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Independent and Interactive Associations of Family Support for Physical Activity and the School PA-Supportive Environment With Physical Activity Among Rural Chinese Adolescents: A Three-Wave Longitudinal Study

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Abstract

Background

This study examined the prospective associations of family support for physical activity and the perceived school PA-supportive environment with physical activity (PA) among rural adolescents and whether their interaction was more consistent with a synergistic or compensatory pattern.

Methods

A three-wave longitudinal study was conducted among 621 students in Grades 7 and 8 from 4 rural junior high schools in Hunan Province, China. Models examined family support, the school PA-supportive environment, and their interaction in relation to subsequent PA, adjusting for prior PA, sex, grade, BMI-for-age z score, and school fixed effects.

Results

Family support (β = .187 and .149) and the school PA-supportive environment (β = .142 and .093) were positively associated with subsequent PA across both intervals. Their interaction was negative from T1 to T2 (β = −.135, P < .001) and from T2 to T3 (β = −.088, P = .018). Simple-slope analyses showed that each source of support was more strongly associated with subsequent PA when the other was relatively low, indicating a compensatory pattern. Sensitivity analyses yielded similar findings.

Conclusions

Family support and the school PA-supportive environment were independently associated with subsequent PA among rural adolescents, and their joint association was more consistent with compensation than synergy.

Background

Physical activity (PA) typically declines during adolescence [1]. National data from China indicate that school-aged children and adolescents accumulate less than 60 minutes of moderate-to-vigorous physical activity (MVPA) per day on average, with lower levels among rural than urban students and lower guideline attainment at later school stages [2]. The China 2022 Report Card on Physical Activity for Children and Adolescents likewise indicates substantial room for improvement in overall PA and in support from family, peers, and schools [3]. Rural children and adolescents are also markedly underrepresented in the Chinese PA intervention literature [4]. These patterns make rural adolescents an important population in which to examine the social contexts that may support PA during a developmental period characterized by declining activity.

Social-ecological models posit that adolescent PA is shaped by multiple proximal contexts, with family and school among the most salient [5]. Large-scale Chinese evidence has linked parental encouragement, accompaniment, coparticipation, and role modeling with higher PA [6], while longitudinal research has shown

sustained associations between family support and subsequent PA [7]. Complementing this evidence on positive family support, a recent three-wave longitudinal study in China found that accumulated family risk was negatively associated with adolescents' home-based PA [8]. School environments are also consistently associated with adolescent PA, with systematic reviews and meta-analyses highlighting the relevance of physical education, extracurricular opportunities, teacher support, and access to PA resources [9, 10]. More recent studies have begun to incorporate parents, peers, teachers, schools, and neighborhoods within the same analytical framework [11–13], but have largely focused on the independent or cumulative contribution of each source. Such approaches identify which contexts are associated with PA, but not whether the association of one source of support varies according to the level of another. A recent systematic review similarly identified interactions across socioecological levels as an important direction for further research [14]. The unresolved question, therefore, is not simply whether family and school matter, but how they operate together.

The joint contribution of family and school support may follow two competing patterns. A synergistic pattern would occur if the positive association of one source of support were stronger when support from the other context was also high, whereas a compensatory pattern would occur if one source of support were more strongly associated with positive outcomes when the other was relatively low. Research in adolescent sport has directly contrasted these possibilities and identified compensatory relations across sources of support [15]. Broader research on adolescent social support likewise suggests that support from different socializing agents may operate conditionally rather than simply additively [16, 17]. However, this evidence has focused primarily on competitive sport or psychosocial outcomes and does not establish whether family support for PA and the school PA-supportive environment show similar conditional associations with adolescents' everyday PA. Longitudinal evidence on interactions across socioecological levels in PA research remains limited [14], particularly among rural adolescents. Accordingly, the present study used three-wave longitudinal data from rural adolescents in Hunan, China, to examine the independent prospective associations of family support for PA and the perceived school PA-supportive environment with subsequent PA, as well as their interaction, while accounting for prior PA and relevant covariates.

Methods

Participants and Procedures

This three-wave longitudinal study included adolescents in Grades 7 and 8 from four rural junior high schools in Hunan Province, China. At baseline, intact classes were sampled within each school and grade, with two classes selected from each grade at each school, yielding 16 participating classes. Valid responses were obtained from 632 students at T1; 621 students participated at T2 and 608 at T3. The primary analytic sample included students with valid T1 data who participated in at least one subsequent wave. Eleven students who participated only at T1 were therefore excluded, resulting in a longitudinal analytic sample of 621 adolescents. The mean age of the analytic sample was 13.49 years (SD = 0.71); 320 participants (51.5%) were girls and 301 (48.5%) were boys. The sample included 313 Grade 7 students (50.4%) and 308 Grade 8 students (49.6%).

The same core measures, item order, and scoring procedures were used at all three waves, and responses were linked across waves using unique anonymous participant identifiers. Data were collected in mid-September 2025 (T1), late October 2025 (T2), and mid-December 2025 (T3), with approximately 6 weeks between consecutive waves. Assessments were scheduled during regular school periods and avoided major

holidays and examination weeks. At each wave, questionnaires were administered by trained research staff in classroom settings using standardized instructions. Students were informed that their responses would be used solely for research purposes and that there were no right or wrong answers. During data screening, duplicate identifiers, implausible demographic responses, invariant responding across the core questionnaire, and extensive missingness were checked. The study protocol received ethical approval before data collection. Written informed consent was obtained from participating students and their parents or legal guardians. Participation was voluntary, and students could withdraw from the study at any time without penalty.

Measures

Family Support for Physical Activity

Family support for physical activity was assessed using the family support subscale of the Chinese version of the Social Support for Exercise Scale validated by Yao et al.[18]. The 12-item subscale assesses adolescents' perceived support from family members during participation in physical activity, including encouragement, accompaniment, reminders, and positive feedback. Items were rated on a 5-point scale ranging from 1 (never) to 5 (often) and averaged to create a composite score, with higher scores indicating greater perceived family support for physical activity. McDonald's ω was .920 at T1, .922 at T2, and .916 at T3.

Perceived School PA-Supportive Environment

The perceived school PA-supportive environment was assessed using the Chinese School Environment Influencing Physical Activity Habits Scale developed and validated by Dai et al. [19]. The total scale score was used in the present study to operationalize adolescents' perceptions of a school environment supportive of physical activity. The scale comprises 19 items rated on a 5-point response scale ranging from 1 (completely inconsistent) to 5 (completely consistent). Negatively worded items were reverse scored according to the original scoring protocol. Item scores were averaged, with higher scores indicating a school environment perceived as more supportive of physical activity. McDonald's ω was .935 at T1, .936 at T2, and .938 at T3.

Physical Activity

Physical activity was assessed using the Chinese version of the Physical Activity Questionnaire for Adolescents (PAQ-A), validated by Qin et al. [20]. Items are scored from 1 to 5, with higher scores indicating higher levels of physical activity. In the Chinese validation study, the lunchtime activity item (Item 3) showed a relatively low factor loading, and model fit improved after its removal. All 8 items were administered at each wave in the present study; however, consistent with the validation findings, the primary PA score was calculated as the mean of the remaining 7 items (Items 1, 2, 4, 5, 6, 7, and 8). McDonald's ω was .852 at T1, .858 at T2, and .844 at T3.

Covariates

Sex, grade, and BMI-for-age z score (BMIz) were included as covariates in the longitudinal models. Sex was coded as 0 = girl and 1 = boy, and grade was coded as 1 = Grade 7 and 2 = Grade 8. BMI was calculated from self-reported height and weight as weight in kilograms divided by height in meters squared (kg/m²). BMIz was derived according to the World Health Organization 2007 Growth Reference for children and adolescents aged

5–19 years, based on sex and age [21]. Because age was recorded in completed years rather than exact months, BMIz calculations were based on participants' reported age in completed years. Age was also used to characterize the sample but was not entered as a separate covariate in the final structural models. To account for the hierarchical structure of the data, the four schools were represented by dummy variables and included as fixed effects. The 16 classes were specified as clustering units, and Mplus TYPE = COMPLEX was used to adjust standard errors for the nonindependence of observations within classes.

Statistical Analysis

Statistical analyses were conducted using SPSS version 27.0 and Mplus version 8.3. First, descriptive statistics, McDonald's ω coefficients, and Pearson correlations were calculated for the primary study variables. Longitudinal measurement invariance of family support for physical activity, the perceived school PA-supportive environment, and PA was then evaluated using the weighted least squares mean- and variance-adjusted (WLSMV) estimator with theta parameterization. Configural invariance and loading-and-threshold invariance models were tested sequentially [22]. Model fit was evaluated using the chi-square statistic (χ^2), comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Measurement invariance was considered supported when $|\Delta CFI| \leq .010$ and $|\Delta RMSEA| \leq .015$.[23]

After measurement invariance was established, robust maximum likelihood (MLR) estimation was used to examine the prospective associations of family support for physical activity and the perceived school PA-supportive environment with subsequent PA across the T1–T2 and T2–T3 intervals. Interaction terms between family and school support were then added to examine their joint associations with subsequent PA. All models adjusted for prior PA, sex, grade, BMIz, and school fixed effects. The 16 classes were specified as clustering units, and TYPE = COMPLEX was used to adjust standard errors for the nonindependence of observations within classes. Significant interactions were probed using simple-slope analyses at 1 SD below and above the mean to determine whether the observed pattern was consistent with compensation.

Sensitivity analyses were conducted by repeating the models in the complete-case sample of participants who completed all three waves and by using the alternative PAQ-A scoring method. All statistical tests were two-sided, with statistical significance set at $P < .05$. Unstandardized coefficients (B), standard errors (SE), standardized coefficients (β), and 95% confidence intervals (CIs) were reported.

Results

Descriptive Statistics and Correlations

Descriptive statistics and correlations among the study variables are presented in Table 1. All core variables were positively correlated across the three waves, with correlation coefficients ranging from .201 to .719 (all $P < .001$). Within-construct correlations across waves were generally stronger than correlations between different constructs, ranging from .521 to .702 for family support for physical activity, from .587 to .719 for the perceived school PA-supportive environment, and from .382 to .530 for PA.

Table 1. Descriptive Statistics and Correlations Among the Study Variables

Variable	M	SD	1	2	3	4	5	6	7	8	9
T1 FES	3.13	0.83	1								
T1 SPSE	3.08	0.70	0.256	1							
T1 PA	2.95	0.78	0.212	0.250	1						
T2 FES	3.13	0.83	0.634	0.221	0.201	1					
T2 SPSE	3.11	0.70	0.287	0.702	0.224	0.232	1				
T2 PA	3.00	0.79	0.316	0.299	0.513	0.237	0.283	1			
T3 FES	3.14	0.82	0.521	0.231	0.209	0.702	0.252	0.271	1		
T3 SPSE	3.14	0.72	0.262	0.587	0.214	0.246	0.719	0.274	0.25	1	
T3 PA	2.99	0.77	0.291	0.247	0.382	0.282	0.261	0.53	0.222	0.258	1

Note. All correlation coefficients were significant at P < .001. FES = family support for physical activity; SPSE = perceived school physical activity–supportive environment; PA = physical activity.

Longitudinal Measurement Invariance

As shown in Table 2, the configural invariance models for family support for physical activity, the perceived school PA-supportive environment, and PA all demonstrated good model fit. After equality constraints were imposed on corresponding factor loadings and thresholds across waves, model fit remained acceptable, and changes in CFI and RMSEA did not exceed the prespecified criteria for measurement invariance. For family support for physical activity, the loading-and-threshold invariance model yielded ΔCFI = −.001, ΔRMSEA = .001, and ΔSRMR = .005. The corresponding values were .001, −.002, and .002 for the perceived school PA-supportive environment and .002, −.005, and .002 for PA. Standardized factor loadings were statistically significant for all indicators across the three constructs, and no inadmissible estimates were observed.

Table 2. Longitudinal Measurement Invariance of the Three Core Constructs

Construct	Model	χ^2	df	CFI	RMSEA	SRMR	ΔCFI	ΔRMSEA	ΔSRMR
FES	Configural invariance	568.449	555	0.999	0.006	0.024	—	—	—
	Loading-and-threshold invariance	694.027	671	0.998	0.007	0.029	-0.001	0.001	0.005
SPSE	Configural invariance	1448.559	1416	0.997	0.006	0.027	—	—	—
	Loading-and-threshold invariance	1609.727	1590	0.998	0.004	0.029	0.001	-0.002	0.002
PA	Configural invariance	175.105	153	0.994	0.015	0.025	—	—	—
	Loading-and-threshold invariance	228.393	215	0.996	0.01	0.027	0.002	-0.005	0.002

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; Δ = change from the configural invariance model to the loading-and-threshold invariance model; FES = family support for physical activity; SPSE = perceived school physical activity–supportive environment; PA = physical activity.

Longitudinal Associations of Family Support, the School PA-Supportive Environment, and Physical Activity

After adjustment for prior PA, sex, grade, BMIz, and school fixed effects, both family support for physical activity and the perceived school PA-supportive environment were positively associated with subsequent PA across both time intervals (Table 3). From T1 to T2, family support for physical activity at T1 (B = 0.179, β = 0.187, P < .001) and the perceived school PA-supportive environment at T1 (B = 0.162, β = 0.142, P < .001) were each positively associated with PA at T2. PA at T1 was also significantly associated with PA at T2 (B = 0.443, β = 0.437, P < .001). The model explained 33.3% of the variance in T2 PA.

A similar pattern was observed from T2 to T3. Family support for physical activity at T2 (B = 0.138, β = 0.149, P < .001) and the perceived school PA-supportive environment at T2 (B = 0.102, β = 0.093, P = .008) were each positively associated with PA at T3. PA at T2 was also significantly associated with PA at T3 (B = 0.452, β = 0.464, P < .001). The model explained 32.0% of the variance in T3 PA.

Table 3. Longitudinal Associations Among the Three Study Variables

Time Interval	Predictor	B	SE	β	95% CI	p
T1→T2	T1PA	0.443	0.036	0.437	[0.373, 0.513]	<0.001
	T1FES	0.179	0.043	0.187	[0.095, 0.263]	<0.001
	T1SPSE	0.162	0.032	0.142	[0.099, 0.225]	<0.001
T2→T3	T2PA	0.452	0.032	0.464	[0.389, 0.515]	<0.001
	T2FES	0.138	0.027	0.149	[0.085, 0.191]	<0.001
	T2SPSE	0.102	0.038	0.093	[0.026, 0.177]	0.008

Note. B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CI = confidence interval; FES = family support for physical activity; SPSE = perceived school physical activity–supportive environment; PA = physical activity. R^2 = .333 for T1→T2 and .320 for T2→T3.

Longitudinal Interaction Between Family and School Support

A significant negative interaction between family support for physical activity and the perceived school PA-supportive environment was observed across both time intervals. From T1 to T2, the interaction was negatively associated with PA at T2 (B = −0.184, β = −0.135, P < .001), with the proportion of explained variance increasing from 33.3% to 35.1%. Simple-slope analyses showed that the school PA-supportive environment was positively associated with subsequent PA when family support was low (B = 0.319, P < .001), but not when family support was high (B = 0.014, P = .704). Conversely, family support was positively associated with subsequent PA when school support was low (B = 0.306, P < .001), but not when school support was high (B = 0.049, P = .214).

The same pattern was observed from T2 to T3. The interaction remained significant (B = −0.114, β = −0.088, P = .018), with the proportion of explained variance increasing from 32.0% to 32.8%. Simple-slope analyses again showed that the positive association of either source of support with subsequent PA was evident primarily when the other source was low, whereas the corresponding associations were nonsignificant when the other source was high (Table 4). This conditional pattern was consistent across both consecutive time intervals. The interaction patterns across the two consecutive intervals are illustrated in Figure 1.

Table 4. Longitudinal Interaction Effects and Simple-Slope Analyses

Effect	B	SE	β	95% CI for B	P
T1→T2					
FES × SPSE	−0.184	0.031	−0.135	[−0.245, −0.123]	<.001
Simple slopes					
SPSE at low FES	0.319	0.039	—	[0.243, 0.395]	<.001
SPSE at high FES	0.014	0.037	—	[−0.058, 0.086]	0.704
FES at low SPSE	0.306	0.047	—	[0.213, 0.398]	<.001
FES at high SPSE	0.049	0.04	—	[−0.028, 0.127]	0.214
T2→T3					
FES × SPSE	−0.114	0.048	−0.088	[−0.208, −0.019]	0.018
Simple slopes					
SPSE at low FES	0.199	0.053	—	[0.095, 0.303]	<.001
SPSE at high FES	0.011	0.054	—	[−0.095, 0.117]	0.842
FES at low SPSE	0.214	0.037	—	[0.141, 0.287]	<.001
FES at high SPSE	0.054	0.048	—	[−0.041, 0.149]	0.262

Note. B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CI = confidence interval; FES = family support for physical activity; SPSE = perceived school physical activity–supportive environment; PA = physical activity. Low support = 1 SD below the mean; high support = 1 SD above the mean.

Sensitivity Analyses

Two sensitivity analyses were conducted to examine the robustness of the primary interaction findings (Table 5). First, the T1–T2 model was re-estimated among the 608 adolescents who completed all three waves. The interaction between family support for physical activity and the perceived school PA-supportive environment remained significant (B = −0.186, β = −0.136, P < .001), closely matching the primary analysis. Second, both longitudinal models were re-estimated using the 8-item PAQ-A score, including Item 3. The interaction remained significant from T1 to T2 (B = −0.196, β = −0.152, P < .001) and from T2 to T3 (B = −0.095, β = −0.078, P = .036). Overall, the primary interaction findings were not materially altered by restricting the analytic sample or by using the alternative PAQ-A scoring approach.

Table 5. Sensitivity Analyses of the Interaction Effect

Sensitivity Analysis	Time Interval	N	B	SE	β	95% CI	p
Complete three-wave sample	T1→T2	608	−0.186	0.032	−0.136	[−0.248, −0.123]	<.001
8-item PAQ-A score	T1→T2	621	−0.196	0.030	−0.152	[−0.255, −0.137]	<.001
8-item PAQ-A score	T2→T3	608	−0.095	0.045	−0.078	[−0.183, −0.006]	0.036

Note. B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; CI = confidence interval. Estimates refer to the family support × school support interaction.

Discussion

Prospective Associations of Family and School Support With Physical Activity

Family support for physical activity and the perceived school PA-supportive environment were both prospectively associated with subsequent PA across the two consecutive time intervals after prior PA and relevant covariates were taken into account, broadly consistent with previous longitudinal evidence [24–26]. Although PA showed substantial stability between adjacent waves, both sources of support remained independently associated with subsequent PA when included in the same models, indicating that these associations were not fully accounted for by previous activity levels. Thus, beyond behavioral stability, the family and school contexts each provided distinct information relevant to adolescents' subsequent PA. By examining both sources of support within the same longitudinal framework rather than considering either context in isolation, the present study further supports a multicontextual understanding of adolescent PA.

The prospective association between family support and subsequent PA may reflect the continuing embeddedness of family support in adolescents' everyday lives. Encouragement, accompaniment, reminders, positive feedback, and shared participation encompass emotional, instrumental, and participatory forms of support that may reinforce adolescents' perceptions that being active is supported, provide behavioral prompts, and create concrete opportunities for participation [27]. Longitudinal evidence supports this interpretation. In a 5-year study using accelerometry to assess PA, Morrissey et al. found that family support remained associated with adolescents' moderate- to vigorous-intensity PA across adolescence [7]. Within the Chinese context, parental encouragement, accompaniment, co-participation, and role modeling have also been associated with PA among school-aged children [6], while research among rural junior high school students suggests that parental co-participation remains relevant to PA-related health processes [28]. More recent longitudinal evidence from China has further linked parental concern and parent–child co-activity to the maintenance or increase of PA among children and adolescents during the COVID-19 pandemic [29]. Thus, even as autonomy increases during adolescence, families may continue to provide social and practical resources for PA through recurring everyday interactions. The persistence of the family-support association after prior PA and the perceived school PA-supportive environment were considered simultaneously further indicates that information provided by the family context was not fully captured by previous activity levels or by the school environment.

The prospective association of the perceived school PA-supportive environment with subsequent PA may instead reflect the role of schools in organizing activity opportunities and shaping conditions for participation. Schools can provide relatively structured opportunities for PA through physical education, extracurricular activities, facilities, and the social environment created by teachers and peers. A recent systematic review and meta-analysis found that the school social environment was positively associated with adolescent PA, with factors such as daily physical education, school-organized extracurricular PA, and encouragement to use sports facilities showing favorable associations; among physical-environment characteristics, the number of PA facilities was also positively associated with PA [9]. Longitudinal evidence from China similarly indicates that features of the school natural environment are prospectively associated with subsequent exercise [25], while longer-term follow-up research has linked school climate with later exercise behavior [26]. Research across urban and rural schools further suggests that access to facilities and equipment, teacher influences, activity organization, and school rules may shape adolescents' participation in context-specific ways [30]. Taken together, this evidence suggests that schools are not merely physical locations in which PA occurs but proximal environments that organize opportunities, social support, and participation conditions. In the present study, the perceived school PA-supportive environment remained prospectively associated with subsequent PA after family support and prior PA were taken into account, indicating that the school context provided information beyond that captured by family support. Whereas family support is embedded primarily in recurring interpersonal interactions, the school environment may operate more through structured opportunities and organizational conditions. Their independent associations within the same longitudinal models provide further support for a multicontextual understanding of PA among rural adolescents.

Compensatory Pattern Between Family and School Support

Beyond their independent prospective associations with subsequent PA, the interaction analyses showed that the joint association of family support for physical activity and the perceived school PA-supportive environment with PA was not simply additive. The simple-slope pattern indicated that when support in one context was relatively low, support in the other was more strongly associated with subsequent PA; when support in one context was relatively high, the additional association of the other source was attenuated. Thus, the observed interaction was more consistent with compensation than with synergistic reinforcement. Research in adolescent sport has directly contrasted these possibilities and found that coach autonomy support was more strongly related to sport-related outcomes when parental autonomy support was relatively low [15]. Broader research on adolescent social support likewise suggests that support from different relationship partners may operate conditionally and may show compensatory relations when another source of support is limited [16, 17]. Although these studies involved different support providers or outcomes and therefore do not directly establish the family–school pattern observed here, they provide a conceptual basis for interpreting conditional relations across support sources. Importantly, the negative interaction does not imply that higher family or school support was detrimental to PA. Rather, it indicates that the association of one source with PA became weaker as support from the other context increased.

When family support was relatively low, the perceived school PA-supportive environment was more strongly associated with subsequent PA. A plausible explanation is partial functional overlap between the two support contexts. Limited family support may mean fewer opportunities for encouragement, accompaniment, behavioral reminders, and shared participation, whereas schools can provide relatively stable and structured opportunities through physical education, organized activities, facilities, and support from teachers and peers.

Previous research indicates that the relevance of different support sources for adolescent PA varies across time and activity contexts, with parental, peer, and school support showing different associations across segments of the school day [31]. When PA-related support within the family is limited, school-based opportunities and social support may therefore represent a larger share of the adolescent's available support resources, which could help explain the stronger association between the school environment and subsequent PA. This interpretation is consistent with the simple-slope pattern observed here, although the processes through which support may operate across settings were not measured directly.

The same logic was evident in the opposite direction. When the perceived school PA-supportive environment was relatively low, family support was more strongly associated with subsequent PA, indicating that the observed conditional pattern was not limited to school support compensating for low family support but was instead consistent with a bidirectional compensatory pattern. Compared with support available primarily within the school setting, family support can extend into after-school periods and weekends through encouragement, accompaniment, and shared participation. Previous research has linked family praise, watching adolescents participate, and participating with them to objectively measured PA during nonschool periods [32], while parental support has also been independently associated with out-of-school moderate- to vigorous-intensity PA among Chinese adolescents [33]. These findings provide a plausible contextual basis for the stronger family-support association observed when school support was relatively limited. Although family and school support arise in different settings, they partially overlap in their capacity to provide opportunities, encouragement, and social support for activity. This partial overlap offers a plausible explanation for why one source may show a stronger association with PA when the other is limited. Compensation in this sense refers to a conditional relation between support contexts, not to functional interchangeability between family and school support.

The compensatory pattern was observed in the same direction across both consecutive time intervals, and the primary interaction findings were not materially altered by changes in sample restriction or PAQ-A scoring. This consistency makes it less likely that the pattern was specific to a single interval or analytic specification. However, the interaction accounted for only a modest increment in explained variance. Accordingly, the family–school compensatory pattern should not be interpreted as a dominant mechanism of PA among rural adolescents, nor do the findings imply that high support in one context can fully offset limited support in the other. A more cautious interpretation is that when one source of support is already relatively favorable, the additional association of the second source is smaller, whereas the second source is more strongly associated with PA when the first is relatively low. The main implication is therefore not that family and school support can substitute for one another, but that examining either source in isolation may provide an incomplete account of adolescent PA. Attention to the relative configuration of support across the two contexts may provide a more informative account of how proximal support environments are associated with PA.

Practical Implications

The findings suggest that efforts to support PA among rural adolescents should not focus on a single source within either the family or school context, but should consider both proximal settings. Because family support for physical activity and the perceived school PA-supportive environment were each prospectively associated with subsequent PA within the same longitudinal models, practice may benefit from assessing the support resources available to adolescents across both contexts. These resources include family encouragement, accompaniment, and shared participation, together with school-based opportunities such as physical

education, organized activities, facilities, and support from teachers and peers. Such a multicontextual perspective may provide a more complete understanding of adolescents' support conditions than approaches that attribute low PA primarily to individual factors or to a single environment.

The compensatory pattern further suggests that practice should consider not only the level of support available, but also its relative configuration across family and school contexts. When family support is relatively limited, greater attention may be directed toward structured activity opportunities and social support available at school; when the school PA-supportive environment is relatively limited, family encouragement, accompaniment, and shared participation may warrant greater emphasis. Identifying the comparatively weaker component of the family–school support configuration may therefore help inform more targeted support strategies. Importantly, this does not imply that family and school support are interchangeable or that support in one context should be reduced when the other is already favorable. Because the present study was observational and longitudinal, these implications should be viewed as possible directions for identifying and configuring support resources rather than as evidence of intervention effectiveness. Intervention studies are needed to determine whether preferentially strengthening the relatively weak support context can improve PA among adolescents.

Strengths and Limitations

The study has several design strengths. The three-wave longitudinal design allowed associations among family support for physical activity, the perceived school PA-supportive environment, and PA to be examined across two consecutive time intervals. Longitudinal measurement invariance strengthened the interpretability of comparisons across waves, while the models accounted for prior PA and relevant covariates. Sensitivity analyses further examined whether the primary interaction findings were consistent under alternative sample restrictions and PAQ-A scoring.

Several limitations should also be considered. First, although the longitudinal design strengthened temporal ordering, the observational nature of the study does not exclude residual confounding or reciprocal associations; the observed compensatory pattern should therefore be interpreted as a conditional prospective association rather than a causal mechanism. Second, family support, the school PA-supportive environment, and PA were all self-reported by adolescents, which may introduce recall error and shared-method bias. The school measure also reflected adolescents' perceptions rather than an objective assessment of the school environment. Self-reported height and weight and age recorded only in completed years may additionally have introduced measurement error into BMI-for-age z scores. Future studies could incorporate accelerometry, parent and teacher reports, and objective assessments of school PA environments. Finally, the sample was drawn from four rural junior high schools in Hunan Province and was limited to students in Grades 7 and 8, while the overall follow-up period was relatively short. Generalization to other regions, urban populations, and developmental stages should therefore be cautious, and the longer-term stability of the compensatory pattern remains uncertain. Because family and school support were also modeled as composite constructs, future research should use broader samples, longer follow-up, and more specific support dimensions to determine whether the observed pattern generalizes across contexts and persists over time.

Conclusion

Using three-wave longitudinal data from rural adolescents in Hunan Province, China, this study found that family support for physical activity and the perceived school PA-supportive environment were each prospectively associated with subsequent PA after prior PA and relevant covariates were taken into account. Their joint association was more consistent with a compensatory than a synergistic pattern, such that each source of support was more strongly associated with subsequent PA when support from the other context was relatively low. These findings suggest that understanding PA among rural adolescents requires attention not only to support within family and school settings individually, but also to the relative configuration and conditional relationship of support across the two contexts.

Declarations

Ethics approval and consent to participate

The study was approved by the Academic Committee of the School of Physical Education, Hunan University of Science and Technology, China, before data collection. No approval number was issued. Written informed consent was obtained from all participants and their parents or legal guardians.

Consent for publication

Not applicable.

Availability of data and materials

De-identified data are available from the corresponding author upon reasonable request, subject to ethical and privacy requirements.

Competing interests

The authors declare no competing interests.

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Authors' contributions

Y.L. and S.Z. conceptualized the study. Y.L. developed the methodology. Y.L. and S.Z. conducted the investigation. All authors contributed to drafting, reviewing, and editing the manuscript and approved the final version.

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Figures

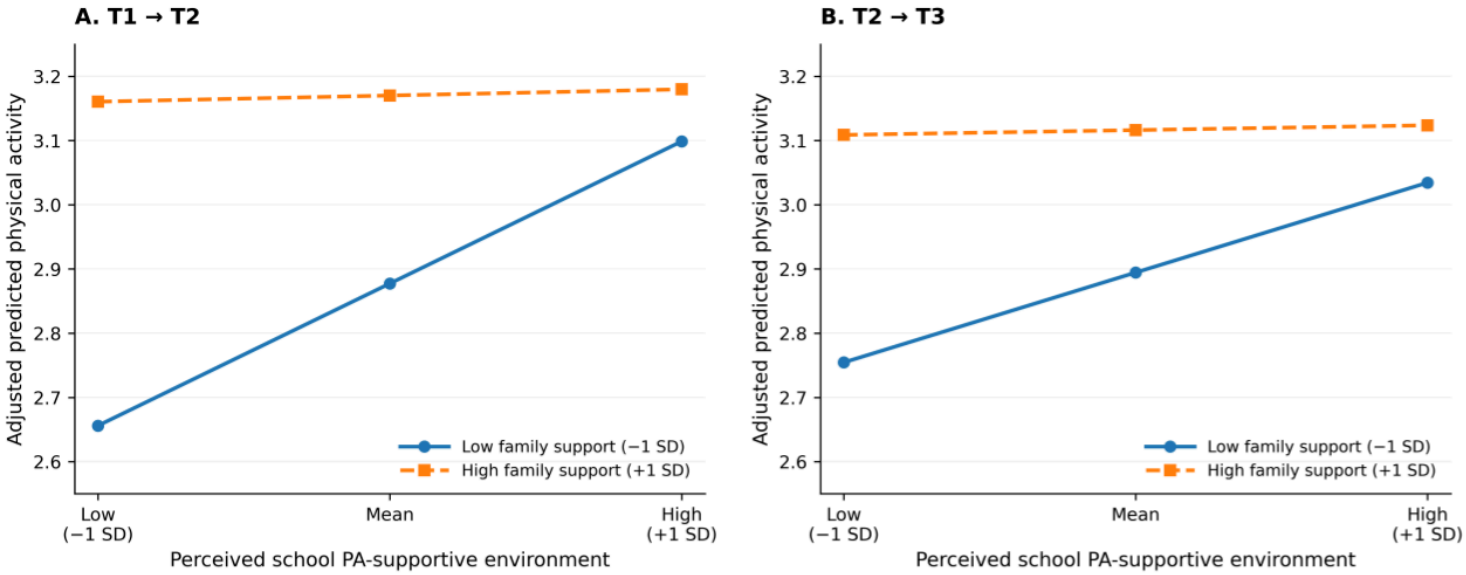


Figure 1

Interaction between family and school support in predicting subsequent physical activity.

Note. Low and high family support represent 1 SD below and above the mean, respectively. Predicted values were estimated with covariates fixed at their sample means.