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ARTICLE

Relationship between Resilience and Physical Activity in Adolescents: The Role of Family Functioning

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ABSTRACT: Background: Physical inactivity among adolescents has become a global public health challenge, with over 80% failing to meet the recommendations of the WHO for activity levels. Existing research predominantly examines how physical activity (PA) enhances resilience, while the predictive role of resilience in PA, particularly its interaction with family factors, has received limited attention. This study aimed to examine the associations between resilience and PA among adolescents, focusing on family functioning and gender differences. **Methods:** In this cross-sectional study, a total of 909 Chinese adolescents (463 males and 446 females, aged 13.3 ± 0.5 years) completed the following validated self-report instruments: the Connor-Davidson Resilience Scale with 10 items, the Physical Activity Questionnaire for Older Children, and the Family Adaptability and Cohesion Evaluation Scale II-Chinese version that was used to categorize family functioning into three types (i.e., lower, balanced, and higher). The generalized linear mixed-effect model (GLMM) was used to determine the contribution of resilience and its interaction with family functioning type on PA after adjusting for age and gender. **Results:** Males presented significantly higher resilience and PA levels (both $p < 0.001$) as well as better family functioning ($p < 0.01$) than females. Compared with the lower functioning group, participants from higher-functioning families showed superior resilience and PA (both $p < 0.001$). The GLMM analysis revealed a positive relationship between resilience and PA ($p < 0.001$), where the lower functioning group was significantly weaker than the higher functioning group. **Conclusion:** Resilience and PA in adolescents vary across gender and family functioning type, with males and adolescents from better-functioning families outperforming their peers. Resilience is a positive predictor of PA in adolescents, with family functioning type being a crucial moderator of such a relationship.

KEYWORDS: Exercise; physical inactivity; family; psychological health; teenager

1 Introduction

Regular physical activity (PA) has many health benefits, which include both physical and mental health, as well as psychological well-being [1]. Adolescence is typically conceptualized as the transitional period from childhood to (emerging) adulthood, spanning 10–19 years of age [2]. This period is critical for the formation of lifelong habits that may play a significant role in fostering healthy lifestyles in adulthood [3]. Individuals'

behaviors, including PA participation during their teenage years, can establish the behavior patterns that persist into adulthood as individuals make numerous lifestyle choices throughout this developmental stage [4,5]. However, a considerable number of adolescents around the world are facing physical inactivity [6]. As early as 2018, the World Health Organization (WHO) launched a global action plan on PA promotion, aiming at reducing the global rate of physical inactivity among adolescents and adults by 15% by 2030 [7]. Yet, the global trend of physical inactivity among adolescents has not seen significant improvement. The latest report by WHO showed that 81% of adolescents aged 11–17 years do not meet the PA recommendation (i.e., engage in moderate-to-vigorous PA for at least 60 min per day) [8], which may lead to their current and future health risks.

Recognizing that adolescent health behaviors are shaped by a complex array of factors, including personal attributes and environmental conditions, it becomes clear that adopting a single-factor approach to this issue is inadequate [9]. Over the last decade, an increasing number of studies and policies have begun to focus on the impact of family factors on individual health promotion and advocate for future public health to place greater emphasis on family-targeted interventions, particularly creating conditions to improve PA levels among adolescents [10,11]. This focus could represent a significant direction for further enhancing health-promoting lifestyles among adolescents worldwide. Moreover, the interplay between family-level factors (e.g., family functioning) and individual-level factors (e.g., resilience) and how these factors work together to influence adolescents' PA is not fully understood. Therefore, to improve PA levels among adolescents, it is important to explore a comprehensive perspective that includes both family and individual factors to understand PA correlates.

1.1 Resilience as a Crucial PA Correlate

Resilience is a positive psychological quality that enables individuals to overcome adversity and thrive positively [12]. Substantial evidence has demonstrated that PA is closely linked to the dimensions of goals, cognition, self-efficacy, and external support, while resilience is strongly correlated with these dimensions [13,14]. In the past, research has explored the relationship between PA and resilience in adolescents and found a positive correlation [15]. One study proposed that PA may facilitate resilience by strengthening individual brain regions as well as large-scale neural circuits to improve emotional and behavioral regulation [16]. In contrast, resilience may be a facilitator of PA engagement. For instance, a recent study has found that university students with high resilience can address challenges in physical exercise with clear goal orientation and perseverance in overcoming difficulties, combined with self-confidence and a sense of joy, accomplishment, and satisfaction from the exercise experience, which may eventually make it easier to enhance adherence to exercise and accomplish long-term PA participation goals [17]. Yet, empirical research on the role of resilience in promoting PA participation among adolescents is still lacking.

1.2 The Role of Family Functioning for PA in Adolescents

Evidence has demonstrated that family plays a major role in shaping adolescents' health behaviors, including PA [18]. According to the family systems theory by Murray Bowen, the family is viewed as an interdependent system in which any interactions and changes among family members not only influence the balance of the whole system but also significantly impact the behavior of each member [19]. For families to effectively support children's developmental needs, optimal family functioning is essential.

Family functioning refers to the family's ability to deal with everyday life and cope effectively with problems and changes, including the effective emotional bonding between family members, family communication, and the management of external events [20], which is an important variable for measuring the overall performance of a family [21]. According to the Circumplex Model of the family system proposed by

Olson, adaptability and cohesion are the core indicators to assess family functioning [22]. Family adaptability is defined as the ability of a family to adapt to problems arising from family circumstances and different developmental stages, while family cohesion is defined as the emotional bonding that family members have toward one another [22].

Based on the status of adaptability and cohesion, families can be further categorized into certain types of family functioning with specific characteristics, thereby evaluating family functioning from a relatively holistic view [23]. Previous research has highlighted the importance of family functioning for PA in adolescents [24], yet it is still necessary to specifically explore whether and how adolescents' PA is influenced by their family functioning type.

1.3 Interactions among Resilience, Family Functioning, and PA in Adolescents

The exploration of interactions among resilience, family functioning, and PA in adolescents is necessary, as adolescents' resilience may not only be closely related to PA but can also be shaped by family functioning. Resilience can be influenced by a complex interplay of factors and shaped by specific cultural and social contexts (like family) in which individuals are embedded [25]. According to the Social Support Theory, strong family relationships, as essential interpersonal networks, are potential sources of social support with both direct and indirect impacts on individuals' psychological health and well-being [26]. Furthermore, as indicated by Self-Determined Theory, strong family functioning boosts psychological resilience in adolescents by satisfying their basic needs for autonomy, competence, and relatedness, which in turn strengthens self-efficacy, emotion regulation, and goal persistence [27]. Recent research highlighted the importance of preventing health problems by enhancing resilience-related factors in individuals through their families [28]. Additionally, a systematic review found that family-based interventions on strengthening resilience can reduce adolescents' risk of psychopathology following childhood adversity [29]. However, the interplay between resilience, family functioning, and PA among adolescents remains underexplored. It is still unclear whether and how family functioning interacts with resilience and PA in adolescents.

In summary, despite the recognized importance of promoting PA participation among adolescents, there remains a knowledge gap on how to design family-based interventions, which requires understanding family-level and individual-level factors influencing PA. Hence, the present study aimed to investigate the associations of PA with resilience and family functioning in adolescents and to examine the potential moderating effects of family functioning type in the relationship between resilience and PA. We posited two hypotheses: (**Hypothesis 1**) there would be significant differences in resilience and PA among adolescents by gender and family functioning type, and (**Hypothesis 2**) resilience would be positively correlated to PA significantly, and such a relationship would be moderated by family functioning type after adjusting for key confounders. The findings from the present study will contribute empirical insights into the impact of family functioning and its interaction with resilience and PA in adolescents. Furthermore, such knowledge will facilitate effective family-centered interventions aimed at promoting PA and health among adolescents.

2 Methods

This study utilized a cross-sectional design, complied with the principles of the Declaration of Helsinki, and was approved by the Medical Ethics Committee of Children's Hospital Affiliated to Zhejiang University School of Medicine (Reference No: 2024-IRB-0419-P-01). Written informed consents were received from all the participants and their parents for participation.

2.1 Participants

A total of 912 Chinese adolescents aged 12–16 years were voluntarily recruited from two public secondary schools in Zhejiang Province, China, in October 2024, using a purposeful sampling method. Three participants were removed during data processing due to incomplete data. Eventually, data from 909 participants (including 463 males and 446 females) with a mean age of 13.3 years (standard deviation [SD] = 0.5) were included in data analyses.

2.2 Outcomes and Measurements

All outcomes and demographic characteristics were measured using self-report questionnaires completed by the participants.

2.2.1 Physical Activity

PA was assessed using the Physical Activity Questionnaire for Older Children (PAQ-C). PAQ-C has been demonstrated to have acceptable validity, reliability [30], and practicality as an appropriate instrument for use with participants who are currently in the school system and have recess as a regular part of their school week (grades 4–8; approximately ages 8–14) [31]. The questionnaire is a self-administered tool that utilizes a 7-day recall method to assess general moderate to vigorous PA levels during the school year. PAQ-C comprises nine items evaluating the participants' levels of PA in different periods on a typical school week using a 5-point scale, including spare time, at school, recess, lunch break, physical education classes, after school, in the evenings, and on weekends. The total PAQ-C score was assessed by the mean score of these nine items, with a higher score representing a higher level of PA. The Chinese version of PAQ-C has been applied in Chinese children and adolescents with good reliability [32]. In the present study, the Cronbach's alpha for the PAQ-C was 0.87.

2.2.2 Resilience

Participants' resilience was evaluated with the Chinese version of the 10-item Connor-Davidson Resilience Scale (CD-RISC-10). CD-RISC is a concise, self-report instrument for measuring resilience that has sound psychometric properties [33], and the total score of the CD-RISC can be accurately estimated using the abbreviated CD-RISC-10 [34]. CD-RISC-10 comprises 10 items and is rated on a 5-point scale (0 = not true at all, 1 = rarely true, 2 = sometimes true, 3 = often true, and 4 = true nearly all the time). The total CD-RISC-10 score is obtained by adding up the points for all 10 items, ranging from 0 to 40, with a higher total score indicating greater resilience. The Chinese version of CD-RISC has been validated as reliable and used among Chinese youth [35]. In the present study, the Cronbach's alpha for the CD-RISC-10 was 0.97.

2.2.3 Family Functioning

Participants' family functioning was evaluated using the Family Adaptability and Cohesion Evaluation Scale, second edition, Chinese version (FACES II-CV) [36]. FACES is one of the effective family assessment tools with good psychometric properties and has been used in numerous projects and clinical evaluations [37]. FACES II-CV comprises 30 items, with 14 items assessing family adaptability and 16 items evaluating family cohesion. The participants were asked to rate each item concerning their family situations using a 5-point scale, ranging from 1 to 5, which is expressed as "never", "rarely", "sometimes", "often", and "always", and to reverse rate the reverse-rating items. In our study, the Cronbach's alpha achieved 0.95 for the whole FACES II-CV scale and 0.92 and 0.86 for the subscales of adaptability and cohesion, respectively.

The raw scores for adaptability and cohesion were calculated separately by summing the scores of all corresponding items in each subscale. Subsequently, each family was classified into different levels in terms of adaptability (i.e., <44.7 as rigid, 44.7~50.9 as structured, 51.0~57.1 as flexible, and >57.1 chaotic) and cohesion (i.e., <55.9 as disengaged, 55.9~63.9 as separated, 64.0~71.9 connected, >71.9 as enmeshed) by referring to cut-off points used in previous research [38] and the Circumplex Model of family systems by Olson [22]. In the present study, the outcome of family functioning was family functioning type categorized into three groups, namely, the lower group, balanced group, and higher group. Each family was classified into a specific group based on predefined combinations of adaptability and cohesion levels in different groups by referring to previous research [23] (see Appendix A). For instance, a chaotic and enmeshed family was classified into the higher group and determined as having higher family functioning.

2.3 Data Analyses

Descriptive analyses were applied to all outcomes. The Mann-Whitney U-test was used to examine gender differences in outcomes with continuous data, including resilience and PA, while the cross-tabulation and chi-square test were used to evaluate the distribution of males and females across different family functioning groups (i.e., lower, balanced, and higher). The Kruskal-Wallis test was used to compare differences in resilience and PA across family functioning types. The Box-Cox transformation was applied to the dependent variable of PA to meet the assumptions required by the data analysis, improving the symmetry and variance stability of its distribution. Generalized linear mixed-effects models (GLMM) were further used to explore the associations between resilience and PA in males and females with different family functioning types, with PA serving as the dependent variable. Specifically, the potential contribution of resilience and its interaction with family functioning type were examined after adjusting for key confounding factors (i.e., age and gender). The distribution of the linear model and the identity correlation function with fixed effects was selected. Data analyses were conducted using SPSS 26.0 (IBM Corp., Armonk, NY, USA), and $p < 0.05$ was considered to indicate statistical significance.

3 Results

3.1 Demographic Characteristics of the Participants

As shown in Table 1, data from 909 participants (mean age, 13.3 years; 49.1% females) were included in the statistical analyses.

Table 1: Demographic characteristics of all adolescent participants (N = 909)

Characteristics	Number	Percentage, %
Gender		
Females	446	49.1
Males	463	50.9
Age (# of years)		
Mean (SD)	13.3 (0.5)	/
Range	12–16	/
Family structure		
Live with parents	761	83.7
Only live with parents	488	53.7
Only live with both parents & grandparents	245	27.0
Only live with both parents & other relatives	20	2.2

(Continued)

Table 1 (continued)

Characteristics	Number	Percentage, %
Live with parents & grandparents & other relatives	8	0.9
Live with a single parent	99	10.9
Only live with mother	68	7.5
Only live with father	31	3.4
Not live with a parent	24	2.6
Only live with grandparents	15	1.7
Only live with other relatives	4	0.4
Siblings		
None	259	28.5
One	540	59.4
Two	85	9.4
Three	15	1.7
Four & Greater than four	10	1.1
Family functioning type		
Lower group	200	22.0
Balanced group	177	19.5
Higher group	532	58.5

Note: SD, Standard Deviation.

The family structure statistics revealed that most of the participants (83.7%) resided with parents, including 488 (53.7%) in nuclear family arrangements and 245 (27.0%) in multigenerational households with grandparents. Single-parent households represented 10.9% of cases, with 7.5% of adolescents living with only their mother and 3.4% with only their father. Notably, 24 adolescents (2.6%) reported no cohabitation with either parent, comprising 15 (1.7%) living exclusively with grandparents and 4 (0.4%) with other relatives. Regarding the number of siblings, 59.4% of the participants had one sibling, 9.4% had two siblings, and 1.1% had four or more siblings. When these characteristics were compared between males and females, no significant gender difference was evident (all $p > 0.05$). Additionally, the number of families in the higher functioning group was the largest (58.5%), followed by the lower functioning group (22.0%) and the balanced functioning group (19.5%), with the family functioning type distribution among participants categorized as shown in Fig. 1.

3.2 Gender Differences in PA, Resilience, and Family Functioning

As shown in Table 2, the results of the Mann-Whitney U test on the comparison of participants' resilience and PA by gender, in which males demonstrated significantly greater scores in resilience and PA when compared to females (both $p < 0.001$). Additionally, the results of the cross-tabulation analysis showed a significant gender difference in the distribution of males and females across the three family functioning groups ($\chi^2 = 12.663$, $p < 0.01$). Specifically, the proportion of males reporting lower-functioning families was significantly lower than that of females, while the proportions reporting balanced and higher-functioning families were higher.

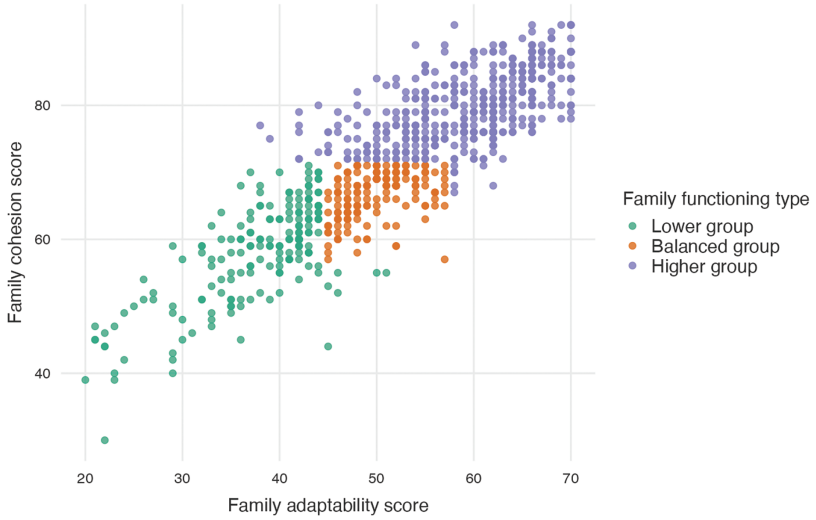

Figure 1: Sample distribution of different family functioning types

Table 2: Comparisons of resilience, physical activity, and family functioning type of participants by gender

Outcomes	PA (PAQ-C Total Score)		Resilience (CD-RISC-10 Total Score)	
	Median (Min to Max)	IQR	Median (Min to Max)	IQR
Total (N = 909)	2.670 (1.000 to 4.889)	0.896	28.000 (0 to 40.000)	19.000
Males (n = 463)	2.864 (1.000 to 4.889)	0.922	30.000 (0 to 40.000)	18.000
Females (n = 446)	2.507 (1.123 to 4.617)	0.867	25.500 (0 to 40.000)	15.000
Mann-Whitney U (Z Test Statistic)	73,994.000 (−7.393)		82,503.000 (−5.283)	
***p*-Value**	<0.001***		<0.001***	
Gender	**Family Functioning Type, N (% within gender)**			
	Lower Group		**Balanced Group**	**Higher Group**
Males (n = 463)	n = 80 (17.3%)		n = 92 (19.9%)	n = 291 (62.9%)
Females (n = 446)	n = 120 (26.9%)		n = 85 (19.1%)	n = 241 (54.0%)

Note: ***$p < 0.001$. IQR (Q3-Q1), interquartile range.

3.3 Differences in Adolescents' Resilience and PA across Family Functioning Types

The results of the Kruskal-Wallis Test showed a significant main effect of family functioning type in both resilience ($\chi^2 = 263.232$, $p < 0.001$) and PA ($\chi^2 = 91.591$, $p < 0.001$). Furthermore, pairwise comparisons of median scores for resilience and PA, respectively, shown in Fig. 2, indicated that the lower functioning group had significantly lower resilience and PA when compared to both the balanced (both $p < 0.01$) and higher (both $p < 0.001$) functioning groups, while the balanced functioning group had significantly lower resilience and PA than the higher functioning group (both $p < 0.001$). These findings demonstrate that those participants from families with better functioning have higher levels of resilience and PA.

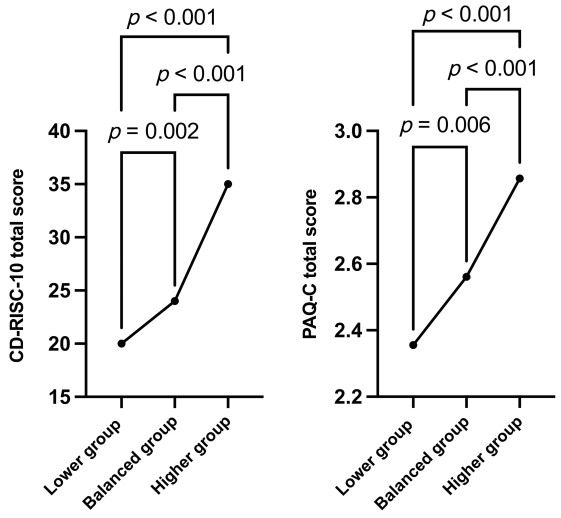

Figure 2: Kruskal-Wallis comparison of resilience and physical activity medians across family functioning types

3.4 Predictors of PA

As shown in Table 3, the GLMM analyses revealed that resilience (F = 62.742, p < 0.001) was a significantly positive predictor of PA after adjusting for key confounders, and the family functioning type (F = 6.053, p < 0.01) moderated such a relationship. Furthermore, the relationship between resilience and PA in the lower functioning group was significantly weaker than that in the higher functioning group.

Table 3: Analyses of predictors of physical activity using generalized linear mixed-effects models

Variables	*F*-Value	*t*-Value	Standard Error	Coefficient (95% CI)	β	*p*-Value
Age	1.418	1.191	0.027	0.032 (−0.021, 0.085)	0.024	0.234
Gender	35.191***	/	/	/	/	<0.001
Male	/	5.932***	0.029	0.172 (0.115, 0.228)	0.122	<0.001
Female	/	0[b]	0[b]	0[b]	/	0[b]
Resilience	62.742***	11.486***	0.002	0.017 (0.014, 0.020)	0.242	<0.001
Resilience × Family functioning type	6.053**	/	/	/	/	0.002
Resilience × lower group	/	−3.461**	0.002	−0.006 (−0.009, −0.002)	−0.070	0.001
Resilience × balanced group	/	−1.165	0.002	−0.002 (−0.005, 0.001)	−0.023	0.245
Resilience × higher group	/	0[b]	0[b]	0[b]	/	0[b]

Note: The coefficient represents the magnitude of changes in the outcomes when compared to the reference group (coded as 0[b]); β, standardized coefficients; Age and gender were adjusted as confounders. **p < 0.01, ***p < 0.001.

4 Discussion

The purpose of the present study was to investigate the associations of PA with resilience and family functioning in adolescents and to examine the potential moderating effect of family functioning type in the relationship between resilience and PA in the context of China. Our findings demonstrated that (1) resilience and PA in adolescents significantly vary across gender and family functioning type, with males and adolescents from higher-functioning families exhibiting higher levels of resilience and PA; and (2) resilience is positively correlated to PA, in which family functioning type is a significant moderator. Our two hypotheses (**Hypothesis 1** and **Hypothesis 2**) were fully supported by these findings.

Our findings reveal significant gender differences in resilience and PA among adolescents, with males outperforming females, which is consistent with previous research demonstrating that males tend to show a relatively higher level of PA than females [39]. Furthermore, previous studies have reported that, when compared to females, males tend to perceive themselves as having a higher level of personal competence, self-efficacy, and self-awareness that are closely linked to psychological resilience [40] and have more PA engagement [41]. Regarding the resilience, recent evidence showed that there was no statistical significance by gender [42], which is different from our findings. It may be influenced by diverse sample contexts and regional specificity, which should be further explored in future investigations.

To a certain extent, gender differences might be attributable to societal expectations on necessary psychological traits for different genders in China under the traditional Confucian culture, in which males, rather than females, are generally expected or encouraged to possess resilient qualities and be physically active. From a young age, males are often encouraged to be strong, independent, and active, while females are socialized toward nurturing and passive roles. This may be shaped by interconnected environmental impacts, encompassing microsystemic interactions across familial, educational, and societal spheres. For instance, parental behaviors, like praising males for toughness and discouraging emotional expression, and tacit permission for females to show vulnerability [43]. This gender stereotype that stems from traditional culture forms can be highlighted by educational settings with the impact of peer support [44], and further reinforced through media, where males are frequently depicted as independent, rational, powerful, and active, whereas females are portrayed as emotionally expressive or peaceful [45]. Additionally, we found that males are more likely to perceive their family as having better family functioning than females do, which is worth further investigation in the future. Further research should not only promote resilience and PA but also the improvement of gender equity in physical and psychological health among adolescents.

We found that participants from families with higher functioning tend to have better resilience and higher PA than those from families with lower functioning, which is in line with previous research indicating that the relationship between family functioning and adolescents' health behaviors may be linear [46]. While the positive correlation between family functioning and adolescents' resilience has been proven by previous research, the potential mechanisms remain understudied. For example, self-efficacy, satisfaction with life, and other relevant variables may be influential in such a relationship indirectly. In addition, although recent evidence shows significant associations of PA in adolescents with multiple domains of family functioning, the results represent only statistically small amounts of correlation [47]. Therefore, additional evaluation and validation are warranted.

To some extent, families with better functioning may provide a more supportive, harmonious, and caring atmosphere for the development of adolescents. In this case, adolescents are more likely to cultivate positive psychology (e.g., a better sense of personal control and ability to cope with stress) and obtain social support for PA participation [48]. In contrast, poor family functioning is characterized by strain, conflict, violence, and weak cohesion, often failing to provide adolescents with adequate emotional support, which may impair their behavioral control, heightened risk of depression, and increased vulnerability and reduced stress-coping capacity [49]. Additionally, families with low functioning often fail to give adequate emotional validation or encouragement. This potentially negative parenting style may diminish children's self-efficacy and motivation to engage in PA [50], with such households more likely to lack resources (e.g., funds, time) and organizational capacity to offer stable exercise conditions that may further inhibit PA behaviors.

Our results also indicate that resilience is a positive predictor of PA in adolescents, which is consistent with previous studies demonstrating that resilience is a crucial factor in motivating individuals to engage in regular exercise [51]. Of note, the importance of bidirectional effects should be further recognized. A recent systematic review and meta-analysis pointed to a significant positive correlation between PA and resilience

among young students, with PA exerting a positive impact on resilience, and in turn, resilience may perform a promotional role in PA engagement [52]. This suggests attention towards the bidirectional relationship complicating the causal direction in future research, such as clarifying the causal weighting of the complex relationship and constructing a PA-resilience reinforcing loop.

We also discovered that family functioning type is an important moderator for such a relationship. Specifically, the amplitude of the link between resilience to PA is notably diminished in families with lower functioning compared to families with higher functioning. We speculate that the opportunities for developing psychological adaptability and fostering the relationship between resilience and behaviors may be reduced when a family does not function well. Our findings highlight the importance of family functioning in building a favorable status of resilience and PA among adolescents. We suggest that future research could place a greater emphasis on the impact of family environment on adolescents' PA, particularly on exploring factors related to family functioning, as well as designing effective intervention programs to improve family functioning. For instance, low-functioning families should be provided with additional support and resources, such as family counseling and designed family communication training programs to enhance family cohesion and offer opportunities for family members and youth to participate in physical activities together.

In China, the "double reduction" policy was launched by the Ministry of Education in 2021, which aims to encourage all school-aged students to have more spare time after school and opportunities to engage in out-of-school activities (e.g., PA) to promote physical and mental health in childhood. Since then, the role of family in healthy development and high-quality education among adolescents has become more important [53]. Families with better functioning probably employ more advantageous parenting styles that can cultivate more psychologically positive, behaviorally healthy, and competitive adolescents. Therefore, researchers and caregivers should pay more attention to the disparities in family functioning and their negative impacts on healthy development for adolescents.

This empirical study investigates the complex interplay between resilience and family functioning in their influence on PA among adolescents in developing Eastern countries underpinned by a robust theoretical framework (i.e., the Circumplex Model of the family system). Nevertheless, we also acknowledge that limitations exist in the present study. First, the use of a cross-sectional design limits causal inferences, potentially obscuring whether observed relationships reflect true causation or mere correlation. Future studies are warranted to further examine their relationships in cohort or intervention studies. Second, to facilitate the feasibility of recruiting a large sample and smooth implementation, PA was reported by the participants using a questionnaire. Although the questionnaire is well recognized and has been widely used in the research field, it may cause recall bias due to its self-report nature, with the risk of misjudgment and a problem of social desirability bias. Third, our participants were recruited from one province located in eastern China, where economic development has progressed relatively well. This may limit the generalizability of our findings to other areas in China and other countries with different sociocultural contexts.

Examining the influence of family factors on individual health has emerged as a crucial direction in global public health promotion. Previous studies have highlighted the positive association between resilience and PA, suggesting that resilient adolescents are more likely to engage in regular PA. Our study extends this understanding by exploring the important role of family functioning and its interaction with resilience in this relationship. Family functioning may have potential effectiveness in enhancing adolescents' resilience, which in turn promotes PA. The present study indicates the possible influence of the family in fostering adolescent health behaviors, emphasizing the potential of resilience and family factors, as well as their interactions, in the development of PA, thereby offering a promising perspective for future research and intervention program development for promoting PA among adolescents.

5 Conclusions

The present study reveals crucial insights into the complex interplay of resilience, PA, and family functioning in adolescents in the Chinese context. Our results showed that resilience and PA in adolescents vary across gender and family functioning type, with males and adolescents from better-functioning families outperforming their counterparts. We also confirmed that there is a significant and positive relationship between resilience and PA, with family functioning type being a significant moderator of such a relationship. These findings highlight the importance of fostering adolescents' PA through cultivating resilience and improving family functioning. Furthermore, we recommend that researchers and stakeholders who aim at improving PA among adolescents incorporate the family (either family-centered or family-involved) into their intervention strategies and place more focus on gender disparities.

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Author Contributions: Dingmeng Mao performed data collection and formal analysis, and wrote the original draft of the manuscript; Guannan Bai and Lin Yang interpreted data and critically edited the manuscript; Jane Jie Yu conceptualized this work, designed the methodology, supervised the entire process of research work, and critically edited the manuscript. All authors reviewed the results and approved the final version of the manuscript.

Availability of Data and Materials: All data are included in the manuscript and the additional file. Any additional questions should be addressed to the corresponding author.

Ethics Approval: This study complied with the principles of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Children's Hospital Affiliated to Zhejiang University School of Medicine (Reference No: 2024-IRB-0419-P-01). Written informed consents were received from all the participants and their parents for participation.

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.

Appendix A

Table A1: The classification of family functioning type

Family functioning type	Adaptability level	Cohesion level
Lower group	Rigid	Disengaged
	Rigid	Separated
	Rigid	Connected
	Structured	Disengaged
	Flexible	Disengaged
Balanced group	Structured	Separated
	Structured	Connected
	Flexible	Separated
	Flexible	Connected

(Continued)

Table A1 (continued)

Family functioning type	Adaptability level	Cohesion level
	Rigid	Enmeshed
	Structured	Enmeshed
	Flexible	Enmeshed
Higher group	Chaotic	Disengaged
	Chaotic	Separated
	Chaotic	Connected
	Chaotic	Enmeshed

Note: Characterization in the present study based on David H. Olson's Circumplex Model of family systems [22], which illustrates the relationship between two key dimensions: adaptability and cohesion; Adaptability levels (i.e., <44.7 as rigid, 44.7~50.9 as structured, 51.0~57.1 as flexible, and >57.1 chaotic); Cohesion levels (i.e., <55.9 as disengaged, 55.9~63.9 as separated, 64.0~71.9 connected, >71.9 as enmeshed).

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