, with rural left-behind children being one of the most concerning subgroups (Chen et al., 2025).

A substantial body of research indicates that prolonged parent-child separation poses multiple challenges to the healthy development of left-behind children (Wang et al., 2024; Chen et al., 2025). A study based on a sample of 2355 rural children found that children with both parents currently migrating and those with parents who had previously migrated reported significantly poorer outcomes than their non-left-behind peers across multiple indicators, including self-rated health, depression, non-suicidal self-injury behaviors, and suicidal ideation (Wang et al., 2024). Furthermore, cumulative family risks, such as low economic status, incomplete family structures, and distant parent-child relationships, can indirectly undermine left-behind children's social adaptation by weakening teacher support and self-worth (Zhang et al., 2025). However, it has also been noted that much of the existing literature adopts a deficit perspective, positioning left-behind children as inherently "lacking" or "vulnerable," while overlooking their agency and developmental potential (Chen et al., 2025).

Within this context, physical education and school sport have been identified as promising contexts for supporting the positive development of left-behind children (Chen et al., 2025). Chen et al. (2023) noted that physical activity can promote the physical and mental health of left-behind children, and that PE teachers hold unique advantages in building trust and providing emotional support to this population. A randomized controlled trial involving left-behind children further demonstrated that a 12-week structured physical education intervention significantly improved their mental health outcomes (Li et al., 2025). School-based practices that safeguard physical activity time, provide accessible sports equipment, and organize intra-school competitions have also been shown to effectively enhance left-behind children's sense of school belonging and learning engagement (Jiang & Feng, 2025).

Thus, the school context, particularly physical education instruction, represents a critical setting in which teacher support can be systematically leveraged to mitigate the adverse effects of parent-child separation and promote positive developmental outcomes for left-behind children.

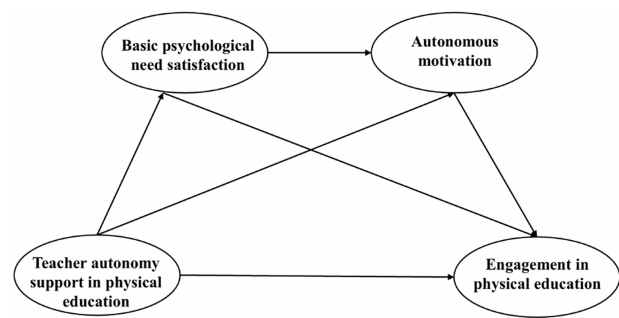


Figure 1. The hypothesized sequential mediation model of the present study.

The present study

The primary goal of this research is to explore how satisfaction of basic psychological needs and autonomous motivation act as sequential mediators in the link between teacher autonomy support and physical education engagement among left-behind children.

Specifically, the present study aims to answer the following question:

1. To what extent does teacher autonomy support in physical education engagement among left-behind children explain their school engagement?

2. What is the role of basic psychological need satisfaction and autonomous motivation in the relationship between teacher autonomy support in physical education and student engagement? (see Figure 1 for conceptual model). The study tested the following hypotheses among children with parent separation vulnerabilities:

Hypothesis 1: Teacher autonomy support in physical education is associated with higher student engagement.

Hypothesis 2: Basic psychological needs satisfaction mediates the relationship between teacher autonomy support in physical education and student engagement for higher student engagement.

Hypothesis 3: Autonomous motivation mediates the relationship between teacher autonomy support in physical education and student engagement for higher student engagement.

Hypothesis 4: Basic psychological needs satisfaction and autonomous motivation sequentially mediate the relationship between teacher autonomy support in physical education among left-behind children.

Methods

Participants and procedure

Participants were a convenience sample of 498 children from eight rural middle schools in Shaoguan, Guangdong Province (females = 69.5%, mean age = 13.18 years, SD = 0.84; grades 7 through 9) (see Table 1 for participant characteristics). To be included in the study, one or both parents of the participants had been away from home for work for more than six months.

The sample comprised 152 males (30.5%) and 346 females (69.5%). Participants were distributed across grades as follows: Grade 7 ($n = 131$, 26.3%), Grade 8 ($n = 168$, 33.7%), and Grade 9 ($n = 199$, 40.0%). Regarding only-child status, 309 participants (62.0%) were

Table 1. Characteristics of the participants

Variables	Category	N	Percentage (%)
Gender	Male	152	30.5
	Female	346	69.5
Grade	Grade 7	131	26.3
	Grade 8	168	33.7
	Grade 9	199	40.0
Only child	Yes	309	62.0
	No	189	38.0
Left-behind type	Both parents working away	128	25.7
	Father only working away	236	47.4
	Mother only working away	134	26.9

only children, and 189 (38.0%) were not. Regarding left-behind status, 128 participants (25.7%) had both parents working away from home, 236 (47.4%) had only their fathers working away, and 134 (26.9%) had only their mothers working away. The most prevalent category was having only the father working away from home.

The Ethics Committee of South China University of Technology approved the study (Approval No.: SCUT-SPT-2025-003). Written informed consent was obtained from legal guardians prior to data collection. The students assented to the study. Data were collected either in paper form or via the online platform.

Measures

Teacher autonomy support in physical education. Perceived teacher autonomy support in physical education was measured using an adapted Sport Climate Questionnaire based on Deci and Ryan's framework (Deci & Ryan, 1987). The scale comprises six items. A sample item is "My physical education teacher provides me with choices and opportunities." A 7-point Likert scale was used for responses. Reliability was strong, with Cronbach's $\alpha = 0.927$ and Guttman split-half reliability = 0.914. The composite reliability (CR) was 0.923, and the average variance extracted (AVE) was 0.660, both exceeding the recommended thresholds (Fornell & Larcker, 1981), indicating good convergent validity.

Basic psychological need satisfaction. Basic psychological needs satisfaction was measured using a 10-item scale from Liu and Chung (2014), which covers three dimensions: competence, autonomy, and relatedness. A sample item is "I feel that I can do things well in physical education class," and all items were rated on a 7-point Likert scale. Reliability was satisfactory, with Cronbach's $\alpha = 0.937$ and Guttman split-half reliability = 0.919. The CR values for the three factors were 0.887, 0.838, and 0.819, and the AVE values were 0.724, 0.636, and 0.604, respectively, all exceeding the recommended thresholds (Fornell & Larcker, 1981), indicating good convergent validity for all three factors.

Autonomous motivation. Autonomous motivation was measured using the 6-item Perceived Locus of Causality

Questionnaire as revised by Zhong et al. (2014). This instrument includes two subscales for intrinsic motivation and identified regulation, each comprising three items. A sample item is "Physical education classes are interesting." Items are scored on a 7-point Likert scale. Reliability was good, with Cronbach's $\alpha = 0.915$ and Guttman split-half reliability = 0.871. The CR values for intrinsic motivation and identified regulation were 0.861 and 0.825, respectively; the AVE values were 0.676 and 0.611, both exceeding the recommended thresholds (Fornell & Larcker, 1981), indicating good convergent validity for both factors.

Student engagement. Engagement in physical education was measured using the Chinese version of the Utrecht Work Engagement Scale–Student, as revised by Fang et al. (2008). The original scale contains 17 items across three dimensions: vigor (6 items), dedication (5 items), and absorption (6 items). Sample items are: "When doing physical education learning, I feel bursting with energy" and "I am immersed in my physical education learning". To adapt the measure for physical education, the word "learning" was changed to "physical education learning" throughout. A 5-point Likert scale was used for responses. Reliability was satisfactory, with Cronbach's $\alpha = 0.936$ and Guttman split-half reliability = 0.901. The CR values for the three factors were 0.854, 0.868, and 0.844; the AVE values were 0.497, 0.572, and 0.482. Although the AVE values for vigor and absorption were slightly below 0.50, according to Fornell and Larcker's (1981) recommendation, when the CR reaches an acceptable level and the latent variable serves as an outcome variable, an AVE slightly below 0.50 may still be acceptable. Therefore, the engagement scale was considered to have acceptable convergent validity.

Covariates. In addition to the primary study variables, this study drew on prior research (Zhao et al., 2025; Huang & Xiong, 2025) and included participants' age, gender, grade, only-child status, and left-behind status as control variables in subsequent analyses.

Statistical analysis

Data were analyzed using SPSS 27.0 and AMOS 26.0. Descriptive statistics were computed, followed by Harman's single-factor test and the unmeasured latent method factor technique for common method bias assessment. Pearson correlations examined variable relationships.

Integrated measurement model

To evaluate the overall structure and discriminant validity of all latent constructs together, an integrated measurement model was examined prior to testing the structural model. This model included teacher autonomy support (as a unidimensional latent variable), the three dimensions of basic psychological need satisfaction, the two dimensions of autonomous motivation, and the three dimensions of engagement. In this model, each item was specified to load only on its respective latent construct, and all latent variables were allowed to correlate freely. The integrated measurement model yielded acceptable fit ($\chi^2/df = 1.764$, CFI = 0.974, TLI = 0.967, SRMR = 0.037, RMSEA = 0.039). All factor loadings were significant ($p < 0.001$) and

Table 2. Comparison of main variables across left-behind status types

Variables	Father only working away	Mother only working away	Both parents working away	F	p
TAS	24.15 (5.87)	24.53 (6.09)	24.51 (5.65)	0.189	0.828
BPNS	40.48 (7.99)	39.56 (8.97)	40.33 (9.20)	0.590	0.555
AM	23.82 (5.19)	23.74 (5.78)	24.04 (5.25)	0.128	0.880
PE	51.49 (10.46)	51.89 (12.55)	51.36 (11.87)	0.102	0.903

Note. Data are presented as means with standard deviations in parentheses. TAS = Teacher Autonomy Support; BPNS = Basic Psychological Need Satisfaction; AM = Autonomous Motivation; PE = Engagement in Physical Education.

the correlation coefficients among latent variables ranged from 0.225 to 0.334, supporting the construct validity and discriminant validity of the measures.

Common method bias analysis

Common method bias was evaluated using Harman's single factor test. An unrotated factor analysis produced several factors with eigenvalues above 1. The first factor explained 28.88% of the total variance, which falls under the 40% cutoff. However, Harman's single factor test is considered a comparatively weak approach for assessing common method variance (Podsakoff et al., 2003). To address this limitation, we further employed the unmeasured latent variable technique as a supplementary test. Comparing models with and without a latent method factor revealed negligible improvement in fit indices ($\Delta\text{CFI} < 0.01$, $\Delta\text{TLI} < 0.01$, $\Delta\text{RMSEA} < 0.005$, $\Delta\text{SRMR} < 0.005$) (Tang & Wen, 2020). This result indicates that common method bias does not pose a major threat to the findings.

To explore whether differences exist across different types of left-behind status on the main variables, this study conducted one-way analyses of variance with left-behind status (father only working away, mother only working away, both parents working away) as the grouping variable and teacher autonomy support, basic psychological need satisfaction, autonomous motivation, and physical education engagement as the dependent variables. The results of the homogeneity of variance test indicated that the variances of all dependent variables across the three groups satisfied the assumption of homogeneity ($p > 0.05$). As shown in Table 2, no significant differences were found among the three groups in teacher autonomy support ($F = 0.189$, $p = 0.828$), basic psychological need satisfaction ($F = 0.590$, $p = 0.555$), autonomous motivation ($F = 0.128$, $p = 0.880$), or physical education engagement ($F = 0.102$, $p = 0.903$). Post hoc comparisons (Least Significant Difference, LSD) further revealed that the mean differences between any two groups did not reach statistical significance (all $p > 0.05$), indicating that scores on the main variables did not differ significantly across different types of left-behind status.

Structural equation modeling tested a sequential mediation model with teacher autonomy support as the exogenous variable, engagement in physical education as the endogenous variable, and basic psychological need satisfaction and autonomous motivation as sequential

mediators, controlling for demographic covariates. Indirect effects were tested using bias-corrected bootstrapping (5000 resamples, 95% CI). Model fit was evaluated using χ^2/df , CFI, TLI, SRMR, and RMSEA, with acceptable fit defined as $\text{CFI}/\text{TLI} \geq 0.90$ and $\text{RMSEA}/\text{SRMR} < 0.08$. All tests were two-tailed, with $p < 0.05$ considered significant.

Results

Descriptive statistics and correlation analysis

The results indicated that all variables were significantly and positively correlated with one another. This pattern of correlations was consistent with theoretical expectations, providing preliminary support for subsequent hypothesis testing. Detailed descriptive statistics and correlation coefficients are presented in Table 3.

Sequential mediation analysis

After establishing the reliability and validity of the measurement instruments, the overall fit of the structural model was evaluated while controlling for relevant covariates (gender, age, grade, only-child status, and left-behind status) (see Table 4). The results indicated that all fit indices were within acceptable ranges. The chi-square to degrees of freedom ratio (χ^2/df) was below 5, the CFI and TLI were ≥ 0.90 , and the RMSEA and SRMR were < 0.08 . These results suggest that the proposed model provides an acceptable fit to the observed data, supporting subsequent path analyses.

Teacher autonomy support and student engagement.

After the model showed acceptable fit, parameters were estimated using maximum likelihood estimation in AMOS (see Table 5). With covariates controlled, teacher autonomy support directly predicted engagement in physical education positively and significantly ($\beta = 0.234$, $p < 0.001$). All hypothesized indirect pathways reached statistical significance (See Figure 2). Teacher autonomy support positively predicted basic psychological need satisfaction ($\beta = 0.267$, $p < 0.001$) and autonomous motivation ($\beta = 0.102$, $p < 0.05$).

Basic psychological need satisfaction positively predicted autonomous motivation ($\beta = 0.276$, $p < 0.001$) and engagement ($\beta = 0.214$, $p < 0.001$). Autonomous motivation also positively predicted engagement ($\beta = 0.104$, $p < 0.05$). Basic psychological need satisfaction and autonomous motivation served as mediators between teacher autonomy support and engagement. Both the separate and sequential mediation

Table 3. Descriptive statistics and correlation analysis (N = 498)

Variables	M	SD	1	2	3	4
1. Teacher autonomy support in physical education	24.42	5.907	1			
2. Basic psychological need satisfaction	40.01	8.787	0.273***	1		
3. Autonomous motivation	23.70	5.507	0.183***	0.306***	1	
4. Engagement in physical education	51.64	11.83	0.301***	0.296***	0.205***	1

Note. M = Mean; SD = Standard Deviation; *** $p < 0.001$.

Table 4. Goodness-of-fit indices for the structural model

Category	Fit index	Fit indices	Recommended threshold
Absolute fit indices	SRMR	0.016	<0.08
	RMSEA	0.029	<0.08
Incremental fit indices	TLI	0.975	>0.90
	CFI	0.983	>0.90
Parsimonious fit index	χ^2/df	1.419	<5

Note. SRMR = Standardized root means square residual; RMSEA = Root mean square error of approximation; TLI = Tucker–Lewis index; CFI = Comparative fit index.

Table 5. Testing the interconnections among variables

Variables	BPNS			AM			PE		
	β	SE	t	β	SE	t	β	SE	t
Age	−0.036	0.454	−0.838	0.051	0.279	1.252	0.066	0.584	1.542
Gender	0.033	0.832	0.753	0.076	0.511	1.667	0.059	1.072	1.404
Grade	0.005	0.475	0.108	−0.010	0.293	−0.201	−0.068	0.610	−1.631
Only-child status	−0.042	0.786	−0.959	0.008	0.483	0.354	0.078	1.010	1.874
Left-behind status	−0.008	0.529	−0.184	−0.004	0.325	−0.208	−0.022	0.679	−0.508
TAS	0.267***	0.064	6.154	0.102*	0.041	2.579	0.234***	0.086	5.410
BPNS				0.276***	0.027	6.038	0.214***	0.060	4.734
AM							0.104*	0.071	2.051
R	0.277			0.329			0.407		
R^2	0.077			0.108			0.165		
F	6.841***			8.492***			12.15***		

Note. β = Standardized coefficient; SE and t -values are derived from the unstandardized solution. TAS = Teacher Autonomy Support; BPNS = Basic Psychological Need Satisfaction; AM = Autonomous Motivation; PE = Engagement in Physical Education. * $p < 0.05$; *** $p < 0.001$.

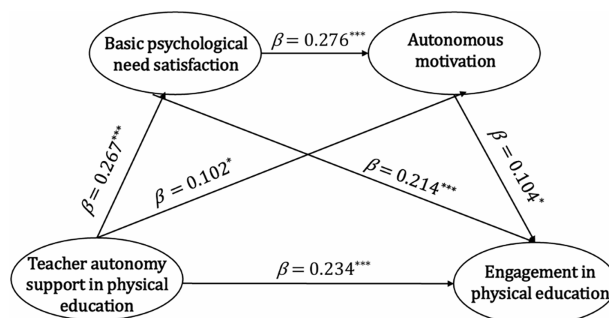
**Figure 2.** Final model of the present study. Note. β = Standardized coefficient; * $p < 0.05$; *** $p < 0.001$.

Table 6. Testing for chain mediation effects

Paths	Effect	Boot SE	Bootstrap 95%CI	Effect size ratio
Teacher autonomy support in physical education → Basic psychological need satisfaction → Engagement in physical education	0.112	0.029	[0.056, 0.178]	18.27%
Teacher autonomy support in physical education → Autonomous motivation → Engagement in physical education	0.021	0.013	[0.003, 0.052]	3.42%
Teacher autonomy support in physical education → Basic psychological need satisfaction → Autonomous motivation → Engagement in physical education	0.013	0.007	[0.004, 0.028]	2.12%
Total indirect effect between Teacher autonomy support in physical education and Engagement in physical education	0.146	0.032	[0.088, 0.215]	23.81%
Direct effect	0.467	0.086	[0.297, 0.638]	76.18%
Total effect	0.613	0.085	[0.447, 0.783]	100%

Note. CI = Confidence Interval; SE = Standard Error.

pathways received support. Thus, Hypothesis 1 was supported, as teacher autonomy support directly and positively predicted student engagement. Hypotheses 2 and 3 were also supported, as the indirect effects through both basic psychological need satisfaction and autonomous motivation were statistically significant.

Sequential mediation effects. Bootstrap analysis with 5000 resamples was conducted to further test the mediating effects (see Table 6). The sequential path from teacher autonomy support through need satisfaction to autonomous motivation and then to engagement yielded a significant indirect effect of 0.013 (95% CI = [0.004, 0.028]). The indirect effects via need satisfaction alone (0.112, 95% CI = [0.056, 0.178]) and via autonomous motivation alone (0.021, 95% CI = [0.003, 0.052]) were also significant. With the mediators in place, the direct effect of teacher autonomy support on engagement remained significant (Effect = 0.467, 95% CI = [0.297, 0.638]), suggesting partial mediation. The total indirect effect was 0.146, representing 23.81% of the total effect. These results indicate that need satisfaction and autonomous motivation operate both independently and as a sequential chain, together connecting teacher autonomy support to engagement in physical education. Therefore, Hypothesis 4 was supported, confirming the significant sequential mediating effect of need satisfaction and autonomous motivation in the relationship between teacher autonomy support and student engagement.

Discussion

Consistent with previous research, the current study found a significant positive relationship between teacher autonomy support and physical education engagement among left-behind children ($\beta = 0.234, p < 0.001$). Two explanations may help explain this positive association. First, autonomy support contributes to a positive classroom atmosphere. When teachers design lessons around student perspectives, offer genuine choices, and give encouraging feedback, students may feel more respected and understood. This might, in turn, encourage them to take initiative, accept challenges, and express themselves in physical education, rather than holding back due to

fear of failure or judgment. Second, autonomy-supportive behaviors contribute to higher-quality teacher-student interactions. Compared with controlling or directive teaching styles, autonomy-supportive communication places greater emphasis on listening and negotiation. Such interactions can strengthen students' trust in their teachers and their sense of classroom safety, thereby enhancing their commitment and willingness to participate in physical education (Rostbøll et al., 2015). For left-behind children who lack long-term parental support, teacher autonomy support may act as an alternative source of emotional connection (Peng et al., 2025), potentially being more strongly associated with engagement. Thus, promoting teacher autonomy support could be a useful strategy for increasing physical education engagement among this population.

Basic psychological need satisfaction mediated the link between teacher autonomy support and physical education engagement among left-behind children. This finding builds on earlier work linking autonomy support, need satisfaction, and engagement. Greater autonomy support from teachers may help fulfill students' basic psychological needs and strengthen their intrinsic motivation (Carriedo et al., 2023), which in turn is associated with higher levels of engagement in physical education (Xia et al., 2025). These results add empirical support for self-determination theory within physical education settings. The relationship between teacher autonomy support and engagement may be observed both directly and indirectly through changes in key psychological experiences during learning.

The partial mediation effect indicates that need satisfaction plays a meaningful but nonexclusive role. When family support is limited, teacher autonomy support may be associated with engagement through both direct and indirect pathways. This finding suggests that for left-behind children, need satisfaction represents a more immediate psychological pathway through which teacher support translates into engagement, consistent with the need satisfaction model (Núñez-Regueiro et al., 2025). Importantly, this study extends this mechanism to left-behind children, showing that need satisfaction plays a meaningful but nonexclusive role.

Autonomous motivation mediated the relationship between teacher autonomy support and physical education engagement among left-behind children. Research attention to students' autonomous motivation has grown in recent years, yet existing studies have primarily focused on general student populations (Vasconcellos et al., 2020; Xia et al., 2025; Hu et al., 2020).

However, research specifically examining autonomous motivation among left-behind children remains limited. This mechanism may be especially relevant for left-behind children, because their access to family-based need support may be relatively constrained (Zhuang et al., 2025). Teacher autonomy support can provide a critical setting for motivational internalization, which is associated with a shift from externally driven regulation toward more self-endorsed and intrinsically valued engagement in physical activity (Vasconcellos et al., 2020).

Teacher autonomy support was associated with physical education engagement through the sequential mediation of basic psychological need satisfaction followed by autonomous motivation. This finding aligns with earlier work showing that autonomy support is associated with need satisfaction (Langøy et al., 2024), which in turn facilitates motivation internalization and the development of autonomous motivation (Vasconcellos et al., 2020), and subsequently contributes to engagement and positive outcomes (Vasconcellos et al., 2020). When need satisfaction is insufficient, students may rely more on external regulation or show reduced adaptive functioning. Together, these results reveal a sequential pathway from teacher autonomy support to engagement, providing empirical understanding of the underlying mechanism and practical direction for enhancing physical education engagement among left-behind children.

Theoretical contributions and practical implications

This study makes two contributions to the existing literature. First, it extends self-determination theory to left-behind children by examining how teacher autonomy support relates to engagement through need satisfaction and autonomous motivation. Although this sequential pathway has been demonstrated in general student populations, its applicability to left-behind children who may have limited family support and rely more on school resources has not been sufficiently examined. Second, by comparing the relative contributions of different mediating pathways, this study finds that the independent mediating effect of need satisfaction substantially exceeds that of autonomous motivation. These findings advance understanding of how needs relate to motivation by indicating that need satisfaction may represent a more direct entry point for promoting physical education engagement in this population, whereas motivational internalization may require more sustained support.

On the practical level, the findings of this study offer several implications for physical education instruction. First, given the significant direct effect between teacher autonomy support and engagement, teachers may directly promote student participation by strengthening autonomy-supportive practices, such as offering choices,

respecting student perspectives, and providing informational feedback (Ma et al., 2018; Patall et al., 2013). While these practices are beneficial for all students, they may be particularly important for left-behind children. Because parents are often absent for extended periods, teachers can actively assume a greater emotional support role in daily interactions—for example, by proactively checking in with students after class and providing more individualized attention during physical activities—to partially compensate for the lack of family support. Second, given that basic psychological need satisfaction plays a partial mediating role, teachers may consider addressing left-behind children's psychological needs through appropriately challenging tasks, cooperative activities, and opportunities for decision-making when designing instructional activities (Cai, 2023). For left-behind children in boarding school environments, teachers can also utilize extracurricular physical activity time (e.g., morning exercises, break-time activities) to create additional opportunities for autonomous choice and peer interaction. Third, given that the mediation effect of autonomous motivation and the sequential pathway were relatively small in this study, efforts to enhance engagement through fostering autonomous motivation should be approached with caution. Value-oriented guidance, such as connecting physical activity to personally meaningful health goals (e.g., improving physical fitness to reduce the caregiving burden on grandparents), may be more effective than abstract interest cultivation for this population, as grandparents often face substantial physical, financial, and energetic barriers to organizing physical activities for children in their care (Budden et al., 2024).

Limitations and future directions

Several limitations should be acknowledged. First, the cross-sectional nature of the data prevents strong causal conclusions. The observed relationships could also operate in opposite directions. Longitudinal tracking or experimental designs would help address this issue. Second, reliance on self-report measures raises the possibility of common method bias. Future studies could incorporate multiple data sources such as classroom observations or teacher ratings. Third, this study constructed a sequential mediation model based on self-determination theory, yet other mechanisms may also operate between teacher autonomy support and engagement in physical education. Previous research has shown that self-efficacy (Huang et al., 2025), perceived competence (Liu et al., 2025), and perceived classroom climate (Marcelino, 2025) are each associated with engagement in physical education. These variables were not included in the present model primarily due to theoretical focus and model parsimony. However, given the cross-sectional design, we cannot rule out the potential influence of these competing mechanisms. Future research could incorporate these variables to clarify whether they operate in parallel with, or interact with, need satisfaction and autonomous motivation in influencing engagement in physical education. Fourth, this study did not include a non-left-behind comparison group, making it impossible to determine whether the observed mechanisms are unique to left-behind children or reflect

more general processes. Future research should employ comparative designs to examine this issue. Fifth, this study did not collect class-level information and did not account for the nested structure of students within classes or schools, which may lead to biased standard error estimates. Future research could employ multilevel designs to examine whether these relationships vary across classes or schools. Finally, the sample of this study was drawn from rural middle schools in Shaoguan, Guangdong Province, and exhibited a gender imbalance. On the one hand, economic development and educational resources in this region differ from those in central and western provinces with more concentrated left-behind children's populations; on the other hand, the proportion of female participants was substantially higher. These regional and demographic factors may jointly affect students' psychological experiences and their engagement in physical education, thereby limiting the external generalizability of the findings to some extent. Future research could adopt cross-regional samples with more balanced gender distributions to further examine the robustness of the proposed mechanisms.

Conclusion

Based on self-determination theory, this study explored the link between teacher autonomy support and physical education engagement among left-behind children. The findings revealed a positive association, both direct and indirect, through basic psychological need satisfaction and autonomous motivation. Notably, the direct effect was the strongest, followed by the independent mediating effect through need satisfaction, while the sequential mediation effect via both need satisfaction and autonomous motivation was comparatively modest. A sequential path emerged in which autonomy support predicted greater need satisfaction, which then predicted higher autonomous motivation, and this in turn predicted stronger engagement. These results emphasize how need satisfaction and motivational internalization work together to shape student engagement, providing a fuller picture of supportive teaching practices for this population. Overall, the study advances understanding of the psychological processes underlying engagement and highlights the value of autonomy supportive instruction.

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Availability of Data and Materials: The data that support the findings of this study are available from the Jinfu Wang, upon reasonable request.

Ethics Approval: The present study strictly adhered to the principles of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, and had been also in accordance with relevant ethics standards of the Ethics Committee of South China University of Technology (SCUT-SPT-2025-003). Written informed consent was obtained from legal guardians prior to data collection. The students assented to the study. Data were collected either in paper form or via the online platform.

Conflicts of Interest: The authors declare no conflicts of interest.

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